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DIGITAL INNOVATION IN PRODUCT PACKAGING: SMART INTERACTIVE PACKAGING TOWARDS ENHANCED CONSUMER EXPERIENCE AND PRODUCT FUNCTIONALITY

PhD dissertation

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TO MY MOTHER

For raising me to believe that anything is possible

AND TO MY HUSBAND AND SON

For making everything possible and far more

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ABSTRACT

In the last decade, the increasing adoption of emerging technologies has given rise to the emergence of interconnected systems, where smart and sensory objects communicate among themselves and their users. The perception of Human-Computer interaction went beyond the conventional mechanical computer systems and started to penetrate everyday objects and environments. Product packaging has recently begun to be investigated as a cyber-physical system that can detect, track, communicate, and apply scientific logic due to the incorporated passive and active electronics. This PhD research refers to such packaging as smart interactive packaging and considers its potential as a digital interactive system that rises above the traditional perception of human-packaging interaction and grants access to an extended user interface.

This PhD study addresses six research questions that were developed to understand, explore, and explain the digital innovation in primary product packaging for enhanced consumer experience and increased product functionality. In light of existing theoretical and practical challenges elaborated by the identified research gaps, the research questions focus on understanding the main elements that need to be taken into consideration when designing smart interactive packaging solutions through the lens of different theories. Drawing on extensive literature reviews and findings from user-packaging experimentation, the PhD research addresses the six research questions through five research papers. As a result, this dissertation represents a collection of five appended papers, which in their combined form, demonstrate the progression of the PhD research activities accomplished in the duration of three years.

First, this study investigates the changes in the traditional “contain-protect-communicate-facilitate convenience” model of the main packaging functions provoked by the emergence of new forms of enhanced consumer packaging due to technological advancements, increased use of smartphones, and the growth of the Internet. Second, by deploying Human-Computer Interaction, Interaction Design, User-centered Design, and Usability Theories, this study explores digitally enhanced and network connected packaging as a digital interactive system. The findings of the study present the principal elements and steps when designing an effective interactive packaging design based on the beforementioned theories. Third, due to the incorporation of NFC technology, the study explores the comprehension of smart interactive packaging as an extended user interface – a touchpoint for visual, tactile, and digital interaction with consumers. The study investigates the current state-of-the-art potential of NFC technology to be applied to product packaging. Fourth, having designed and performed user-packaging experimentation, the study seeks to understand better how different variables affect consumers’ perception and willingness to accept the NFC technology applied to the product’s packaging. Fifth, in search of the most impactful factors for NFC technology acceptance, the study develops an extended TAM model in combination with seven other prevailing technology acceptance theories and models.

Drawing on findings from the appended five papers, the PhD study sheds light on consumer packaging as a digital interactive system and provides theoretical and practical guidelines for successful and engaging product packaging design for brand owners and retailers that target to uplift their consumer engagement and create memorable, long-lasting connections that would facilitate the recurrent use of their products.

DANSK RESUME

I de senere år har emergente teknologier givet anledning til fremkomsten af indbyrdes forbundne systemer, hvor smarte og sensoriske objekter kommunikerer indbyrdes og med deres brugere. Opfattelsen af menneske-computer-interaktion kan være mere innovativ eller kreativ end konventionelle fysiske computersystemer. Digitaliseringen trænger ind i hverdagens objekter og miljøer og bliver allestedsnærværende. Produktemballage og forbrugerprodukters forsyningskæder har ligeledes potentiale for at blive ”cyberfysiske” systemer. Dette PhD projekt fokuserer på emballagens muligheder for identificere, detektere, spore, kommunikere og anvende en forskningsmæssig tilgang til emballage med indbyggede passive og aktive elektroniske enheder eller ”smarte” kapabiliteter. Denne PhD afhandling diskuterer emballage som ’smart interaktiv emballage’ og betragter dens potentiale som et digitalt interaktivt system, der udvider den traditionelle opfattelse af menneske-emballage-interaktion og bygger bro til en udvidet brugergrænseflade.

Dette ph.d.-studie tager udgangspunkt i seks forskningsspørgsmål, der er formuleret til at forstå, udforske og forklare den digitale innovation i primært produktemballage for forbedret forbrugeroplevelse og øget produktfunktionalitet. I lyset af eksisterende teoretiske og praktiske udfordringer udviklet af de identificerede forsknings-”gab”, fokuserer forskningsspørgsmålene på at forstå de vigtigste elementer, der skal tages i betragtning, når man designer smarte interaktive emballageløsninger. Med udgangspunkt i omfattende litteraturgennemgange og resultater fra eksperimenter med (for-)brugeremballage, behandler ph.d.-studiet de seks forskningspørgsmål gennem fem publicerede forskningsartikler. Som et resultat heraf præsenterer denne afhandling en samling af de fem vedhæftede artikler, som i deres kombinerede form demonstrerer progressionen af ph.d.-forskningsaktiviteterne gennemført i løbet af tre år.

De seks spørgsmål er følgende: (1) Hvordan påvirker fremkomsten af ’smart emballage’ de traditionelle opfattelser af emballagens hovedfunktioner? (2) Hvad er de væsentligste karakteristikker af smart interaktiv emballage forstået som et digitalt system i relation til et teoretisk grundlag for interaktionsdesign? (3) Hvilke potentielle teknologier kan nyttiggøres og integreres i smart interaktiv emballagedesign? (4) Hvad er de væsentligste karakteristikker af NFC (near-field communication) teknologi anvendt i produktemballage? (5) Hvilke faktorer relateret til tekniske og bruger-orienterede barrierer påvirker forbruger-opfattelse og -villighed til at adoptere NFC teknologi i produktemballage anvendelser? (6) Hvad er de mest påvirkende faktorer for NFC teknologiens accept i produktemballage anvendelser?

Metodisk anvender dette studie overvejende den design-videnskabelige forskningstradition (”DSR”). Med et mål om at afklare design-tænkningen af digitale elementer i emballage. Der er dog også elementer af blandede forskningsmetoder i relation til (for-) brugeropfattelser, teknologiaccept og beslutningsmodellering. Studiet kan også læses som en metodisk tilgang til at anvende digitale elementer i brobygningen mellem brand-ejer, forsyningskæde, detailhandel og forbruger. Følgelig anvendes derfor metodiske elementer fra produktledelse, forsyningskæder, distribution og marketing.

Første artikel undersøger ændringerne i den traditionelle emballageteori baseret på en "indhold-beskyttelse-kommunikation- bekvemmelighed"-model af de vigtigste emballagefunktioner. Der argumenteres for en fremkomst af nye former for forbedret forbrugeremballage på grund af teknologiske fremskridt, øget brug af smartphones og væksten af internettet. Anden artikel ser på at implementere menneske-computer-interaktion, interaktionsdesign, brugercentreret design og brugervenlighedsteorier, udforsker denne undersøgelse digitalt forbedret og netværkstilsluttet emballage som et digitalt interaktivt system. Resultaterne af undersøgelsen præsenterer de vigtigste elementer og trin i design af et effektivt interaktivt emballagedesign baseret på de førnævnte teorier.

Tredje artikel tager udgangspunkt i NFC-teknologien, undersøger forståelsen af smart interaktiv emballage som en udvidet brugergrænseflade – et touchpoint for visuel, taktil og digital interaktion med forbrugerne. Undersøgelsen undersøger de nuværende og fremtidige potentialer ved NFC-teknologi i forbindelse med produktemballage. Fjerde artikel tager en designorienteret og eksperimentel tilgang til forbrugeremballage, og søger bedre at forstå, hvordan forskellige variabler påvirker forbrugernes opfattelse og vilje til at acceptere den NFC-teknologi, der anvendes på produktets emballage. Femte artikel søger de mest betydende faktorer for NFC-teknologiaccept, og ud fra dette udvikles en udvidet teknologi-accept (TAM)-model i kombination med syv andre fremherskende teknologiacceptteorier og -modeller.

Baseret på resultaterne af de fem vedhæftede artikler, kaster dette PhD studie lys på produktemballage og de efterfølgende forbrugeroplevelser som et digitalt interaktivt system. Studiet fremlægger teoretiske og praktiske retningslinjer for succesfuld og engagerende design af produktemballage. Dette kan bruges af markedsførende virksomheder, brand-ejere, og detailhandelsvirksomheder som arbejder med af løfte deres forbrugerengagement og skabelse af erindringsværdige og vedblivende loyalitetsrelationer og positiv genkøbsadfærd.

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Contribution papers (included in this dissertation)

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Lydekaityte[1], J., & Tambo, T. (2020). Smart packaging: Definitions, models and packaging as an intermediator between digital and physical product management. The International Review of Retail, Distribution and Consumer Research, 30(4), 377-410. https://doi.org/10.1080/09593969.2020.1724555

PAPER II:

Lydekaityte, J. (2019). Smart interactive packaging as a cyber-physical agent in the interaction design theory: a novel user interface. In IFIP conference on human-computer interaction, Springer, Cham, 687-695. https://doi.org/10.1007/978-3-030-29381-9_41

PAPER III:

Lydekaityte, J. (2020). Extended User Interface: NFC-Enabled Product Packaging for Enhanced User Experience. In International Conference on Human-Computer Interaction, Springer, Cham, 285-304. https://doi.org/10.1007/978-3-030-50344-4_21

PAPER IV:

Karpavičė, J., Hafith, I., A., Tambo, T., Chinello, F., Venytė, L., Gegeckienė, L. (2023). Experimental Approaches to NFC-enabled Packaging for UX / CX of Physical Artefacts: A Technology Maturity Study. Procedia Computer Science, 219, 577-585. https://doi.org/10.1016/j.procs.2023.01.326

PAPER V:

Karpavičė, J., Tambo, T., Venytė, L., Gegeckienė, L. (2023). Digitalisation of product packaging using near-field communication: towards an extended Technology Acceptance Model. International Journal of Retail and Distribution Management. (Submitted)

Supporting papers (not included in this dissertation)

PAPER a1:

Lydekaityte, J. (2016). Multi Criteria Decision Analysis of Green Alternative Materials for Paper in a LEGO Group Planet Promise Perspective. Working Paper. Department of Business Development and Technology.

PAPER a2:

Lydekaityte, J. (2017). Preventions of Relative Humidity and Moisture Content Control for Lego Group Corrugated Board Packaging. Working Paper. Department of Business Development and Technology.

PAPER a:

Lydekaityte, J., & Tambo, T. (2019). Connected stores, connected brands, connected consumers, connected goods: On business model ecosystems in Internet of Packaging. NB! ICT Innovation, Regulation, Multi Business Model Innovation and Technology, pp. 77-94. https://doi.org/10.1080/09593969.2020.1724555

[1] During the course of PhD research, the PhD student's last name has changed from maiden (Lydekaityte) to married (Karpavičė)

PAPER b:

Tambo, T., & Lydekaityte, J. (2019). Smart and interactive packaging – on long term studies and technological enablers in retailing of consumer packaged goods (CPG). In Proceedings of the 28th International Association for Management of Technology Conference. Mumbai: Excel India Publishers. pp. 82-94.

PAPER c:

Tambo, T., & Lydekaityte, J. (2019). Internet of packaging (iop) for consumer experience: a performance management and measurement design case. Paper presented at PMA Symposium 2019, Padua, Italy, pp. 1-4.

PAPER d:

Lydekaityte, J., & Tambo, T. (2021). Internet of Packaging and the Bridge Between Digital Marketing and Physical Retailing. In Encyclopedia of Organizational Knowledge, Administration, and Technology, IGI Global, pp. 2057-2070. https://doi.org/10.4018/978-1-7998-3473-1.ch141

PAPER e:

Mikkelsen, J. S., Lydekaityte, J., & Tambo, T. (2022). Optimization of Packaging Processes for Special Orders Using Process Activity Mapping. In Advances in Manufacturing Processes, Intelligent Methods and Systems in Production Engineering: Progress in Application of Intelligent Methods and Systems in Production Engineering. Cham: Springer International Publishing, pp. 1-14.
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Lydekaityte, J., & Tambo, T. (2019). Technological capabilities of printed electronics: features, elements and potentials for smart interactive packaging. In 2019 Portland International Conference on Management of Engineering and Technology (PICMET), IEEE, pp. 1-11.
https://doi.org/10.23919/PICMET.2019.8893810

PAPER g:

Karpavičė, J., Tambo, T., Venytė, I., & Gegeckienė, L. (2022). NFC-enabled Product Packaging: Designing the Research Methodology for the User Experiment. Paper presented at The International Young Researchers Conference "INDUSTRIAL ENGINEERING 2022", Kaunas, Lithuania, pp. 1-8.

PAPER h:

Gegeckienė, L., Venytė, I., Karpavičė, J., Tambo, T., Vaitasius, K., & Pauliukaitis, D. (2022). Near field communication (NFC) technology in the packaging industry. Paper presented at GRID 2022, Novi Sad, Serbia, pp. 1-8. https://doi.org/10.24867/GRID-2022-p54

PAPER i:

Karpavičė, J., Tambo, T., Gegeckienė, L., Venytė, I. (2023). Mechanical characteristics of NFC sticker under the environmental impacts (Work in Progress).

PAPER j:

Lalisova, D., Karpavičė, J., Tambo, T. (2023). Technology Acceptance Model for Enhanced Shopping Experience Through Online Recommendation Agent. In International Conference on Human-Computer Interaction (Accepted / Work in Progress).

1 Chapter - Introduction

As the dissertation title indicates, this chapter sets the scene for smart interactive packaging toward enhanced consumer experience and product functionality. First, the motivation and background of the PhD research project are determined, followed by a presentation of the PhD research objectives and questions. The chapter closes by elaborating on the dissertation structure and a visual demonstration of the appended papers' connection to research objectives and questions.

1.1. Motivation and background

The challenges of dynamic and complex business environments provoked by growing customer demands and product interoperability led multiple industries to severe changes in their technologies and induced the continuous introduction of new products (Ben-Daya et al., 2019). Businesses have entered a new evolution by applying new technologies and strengthening branding channels (Rajagopal, 2019). Nowadays, IoT-enabled smart objects already collect, store, and transfer data that afterward is processed and transformed into useful action-oriented information, such as timely warnings, conjectural outcomes, or beneficial courses of action (Ben-Daya et al., 2019). The possibility to connect and communicate with anyone, everywhere, at any time, impacts how brands can engage with their consumers by creating meaningful interactions with their products or services (Dutot, 2015). Furthermore, the development of Information and Communication Technologies (ICT) and broadband cellular networks empowered mobile technologies to become an inherent part of everyday life (Gbongli et al., 2019). The expeditious societal adoption of mobile phones and their capabilities to largely enrich personal and professional activities clarify the widespread and increasing use of mobile devices (Liébana-Cabanillas et al., 2015). As a consequence, the digital revolution, induced by technological advancements, the growth in e-commerce, and the increased utilization of smartphones, has prompted phenomenal shifts and disruptions in the retail environment (Boudkouss and Djelassi, 2021; Shankar et al., 2021). Recent studies revealed the increasing trend in stores to shift toward the "phygital" experiences by introducing digitally enhanced consumer touchpoints as the first points of interaction between consumers and brands/retailers (Vannucci and Pantano, 2020). In fact, products and their packaging are transformed into such smart objects providing an extended user interface (Lydekaityte, 2020). Especially, when a package is built with sensors or any other wireless communication devices, the product becomes connected to the IoT concept (Fernandez et al., 2023). As a result, traditional passive packaging faces alternatives, and therefore, more preeminent forms of packaging are being presented in the market.

> "The history and development of packaging began with the primary need for containment. From its earliest forms as leaves, hollowed-out tree limbs, straw, and skins, packaging has developed, become more sophisticated, and improved to meet the specific needs of product handling."
>
> Lydekaityte and Tambo (2020)

In general, packaging has always performed its pragmatic functionality to hold goods together and protect them throughout the supply chain operations until the products reach the end user (Loucanova et al., 2017). In the literature, the packaging is also addressed as a "communication surface", "communication medium", "contact point", or "silent salesman" that engages with consumers on a daily basis (Ryynänen and Rusko, 2015). However, the magnitude of packaging has significantly expanded over the last decades due to improved packaging functionalities. Since packaging has evolved from its predominant role to containing goods to actively interacting with the surrounding environment, the complexity of packaging's comprehension and role have grown (Mumani and Stone, 2018). The rapid

development of new computing and communication technologies, the evolution of wireless networks, and the growth of the Internet "have enabled the digital transformation from physical passive to digital network-connected packaging" (Lydekaityte and Tambo, 2019, A). The latter transcends the traditional communication concept and enables bi-directional interaction between the consumer and the brand (Lydekaityte and Tambo, 2018). This PhD research refers to such packaging as smart interactive packaging and considers its potential as a digital interactive system that goes beyond the long-established perception of human-packaging interaction and grants access to an extended user interface.

Smart Interactive Packaging as a Digital Interactive System

In the last decade, the accelerating adoption of emerging technologies, such as augmented reality, cloud computing, IoT, smart sensors, data carriers, and touch-sensitive surfaces, has given rise to the emergence of interconnected systems, where smart and sensory objects communicate not only among themselves but also with their users (Horan, 2016; Tolino and Mariani, 2018). The progressive use of the internet and the development of interconnected digital-physical systems have joined together two disciplines of engineering and design into one due to a mutual goal to enhance user experience (Lowgren, 2013). As a result, the notion of Human-Computer Interaction (HCI) has risen above the conventional mechanical computer systems and started to pervade into ordinary objects and environments that people are in contact with during their daily chores (Lorenzini and Olsson, 2019). In fact, product packaging has recently begun to be explored as one of the digital ICT systems in relation to HCI theory (Forcinio, 2019; Schaefer and Cheung, 2018). The perception of product packaging as a digital interactive system came to the surface due to the advances in conductive ink and nanomaterials and printing electronics techniques that allowed to embed, laminate, or directly print a wide range of passive and active electronics, such as microprocessors, sensors, actuators, data carriers, and memory chips, onto packaging design (Lydekaityte, 2020). Such packaging can collect, store and exchange data for immediate access to information about the surrounding physical world and its objects (Wang and Wu, 2012). On behalf of the digital capabilities of attached computing devices to packaging design, it is able to detect, track, communicate, and apply scientific logic to facilitate the decision-making for separate individuals (Loucanova et al., 2017). For instance, retailers deploy network-connected packaging to enrich the consumer experience by providing access to additional product information, proof of product authenticity, reward-based incentives, and better brand communication (Savastano et al., 2019; Karpavičė et al., 2023, PAPER V).

Smart Interactive Packaging as Extended User Interface

The consumer market is driven by diverse digital interfaces to build a bridge between consumers, products, and brands in order to deliver unique and unexpected experiences (Bezerra et al., 2015). With an exponential rise in computer systems applications, a multitude of diverse digital-physical artifacts and interfaces have emerged, starting from mobile devices and domestic appliances and finishing to autonomous vehicles and smart homes (Bezerra et al., 2015). Product packaging also turned into one of such digital interfaces. Users interact with packaging in every supply chain process, including manufacturing, distribution, retailing, and end-consumption (Mumani and Stone, 2018). According to Weser (2016), research activities related to human-packaging interaction, also called user-packaging interaction (Mumani and Stone, 2018) or consumer-packaging interaction (Ryynänen and Rusko, 2015), mainly evolve around marketing-, ergonomic-, and human-oriented factors. For instance, human-packaging interaction literature takes into consideration the concerns related to the proper handling of packaging, convenient packaging opening, factors affecting package accessibility, and storage and disposal of the package (Joutsela et al., 2017). However, the development of advanced wireless communication devices and IoT triggered the rise in cyber-physical systems that opened "a new digital dimension for interaction and user experience" and went beyond the pragmatic features of human-

packaging interaction (Petrelli, 2017). As a result, product packaging with incorporated electronic intelligence becomes a visual, tactile, and digital encounter with consumers – an extended user interface that designers can fill with distinctive moments and experiences, giving brands and retailers a chance to have enhanced communication with their consumers (Lydekaityte, 2020).

Near Field Communication for Enhanced Consumer-Packaging Interaction

Near Field Communication (NFC) is one of the progressively increasing technologies that professionals have started to investigate as a potential tool for enhanced consumer-brand interaction (Lydekaityte, 2020). Researchers draw attention to the ability of mobile devices and mobile apps, in combination with various wireless communication technologies, to transform consumer experience and impact behavioral intentions (Castillo and Bigne, 2021). The NFC tag attached to the product's packaging turns these items into "a direct communication channel with consumers filling up their shopping experiences with authentic and secured product information, product differentiation, and brand promotion" (Karpavičė et al., 2022, PAPER V). With the standardization of NFC technology, the packaging industry could be able to reduce counterfeiting, reduce investment risk, and attain greater transparency in business operations (Shin, 2014). Consequently, NFC-enabled packaging is expected to attract consumer interest further, leading to more memorable and engaging experiences that directly affect the consumers' perception of the packaged product and, in turn, the brand or retailer (Karpavičė et al., 2023, PAPER V).

1.2. Problem formulation and research questions

However, the potential of smart interactive packaging is not yet fully explored, whereas the other smart packaging types, active and intelligent packaging, have been researched thoroughly (for instance, Biji et al., 2015; Kontominas, 2015; Loucanova et al., 2017; Yam et al., 2005; Van Long et al., 2016; Castro Mayorga et al., 2018) and already commercialized for perishable products. While this packaging ensures improved security and preservation of packed goods, brands are still in need to find better ways to connect with their consumers, build stronger relationships and prolong consumers' experience with their products. Consequently, new forms of packaging can contribute to retailers' differentiation and optimization and connect in-store and at-home experiences with the brands' digital marketing activities. However, although studies (Underwood, 2003; Ryynänen and Rusko, 2015; Rundh, 2005; Ampuero and Vila, 2006) approved packaging as a powerful communication tool for product positioning but did not consider the influence of information and communication technology. Similarly, research on human-packaging interaction only investigates the pragmatic aspects of users' interplay with packaging, mainly emphasizing the need for convenient handling, storage, and disposal (Weser, 2016; Joutsela et al., 2017). Furthermore, the literature on the digital capabilities of smart interactive packaging to enhance consumers' engagement is limited. Most of the research related to enhanced packaging (Nilsson et al., 2012; Fernández-Salmerón et al., 2015; Shen et al., 2017) only explored and designed solutions for the improvement of logistics operations, whereas further steps of the supply chain after the warehousing are not taken into consideration. Digitally enhanced packaging is still not widely recognized or even explored as a potential tool for enhanced consumer experience and product functionality during human-packaging interaction occurring in-store and at the consumer's home. In response to this apparent lack of research, the following research gaps are identified with the corresponding research questions proposed in this PhD research to fill them in:

1. The current model of the primary packaging functionalities is well established from a passive packaging perspective and does not take into consideration the influence of technological capabilities provided by the smart packaging, as seen in the following literature (Rundh, 2005; Loucanova et al., 2017; Ampuero and Vila 2006; Underwood, 2003; Lindh et al., 2016; Mumani and Stone, 2018; Ford et al., 2012). Furthermore, since most of the research only concerns

active and intelligent packaging (Mumani and Stone, 2018; Asgari et al., 2014; Raheem, 2013; Biji et al., 2015; Brockgreitens and Abbas, 2016; and others), the literature only considered these types of smart packaging impact on the main packaging functions. Consequently, there is a need to investigate how new forms of enhanced packaging change the long-standing comprehension of the primary packaging roles and functionalities. As a result, the following research question has been proposed:

RQ1: How does the emergence of smart packaging impact the traditional concept of the main packaging functions?

The proposed research question aims to examine the traditional model of packaging functions, propose a distinctive classification of smart packaging types, and develop a new model of the main packaging functionalities based on the features of enhanced packaging.

2. Product packaging is still predominantly understood as a static and passive element of a product. Research on the digitally enhanced or network-connected product packaging for better consumer interaction, brand-consumer communication, and increased product functionality is scarce. There is a lack of studies that investigates smart interactive packaging as a digital interactive system that provides new forms of human-packaging interaction, and, thereby, has to be appropriately built to address the complex relationship between user behavior and interactive system design (Candy and Costello, 2008). Consequently, the following research question has been proposed:

   RQ2: What are the main peculiarities of smart interactive packaging as a digital interactive system in regard to the interaction design theory?

   The proposed research question aims to explain the comprehension of smart interactive packaging as a digital information system and a cyber-physical object through the lens of interaction design theory. The research activities include investigating the main interacting agents in enhanced human-packaging interactions, the critical elements of the digital interactive system, and the main concerns to address while designing smart interactive packaging.

3. A wide range of emerging technologies can be integrated into product packaging for enhanced consumer experience and product functionality in retail and at-home environments. However, there needs to be more consistency and coherence in knowledge about state-of-the-art technologies and their applicability for product packaging between academic institutions and actors outside of academia. Jackson (2022) states that “true innovation requires big tech, academia, and government to work together”. Therefore, gathering knowledge about the potential technologies must take place at both scientific and industrial events. The research question is constructed below:

   RQ3: What potential technologies can be integrated into the smart interactive packaging design?

   The purpose of this research question is to bridge the gap between academia and society in relation to the current developmental status of emerging technologies that can be applied to product packaging. The research question aims to provide a comprehensive list of the most nascent materials, devices, computing systems, and manufacturing techniques that enable new forms of enhanced packaging to come to the market.

4. Near Field Communication technology has recently attracted practitioners’ attention for its potential for enhanced consumer-product interaction (Karpavičė et al., 2023, PAPER IV). Based on the technology screening activities performed at both academic and industrial events, in this

PhD research, NFC has been selected as the main emerging technology to explore. Currently, NFC technology is widespread in door access, transport cards, contactless payments, and other mediums that require secure and fast data exchange between devices (Nguyen et al., 2019). However, despite the fact that the technology has been on the market since 2010, it still "has not yet reached its way to enhanced consumer engagement through the product's packaging" (Lydekaityte, 2020). Although the technology has already been commercialized, it is up to the present time, it has not been broadly applied to the packaging industry. The research related to NFC is limited to only a small number of studies investigating NFC as a way to communicate information from sensors for monitoring and tracking applications (Escobedo et al., 2017; Zhang et al., 2017; Li et al., 2018; Nguyen et al., 2019; Barandun et al., 2019). To the best of our knowledge, none of the studies explore NFC as a branding and marketing tool incorporated into a product's packaging. Therefore, the following research question is constructed:

RQ4: What are the main particularities of NFC technology utilized for product packaging?

The research question aims to provide an overview of the main NFC technology elements, characteristics, and working principles. Research activities consist of investigating NFC's technological capabilities and benefits related to enhanced consumer, retailer, and brand experiences, as well as identifying potential technological barriers of NFC technology that might intercept the coherent interaction with the NFC system.

5. The benefits of NFC have already been outlined by multiple researchers, including product identification and authentication (Violino et al., 2019), extremely low power consumption (Dutot, 2015), and the ability to achieve better transparency in businesses (Shin, 2014), to name a few. Although the potential of NFC-enabled packaging is significant, "various challenges related to technological feasibility, customer acceptance, and economic benefit for the business model hinder NFC technology from being widely applied to the packaging industry" (Karpavičė et al., 2023, PAPER IV). Furthermore, regarding the HCI theory, the design of NFC-enhanced product packaging as a digital interactive system has to be based on the fundamentals of interaction design to build functional and effective relationships between the consumer and the brand (Lydekaityte, 2020). The success of this connection highly depends on whether the developed digital-physical object can create and maintain a pleasing interface with the user incorporating both technology- and human-oriented variables. In addition, Museli and Navimipour (2018) claim that NFC adoption highly depends on users' willingness to accept and utilize the technology, especially when their behavior and changing needs are essential factors for driving innovations. Consumers are unaware of the existing technologies around them, do not trust the technology entirely, and have limited understanding and perception of it (Tiekstra et al., 2021). Consequently, it is necessary to investigate the determining factors related to technical feasibility and consumer perception, and therefore, the fifth research question is formulated as follows:

   RQ5: How do different factors related to technical- and user-oriented barriers affect the consumers' perception and willingness to adopt the NFC technology for product packaging applications?

   The research question aims to develop and present the preliminary results from user-packaging experimentation, where individuals will interact with NFC-enabled product packaging in order to provide an overview of all potential barriers that may prevent the successful acceptance of NFC technology applied to the product packaging.

6. The assessment of user acceptance of technology enables researchers and developers to explain and predict the determining factors that can impact individuals' adoption of new technologies (Dutot, 2015). The existing technology acceptance models examine how a particular system's design elements influence users' perception and behavior toward that technology aiming to reduce the risk of resistance or rejection (Rostam et al., 2015). This PhD study selected the well-established and acknowledged Technology Acceptance Model (TAM) to investigate the determinants of NFC technology acceptance for product packaging applications. However, there is a scarcity of published studies on TAM and NFC-enhanced product packaging (Karpavičė et al., 2023, PAPER V). Research on the adoption of NFC is mainly focused on contactless payments (Flavián et al., 2020; Zhao et al., 2020; Khalilzadeh et al., 2017; Ooi et al., 2016; Ramos-de-Luna et al., 2016), with several studies on medication prescription, dosage, and intake (Aldughayfiq and Sampalli, 2021), tourism for smart posters and mobile apps (Boes et al., 2015; Liébana-Cabanillas et al., 2020), conferences and expositions (Han et al., 2016), education in ULE (Osman et al., 2018), and home appliances (Teh et al., 2014). As a result, there is a need to identify external variables for the TAM model that would positively impact the adoption of NFC technology in product packaging. The final research question is as follows:

   RQ6: What are the most impactful factors for NFC technology acceptance in product packaging applications?

   Within this research question, the PhD study aims to identify the potential variables impacting the NFC technology acceptance for consumer packaging, develop an extended version of the TAM model by aggregating factors presented in other related studies, and recognize the most influential variables for NFC-enabled packaging acceptance.

1.3. Research objective

Based on the presented research gaps that emerged from smart packaging, Human-Packaging Interaction, Interaction Design, NFC, and TAM literature concerning the digitally enhanced interactive system's capabilities and design for successful and effective user interaction, this PhD research aims to investigate the potentials of NFC technology to be applied for product packaging for enhanced consumer experience. Overall, the research intends to provide the reader with an understanding of the main elements that need to be taken into consideration when designing smart interactive packaging solutions through the lens of different beforementioned theories. The main research objective is articulated as follows:

How digital innovation in primary product packaging can enhance CPG consumers' experiences and products functionalities

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By digital innovation, the author refers to any physical element that could be embedded, attached, laminated, or incorporated directly into the product packaging in the form of electronics, inks, stickers, graphics, and other that enables reciprocal actions and thereby creates two-way communication between the user and brand though the product package.

The PhD research activities are divided into four stages in which the first stage, work package 1 (WP1), explores the current understanding of smart packaging, the second stage, work package 2 (WP2), explains the concept of packaging as a cyber-physical agent, work package 3 (WP3), explores the potential of NFC technology, and the final work package 4 (WP4) explores the determining factors for the adoption of NFC technology in product packaging. Table 1 presents the WPs' relation to research questions and research PAPERS I-V.

Table 1. The relation between PhD research Work Packages, PhD Research Questions and PAPERS I-V

Work Packages	PhD Research Questions	Papers
WP1: Exploring the current understanding of smart packaging and its influence on traditional packaging functions.	RQ1: How does the emergence of smart packaging impact the traditional concept of the main packaging functions?	PAPER I
WP2: Explaining the conception of smart interactive packaging as a cyber-physical agent for an extended user interface	RQ2: What are the main peculiarities of smart interactive packaging as a digital interactive system in regard to the interaction design theory? RQ3: What potential technologies can be integrated into the smart interactive packaging design?	PAPER II
WP3: Exploring the potential of Near Field Communication (NFC) technology to be applied for smart interactive packaging	RQ4: What are the main particularities of NFC technology utilized for product packaging?	PAPER III
WP4: Exploring the determining factors for the adoption of NFC technology in product packaging	RQ5: How do different factors related to technical- and user-oriented barriers affect the consumers' perception and willingness to adopt the NFC technology for product packaging applications? RQ6: What are the most impactful factors for NFC technology acceptance in product packaging applications?	PAPER IV PAPER V

1.4. Dissertation structure

The PhD dissertation frames the culmination of three years of work. The thesis is established on a collection of five papers written during the PhD research project to answer the main PhD research objective presented in the previous section. Furthermore, a list of supporting papers (see LIST OF APPENDED PAPERS) is also presented, consisting of eight published scientific papers, two scientific papers in progress, and two unpublished papers. Figure 1 illustrates how contribution papers and supporting papers are linked to the PhD research questions.

The dissertation is divided into six chapters that summarize the main research activities from the appended papers, PAPERS I-V. Although the appended papers are the synthesis of the PhD research activities performed, the dissertation aims to describe them from a broader perspective by aligning their main findings and contributions and clarifying the red thread throughout all papers. The latter is graphically illustrated in Figure 2, demonstrating the connectedness between the work packages and the main findings from the appended papers.

Chapter 1, the **Introduction**, presents the motivation and background for the PhD research project. This chapter defines the overall PhD research frame by determining the main research objective, raised research questions, and research division into work packages.

Chapter 2, the **Theoretical Background**, determines the theoretical positioning of the PhD research and elaborates on the main themes related to digital innovation in product packaging for enhanced consumer experience and product functionality. The main aim of this chapter is to synthesize the theoretical foundations from PAPERS I-V into a coherent narrative for the dissertation.

Chapter 3, the **Research Methodology**, presents the methodological choices that have been made to address the main PhD research objective by explaining the PhD project's philosophical position and overall research approach. Furthermore, this chapter presents the research methodology of each

appended paper I-V by establishing a consistent and holistic depiction of PhD research activities and the coherence among them.

Chapter 4, the **Research Findings**, describes the findings of the conducted PhD research activities. The chapter encompasses the main findings and contributions from PAPERS I-V answering the PhD research questions.

Chapter 5, the **Discussion**, deliberates on the PhD research findings by reflecting on theoretical and practical implications, the limitations of the study, and further research considerations for future studies.

Finally, *chapter 6*, the **Conclusion**, finalizes answers to the main research objective posed by this thesis.

1.5. Chapter summary

This introductory chapter established the motivation and background for the PhD research by elaborating on smart interactive packaging as a digital interactive system that becomes an extended user interface for enhanced human-packaging interaction. Moreover, the PhD research questions were clarified by specifying the research gaps in the corresponding literature domains, including Human-Computer Interaction, Human-Packaging Interaction, Interaction Design, and Technology Acceptance theories. The research questions were framed in such a way as to generate three types of knowledge: understanding, exploring, and explaining digital innovation in product packaging for enhanced consumer experience and increased product functionality. The chapter presented the main PhD research objective and the research activities division into four work packages. The chapter concluded with an overview of the PhD dissertation's structure, a visual demonstration of appended articles' relation to the research objective and research questions, and a graphical demonstration of the connectedness between the work packages and the main findings from the appended papers.

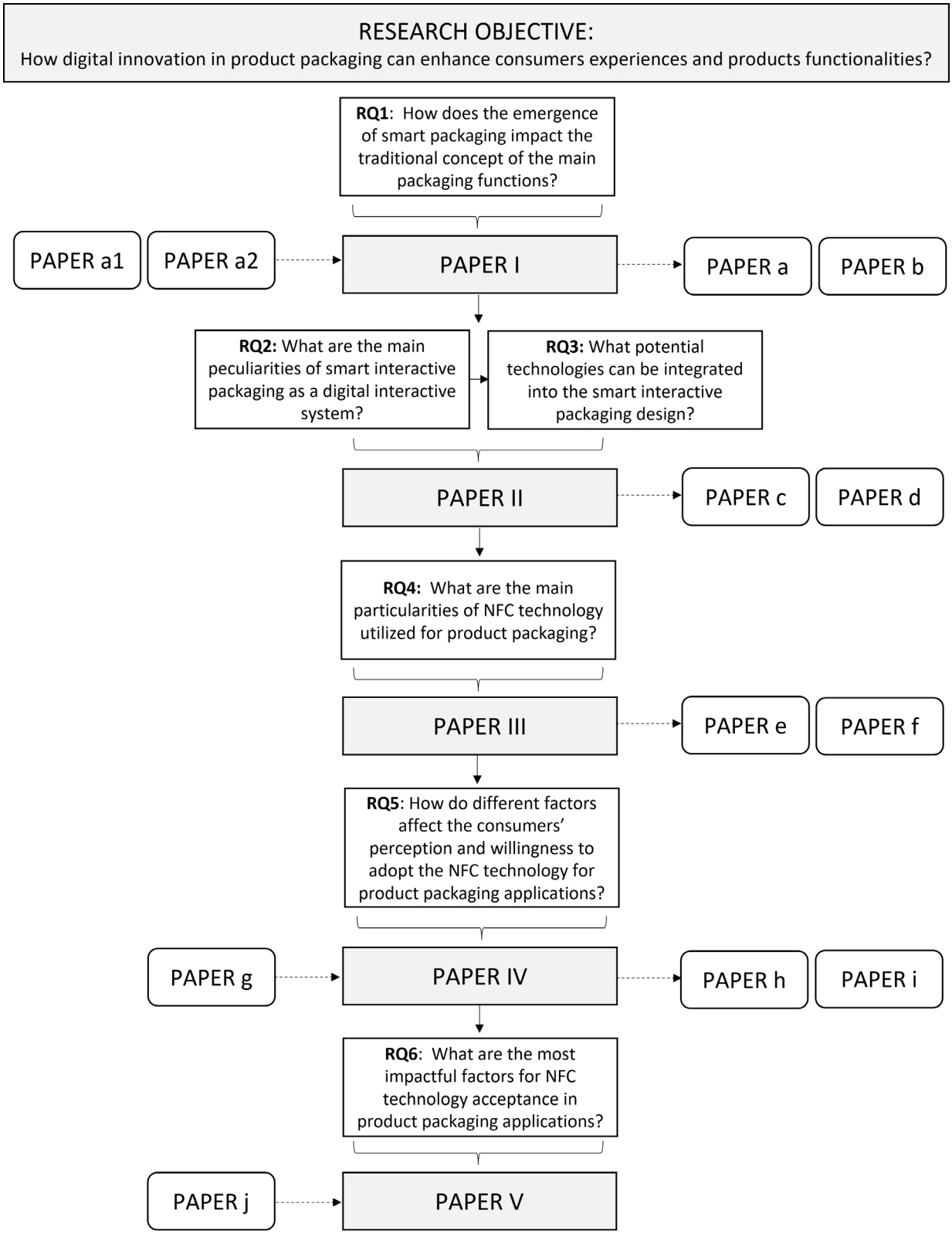


Figure 1. Appended papers and their relation to the research objective and research questions

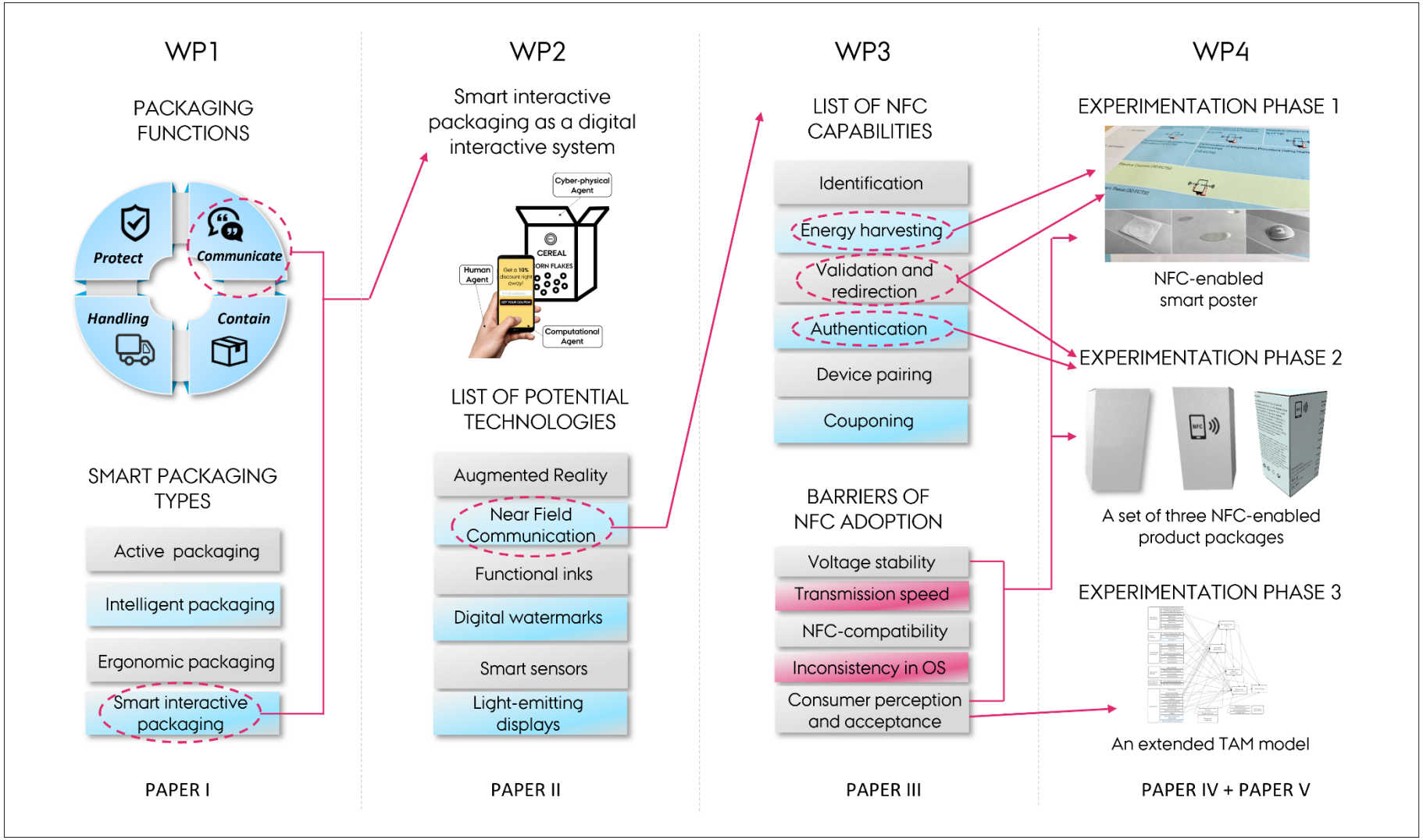


Figure 2. Demonstration the connectedness between the work packages and the main findings from the appended papers (sources of elements: www.pngaaa.com, Microsoft 365 stock images, self-created)

2 Chapter – Theoretical Background

2.1. Theoretical positioning

Every smart packaging-enabling technology associated with the phenomenon of digitization is determined by the following terminology of digital innovation, digital artifacts, digital capabilities, and digital affordances. Yoo et al. (2010) define digital innovation creating new combinations of digital and physical components in order to create novel products. Meanwhile, digital artifacts involve the action of human beings. They are objects created by and composed of digital technology and the outcome of coordinated human action (Yoo et al., 2010). As a result, every enabling technology, such as RFID, NFC, or AR, can be further referred to as a digital innovation, whereas smart interactive packaging – as a digital artifact (Lydekaityte and Tambo, 2019, A). The main distinction between physical artifacts, i.e., passive packaging, and digital artifacts, i.e., smart packaging, is that the latter ones are intentionally incomplete, unfinished technologies that are continuously being improved, updated, and perpetually in the making (Kallinikos et al., 2013). Moreover, the attributes or characteristics of digital artifacts, like editability, interactivity, distribution, recursion, and homogenous data, enable them to develop innovative properties and implicate innovation in products and services.

Digital artifacts enable and facilitate innovation by employing their digital capabilities and affordances (Lydekaityte and Tambo, 2018). While capabilities refer to functions and abilities to do something without any involvement of the surrounding environment, affordances go beyond functions and characteristics involving the environment around the artifact, it is an action supported or enabled by something or someone (Maier and Fadel, 2009). For instance, the NFC tag has a digital capability to store information about a product's authenticity that allowing to combat counterfeiting and grey market diversion. Digital innovation in product packaging transforms it into a programmable, addressable, sensible, and communicable smart object, and, thereby, broadens the definition of packaging, bringing a new expression of Human-Packaging Interaction and the Internet of Packaging into the surface (Lydekaityte and Tambo, 2019, A).

In relation to smart interactive packaging, digital capabilities and affordances enable brands and retailers to address a wide range of challenges occurring in the supply chain (Barbier et al., 2016). This PhD research has divided the touchpoints of user-packaging interaction into the following environments: manufacture and distribution system, retail or in-store, and at-home. This study is particularly interested in human-packaging interaction in retail and at-home settings, where consumers interact with product packaging the most. The study mainly investigates the enhancement of the primary packaging, leaving the secondary and tertiary packaging out of the research scope. Furthermore, in this PhD research, smart interactive packaging is also referred to as "enhanced packaging", "digitally enhanced packaging", "connected packaging", and "network connected packaging".

Overall, this chapter presents the theoretical background of the PhD dissertation summarized from the appended PAPERS I-V. It reviews the main theoretical domains on digital innovation in product packaging in the context of traditional packaging functionalities, the perception of smart interactive packaging as a digital interactive system, technologies applied to smart interactive packaging, near field communication, and the theory of technology perception and acceptance. Furthermore, this section identifies the research gaps in the scientific literature linking them with appended papers and their novelty and originality for the purposes of solving the corresponding inconsistencies. Table 2 presents a summary of the research gaps and research originality of PAPERS I-V.

Table 2. A summary of research gaps and research originality of PAPERS I-V

	Research Gaps	Novelty and Originality
PAPER I	1) There is no consistent classification of the main packaging functions provided by the packaging literature. 2) There is no distinctive classification of smart packaging types in the literature. 3) The current model of packaging functions does not take into account the additional functionalities of smart packaging. 4) The research in smart packaging is mainly focused on active and intelligent packaging with a modest amount of knowledge about smart interactive packaging.	This paper proves its originality by exploring a shift from passive packaging to digitally enhanced network-connected packaging triggered by technological developments. Also, the paper presents smart interactive packaging as a novelty in retailing and brand management that bridges the general consumer experience between digital marketing and physical shopping throughout the product package.
PAPER II	1) Packaging is still mainly understood as a static and passive element of a product. 2) There is a scarce amount of research on smart interactive packaging that concerns the package as a digital interactive system. 3) There is a lack of understanding in the literature of smart interactive packaging as a cyber-physical agent/system.	This paper presents smart interactive packaging as a "non-conventional" element of computer and mechanical systems and refers to it as a cyber-physical agent consisting of embedded electronics into consumer products. The traditional comprehension of packaging as a "communication surface", "communication medium", and "silent salesman" is broadened by digitalization turning enhanced product packaging into a digitally extended user interface.
PAPER III	1) The scientific literature in regard to NFC is limited to only a handful of research on NFC performance as a sensor's data carrier for monitoring and tracking applications, none of the existing studies investigates NFC as a potential branding and marketing tool attached to a product's packaging. 2) There is a lack of a comprehensive overview of NFC technological capabilities.	This paper presents an unexplored and uncharted topic in the scientific community by investigating the potentials of NFC technology to be applied to the product packaging for enhanced consumer, retailer, and brand experiences, such as engagement and entertainment, confirmation of authenticity, prevention of counterfeiting and grey market division.
PAPER IV	1) There is a lack of research investigating how the technological barriers of NFC technology impact the perception and acceptance of the NFC system.	This paper presents a distinctive experiment design for NFC technology acceptance for product packaging applications.
PAPER V	1) The scientific literature in regard to NFC and TAM is limited to only mainly investigating the NFC technology acceptance for wireless payments, whereas none of the existing studies explores NFC technology acceptance for product packaging applications.	This paper presents an unprecedented case of applying the TAM model to investigate the potential factors of NFC technology adoption for product packaging applications.

2.2. The main functions of passive traditional packaging (PAPER I)

In general, traditional product packaging has always served the functionalities from holding goods together and protecting them throughout the supply chain until the point of disposal. Previous studies (Underwood, 2003; Ampuero and Vila, 2006; Lindh et al., 2016; Loucanova et al., 2017; Mumani and Stone, 2018) have presented distinct classifications of packaging functions. For example, Lindh et al. (2016) indicated three main packaging functions: to protect, to facilitate handling, and to communicate.

Ampuero and Vila (2006) added the function of convenience during logistics, retailing, and consumption. Moreover, Underwood (2003) expanded the comprehension of product packaging by considering the package's role of attracting attention, imparting a distinctive brand identity, and communicating the brand's values. To summarize, the most common packaging functions found in the literature were: protection, communication, convenience, and containment (Figure 3).

Protection function to maintain quality, safety and prolong shelf-life

In general, the protection function is meant to eliminate all the potential deteriorative and containing impacts from the external environment, including movement and robust handling during distribution, storage, and transportation (Shah et al., 2010; Rundh, 2005; Olsmats, 2017). The methods for protection can be grouped into physical, barrier, tamper-evident, and preservation-based. Firstly, the design of the package has to ensure mechanical strength and shatter resistance, including protection against vibration, electrostatic discharge, mechanical shock, etc. (Raheem, 2013; Olsmats, 2017). Secondly, packaging must behave as a barrier from diverse physical, chemical, and microbiological attacks (Rundh, 2005). Thirdly, packaging has to protect against product tampering, pilferage, and theft (Olsmats 2017). Finally, preservation, as a part of the protection function, seeks to prevent food spoilage, maintain the quality of the product, and prolong its shelf life (Asgari et al., 2014).

Communication function to identify, inform, and advertise

Lydekaityte and Tambo (2020) describe packaging "as a means of communication to deliver messages about the product through various graphical cues that affect consumers' perceptions." Based on the research, the communication function aims to "(i) identify the product, (ii) inform about the product, (iii) attract attention, (iv) persuade the consumer to purchase the product, (v) identify brand values, and (vi) advertise and promote the product and the brand." (Lydekaityte and Tambo, 2020). First of all, since packaging is an inseparable part of a product, it imparts identification, differentiation, and perception of the product (Underwood, 2003; Rundh, 2005; Ampuero and Vila, 2006). Secondly, packaging also plays an instructive part by imparting detailed product information, such as the expiration date, nutritional value, level of sustainability, consumption instructions, and similar (Asgari et al., 2014; Brockgreitens and Abbas, 2016; Wyser et al., 2016). Thirdly, "packaging communicates visual attributes to attract attention and influence the consumer's perception of the product and its quality, which persuades the consumer to purchase the product" (Lydekaityte and Tambo, 2020). Furthermore, packaging is an enabling tool for brand image (Ford et al., 2012) that communicates brand cues, features, and brand personality (Ryynänen and Rusko, 2015; Ampuero and Vila, 2006). Finally, packaging has also become a great marketing tool to promote and merchandise the product to consumers on the store's shelf (Nilsson et al., 2012).

Convenience function to facilitate handling, logistics, and consumption

The other packaging function is to facilitate convenience throughout the supply chain. Firstly, packaging has to serve the distribution system (Rundh, 2005), encompassing storage, transportation, distribution, warehousing, and stacking (Olsmats, 2017; Lindh et al., 2016). Secondly, packaging also impacts the way products are put on display in the retail store (Shah et al., 2010). Thirdly, Mumani and Stone (2018) argue that consumers' satisfaction highly depends on the packaging attributes that provide benefits after the purchase. Once the product is purchased, it has to conform to the needs of portability, rigidity, and easy-fit storability (Underwood, 2003). Furthermore, a package should provide easy access to the product (Rundh, 2005; Lindh et al., 2016). Smooth consumption or utilization of the packed product is also significant (Ryynänen and Rusko, 2015). Finally, packaging has to provide a clear declaration of how it has to be disposed of (Rundh, 2005).

Containment function to enclose, envelop, and hold products together

Overall, packaging is frequently referred to as a source of containment that holds goods together (Ampuero and Vila, 2006; Ryynänen and Rusko, 2015; Olsmats, 2017). However, the inclusion of containment as one of the main packaging functions is questionable at the moment (Lindh et al., 2016).

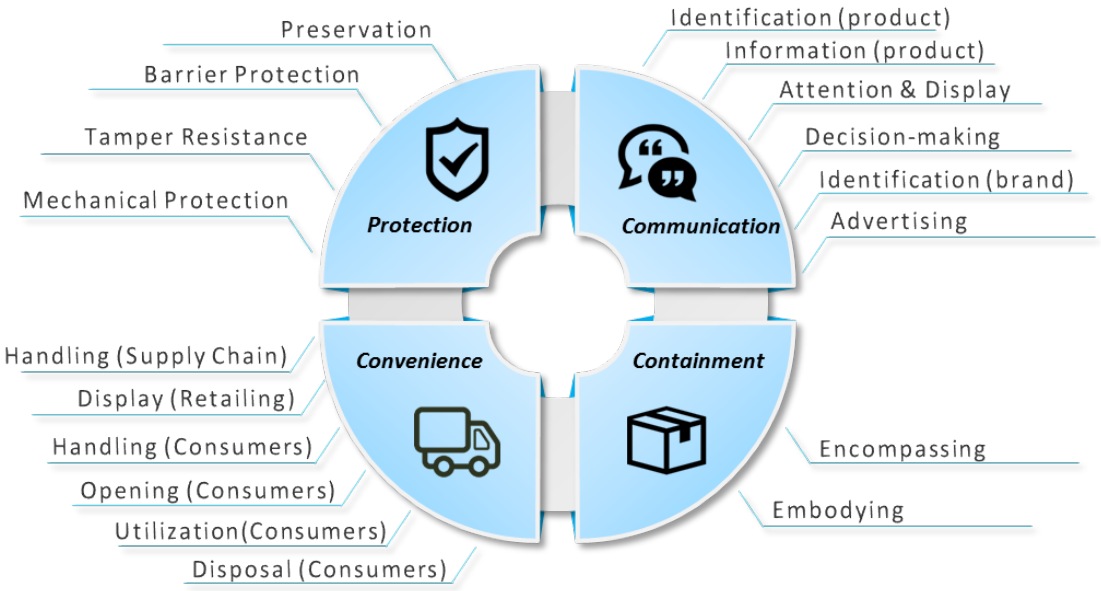


Figure 3. The model of the main functions and features of traditional primary packaging (Lydekaityte and Tambo, 2020)

2.3. From passive to smart packaging (PAPER I)

Generally, product packaging can be defined as: "a socio-scientific discipline that operates in society to ensure the delivery of goods to the ultimate consumer" (Lorenzini and Olsson, 2019). It is also described "as a combination of product, package, and distribution, which is intended to provide protection, convenience, containment, and communication throughout the entire supply chain until goods reach the end user" (Lydekaityte, 2020). However, the importance of the packaging role and the enhancements of its functionalities have uplifted over the years in relation to shifts in demographics, market globalization, lifestyles, and consumers' preferences (Azzi et al., 2012). Furthermore, the development of advanced technologies and manufacturing processes, such as printed electronics, nanomaterials, wireless connectivity standards, etc., has largely contributed to the change of the long-established perception of the packaging role (Lydekaityte and Tambo, 2020). Consequently, more advanced forms of packaging are being presented to the market and becoming an enhanced tool for supply chain communication (Lydekaityte and Tambo, 2020). Brockgreitens and Abbas (2016) describe smart packaging as any packaging that encompasses advanced technologies to either improve the primary functionalities of a package or to add new functions in comparison to traditional packaging.

Smart packaging types

In connection with the function that smart packaging elevates, a study by Lydekaityte and Tambo (2020) classified smart packaging into active packaging, intelligent packaging, ergonomic packaging, and smart interactive packaging:

- ***Active packaging***. According to Biji et al. (2015), active packaging maintains the internal packaging environment favorable for the packed product to retain its quality and extend its shelf-life. Active packaging is able to delay oxidation, control respiration rate, microbial growth, and moisture migration (Biji et al., 2015).

- ***Intelligent packaging***. On the other hand, intelligent packaging does not have any direct impact on the packaged goods. Instead, it monitors either the external environment surrounding the packaging or the state of the packaged products to inform users about the changes and current condition of the goods (Biji et al., 2015). Lydekaityte and Tambo (2020) define intelligent packaging as "a system that is capable of performing intelligent functions such as detecting, sensing, recording, tracing, communicating, and applying scientific logic in order to facilitate decision-making to prolong shelf-life, improve safety and quality, provide information, and alert people about possible issues".
- ***Ergonomic packaging***. Meanwhile, ergonomic packaging facilitates convenience throughout the supply chain (Brockgreitens and Abdennour, 2016).
- ***Smart interactive packaging***. Finally, contrary to intelligent packaging with integrated sensors and indicators that sends the information without any request from the user, smart interactive packaging establishes reciprocal actions and, thus, creates two-way communication between the package and the user (Wyser et al., 2016). Smart interactive packaging is the main interest in this research, therefore, a more in-depth description follows below.

2.4. Smart Interactive Packaging (PAPER II, PAPER III)

Taking into consideration that packaging already serves as an effective tool of communication medium (Schaefer and Cheung, 2018), the latest advances in conductive printed materials, printed electronics, IoT, wireless communication devices, and standardization of communication protocols have enhanced the communication function even further (Lydekaityte, 2019; Wyser et al., 2016). This alteration enabled packaging to induce digital innovation and become network-connected (Nilsson et al., 2012). Consequently, "smart interactive packaging goes beyond the traditional one-way informational flow and triggers the unique interaction capability between the package and consumer" (Lydekaityte, 2019). Such packaging involves the participation of users and their actions in order to get a response from a technology-enabled interactive packaging system to enhance consumers' experience and engagement with the products. Therefore, in this PhD research, smart interactive packaging is defined as "packaging that provides an interactive dimension between the consumer and the brand with the help of various enhanced communication devices, where the user initiates the interaction willingly to get some response" (Lydekaityte, 2020). As a result, the Consumer Packaged Goods (CPG) industry is particularly interested in making use of such packaging in their operations. The development of smart interactive packaging would greatly benefit businesses at multiple consumer-product interaction touchpoints (Ryynänen and Rusko, 2015) by adding such features as instant customer feedback, visual product enhancement, and brand protection (Lowgren, 2013). Furthermore, the growth of the internet allowed businesses to have access to an abundant amount of data (Teece, 2010). The induced digital transformation from conventional passive packaging to smart interactive packaging opens new digital capabilities that can generate valuable and profitable business data (Figure 4). As a result, the CPG industry is particularly interested in making use of such packaging in their operations. The development of smart interactive packaging would greatly benefit businesses at multiple consumer-product interaction touchpoints (Ryynänen and Rusko, 2015) by adding such features as instant customer feedback, visual product enhancement, and brand protection (Lowgren, 2013).

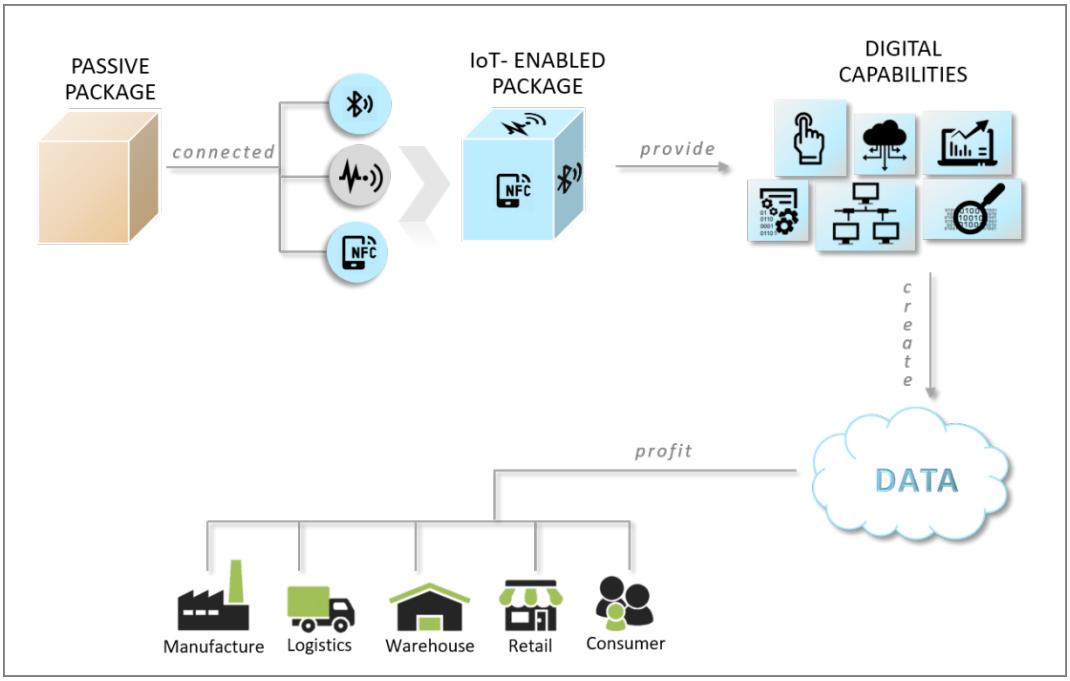


Figure 4. Digital transformation of product packaging (Lydekaityte and Tambo, 2019, A)

2.5. Smart interactive packaging as a novel user interface (PAPER II and PAPER III)

In regard to the increasing use of the internet, computing, and digitalized consumer products, the perspective of a user and a context of use surpassed the traditional perception of computer and mechanical systems and has begun to penetrate into everyday objects that consumers interact with in their daily life (Lorenzini and Olsson, 2019). The spread of consumer-oriented ICT systems forms an exclusive relationship between consumers and brands by creating unique moments and interfaces that brands can use as an opportunity to have emotional and sensorial interactions with their consumers (Bezerra et al., 2015). In the retail context, there is a growing trend in digitizing in-store services through digital touchpoints providing the first contact point with consumers with the help of mobile devices (Pantano and Vannucci, 2019). When consumers enter the store, the first point-of-purchase touchpoint is the package (Frydrychowski, 2020). Consequently, "a product's packaging with integrated electronic intelligence turns into a visual, tactile and digital encounter with consumers influencing their shopping experience and purchase behavior" (Karpavičė et al., 2023, PAPER IV). The integrated printable circuits, consisting of data carriers and sensors, onto product packaging can add an abundant number of features, such as visual product enhancement, instant customer feedback, authenticity, and brand protection, to name a few (Lydekaityte, 2019). According to Lydekaityte (2019), "connected packaging ability to collect and analyze data empowers brands to understand the effectiveness of the packaging/product and consumers' engagement better, and dynamically adapt to emerging needs by improving their services and products.".

Nevertheless, the success of this relationship depends on whether the designed artefacts impart a pleasing interface with a user since the aim of interaction design is to "create interactive products and systems which are usable – easy to learn, effective and pleasant to use" (Bezerra et al., 2015). In general, the interaction design "combines elements of HCI and user experience design to build overall essence and structure of interactive systems that support and facilitate user's goals for helpful and engaging product interfaces" (Lydekaityte, 2019). Consequently, the design of digitally enhanced packaging, considered a digital interactive system, has to comply with the principles of interaction design to create intuitive, effortless, and enjoyable systems (Lorenzini and Olsson, 2019).

Figure 5 illustrates how the emerging infrastructure of digital-physical systems encompassing everyday items, i.e., product packaging, and advanced communication technologies, such as unique identifiers, nanomaterials, data carriers, etc., transforms the traditional packaging into smart interactive packaging,

that in the context of IxD and UX, could be described as a phygital interactive system consisting of a human agent, computation agent, and cyber-physical agent (Lydekaityte, 2020).

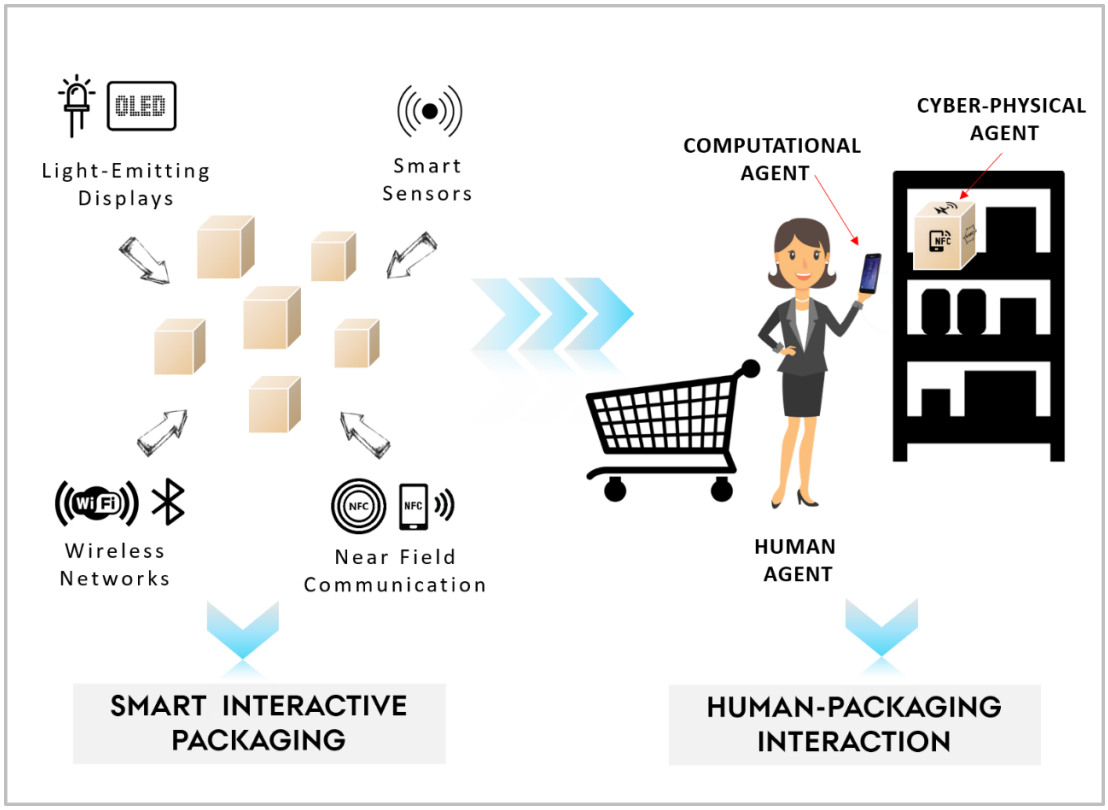


Figure 5. Smart Interactive Packaging as interactive system as a novel user interface (Lydekaityte, 2020)

2.6. Technologies applied to Smart Interactive Packaging

Throughout the PhD research, numerous different technologies have been found for potentials for smart interactive packaging. In this study, a potential technology refers to the physical elements that could be embedded, attached, laminated, incorporated, or printed directly or indirectly onto the product packaging in the form of electronics, inks, stickers, labels, graphics, and similar. Table 3 contains a summary of discovered technologies investigated and/or applied for product packaging. The table presents a precise definition of each technology together with the main enabling elements, primary purposes, environments of stakeholders' interactions, and assessed Technology Readiness Level (TRL). The information for the last two categories was gathered throughout the interviews with smart packaging experts from the AIPIA World Congress 2022 event and were conducted in Autumn 2022. Originally, Technology Readiness Levels (TRLs) were developed by NASA as "a systematic measurement system that supports the assessment of the maturity of a particular technology" (Petrovic and Hossain, 2020). In Table 3, the technologies are assessed based on the TRLs scale suggested by Petrovic and Hossain (2020). The assigned TRL addresses how mature is a given technology for smart interactive packaging applications. Therefore, even though the technology might be well-established and market available, its application to product packaging might still be developing. Furthermore, this study employs the touchpoints classification proposed by Ryynänen and Rusko (2015), that claim that the development of smart interactive packaging benefits businesses in several environments, including the supply chain, where smart packaging monitors and informs about the condition of the package products, the retail environment, where packaging aims to attract attention and facilitate the purchase, and the use environment/post-purchase situations at home, where the products are consumed or utilized.

Table 3. A summary of potential technologies for smart interactive packaging applications

Potential Technology	Description	Enabling components	Primary Purposes	Touchpoint of interaction	Technology Readiness Level*
Near Field Communication	A standard for a wireless data transmission to provide secure, short-range, and paired communication between devices triggered by a simple touch (Coskun et al., 2015)	Electronic microchip Antenna coil Reader UID	Product information and authentication, counterfeit, product origin, marketing insights	In-store At home	TRL9: Commercialized
Radio Frequency Identification	Passive, semi-passive, and active tags with Gen2 standard based on automatic identification technology (Shen et al., 2017)	Electronic microchip Antenna coil Reader UID	Real-time location and surveillance, access management, track & trace, inventory control	Supply Chain	TRL9: Commercialized
QR codes*	A two-dimensional code embedded in the physical environment that once read by a smartphone or a scanner, connects users to particular online content on a website in a form of an email address, link to coupons or vouchers, AR experiences, etc. (Acuti et al., 2022)	Graphical print Pictographic hyperlinks Cloud-based Reader	Quick access to information, consumer tracking (browsing time, geolocation, scan frequency,) marketing features	In-store At home	TRL9: Commercialized
Augmented Reality	"A technology that identifies and tracks data from the physical world, in combination with data drawn from digital sources to present the user with a view of the physical world overlaid with relevant computer-generated information" (Sorrell, 2015)	Image tracking and recognition Mobile app/web-based Reader (CPU, camera accelerometer, GPS)	Virtual engagement with products prior purchase, enhanced brand experience	In-store At home	TRL9: Commercialized
Light-emitting displays	Flexible, lightweight, biodegradable, low-power consuming, and cost-efficient light-emitting devices, including OLED, EPD, electrochromic displays, electroluminescent displays, thermochromic displays (Lydekaityte and Tambo, 2019, B)	Nanomaterials Nano particles Microcapsules Printed Electronics	Attract attention, enhanced brand experience, monitoring and informing about product condition and changes	Supply Chain In-store At home	TRL8: Pre-production
Monitoring and informing smart sensors	Light-weight, rollable, bendable, portable, and foldable sensing devices with multiple capabilities fabricated by PE techniques (Biji et al., 2015)	Nanomaterials Conductive Inks Printed Electronics	Monitoring product condition and changes	Supply Chain	TRL9: Commercialized
Kezzler codes	A cloud-based traceability platform that supports the entire product lifecycle from serialization aggregation to recycling (www.kezzler.com)	UID management GS1 EPCIS standard Cloud-based, Digital twin Geofence	Product digitization and supply chain traceability, enhanced product experience, item authentication	Supply Chain In-store At home	TRL9: Commercialized
Physical Unclonable Function (PUF)	PUF is a resemblance to the human biometric fingerprint that is based on "the exploitation of nano-scale device-level intrinsic	Digital/electronic fingerprint – secret keys	Cryptographic key generation, marketing, identification and	Supply Chain In-store At home	TRL9: Commercialized

	process variations from which device-specific random keys are derived" (Mispan and Halak, 2021)		authentication (counterfeit, product origin, geo-location)		
Smart labels	A combination of various electronics with diverse capabilities, data carriers, and energy supplying devices incorporated into different substrates, such as paper, PET, etc. (Wróblewski et al., 2014)	Data Carrier Sensor Battery (if needed)	Monitoring and informing about product condition and changes	Supply Chain	TRL 4-5: Lab Testing
Touch-interactive power paper (TiPP)	Self-powered devices for providing smart security applications, that "generate current due to a mechano-responsive charge transfer mechanism and convert it for activating a unique coding system" (Ferreira et al., 2022)	Touch-interactive electronics Unique coding system Wireless communication	Self-powered sensing and identification, security applications	Supply Chain In-store	TRL 2: Conceptual Design
Conductive Inks	Specialized ink designed for printed electronics manufacturing containing highly conductive nanoparticles, nanowires, nanotubes, or flakes, made from silver, graphene, copper (Huang et al., 2015)	Nanomaterials with high electric conductivity	Fabrication of printed electronic circuits, sensors, batteries, displays	Supply Chain In-store At home	TRL 9: Commercialized**
Functional Inks	Inks that "report exposure to environmental influences by switching between two states of optical properties" (Isohanni, 2022)	Nanometer particles with different properties	Information about product condition and changes	Supply Chain	TRL 9: Commercialized**
Security labels and seals	Tamper proof seals and customized security labels with unique identification (www.securikett.com)	Digital Optically Variable Devices (holograms) Microtext Security inks UID (QR, NFC, RFID) Cloud services	Counterfeit protection, product authentication, consumer engagement, digital platform for product identification, traceability, serialization	Supply Chain In-store	TRL9: Commercialized
IoT Pixel, Battery-Free and Battery-Assisted Pixel	Embeddable, low-cost computers based on Bluetooth Low Energy and RFID technologies that with the help of ML and AI in the could connects things to the internet (Williot, 2020)	RF energy harvester or Printed Battery Integrated sensing unit Security Unit Processing unit Bluetooth transmitter	Sensing (temperature, location), AES encryption, data confidentiality, authentication protection, item level visibility	Supply Chain In-store At home	TRL8: Pre-production
Digital Watermarks	A secure, imperceptible and covert data carrier containing relevant authentication information that is inserted to the print mark of the object linking physical product to a digital twin (Zheng et al., 2022)	Digital Watermark (pattern of bits inserted into an object)	Counterfeit protection, product authentication, product information, enhanced consumer experience, improved recycling	Supply Chain In-store At home	TRL8: Pre-production
NaviLens	User friendly technology for visually impaired people (www.navilens.com)	Printed unique code Mobile app	Product information, enhanced consumer experience	In-store	TRL9: Commercialized

* 3rd generation QR codes are more preeminent than the earlier versions broadening the technological capabilities, number of touchpoints and applications.

** Some functional inks are commercialized, whereas some are being under development due to the rising demand in innovative solutions

2.7. Near Field Communication for Smart Interactive Packaging (PAPERS III-V)

In recent years, different kinds of short-range wireless communication technologies have been attached to mobile devices, including infrared transceivers, Bluetooth, Radio Frequency Identification (RFID), and Near Field Communication (NFC) (Bandinelli et al., 2017). The latter is currently perceived not only as one of the most promising technologies for mobile devices (Bandinelli et al., 2017) but also is expected to influence consumers' everyday lives (Museli and Navimipuor, 2018). Even though the NFC technology has been around longer than a decade, it has just recently come to the surface, prompted by the significant growth of the IoT (Nguyen et al., 2019). Furthermore, the development of NFC-compatible smartphones has drawn consumers' attention and facilitated the NFC technology application in the market, as can be seen in Figure 6 and Figure 7 (Boes *et al.*, 2015). As a result, there is an increased interest in NFC from academics and professionals to explore this technology as a potential tool for enhanced consumer interaction and engagement (Lydekaityte, 2020).

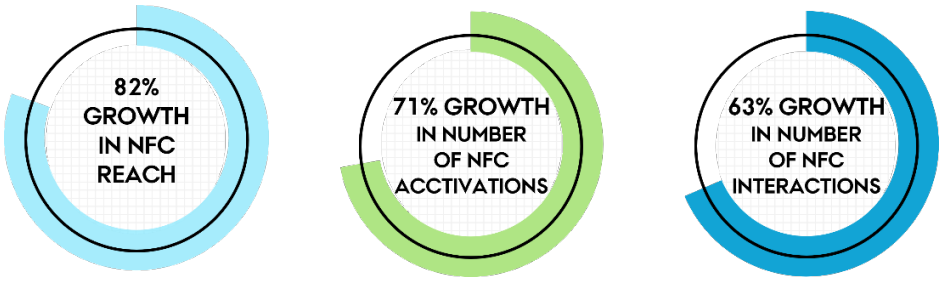


Figure 6. NFC usage growth from 2018-2020 (adapted from Blue Bite, (2021))

In general, NFC is "a standardized technology that enables bi-directional wireless proximity communication between electronic devices through an intuitive, simple and secure wireless connection" (Karpavičė et al., 2023, PAPER V). NFC is a short-range wireless connectivity standard based on the ISO/IEC14443 protocol that makes use of a magnetic field to send and receive information when two devices are brought within a few centimeters of each other (Dutot, 2015). It operates at 13.56 MHz frequency with a maximum transmission speed of 848[2] kbit/s with a typical range of 4 to 10 cm, depending on the output power and the antenna design, to create a peer-to-peer network to provide data exchange (Zhu et al., 2018; Basili et al., 2014). In the NFC system, the initiator is an actively functioning element, such as a mobile device, and the target is a passive element, such as the NFC tag (Cerruela García et al., 2016).

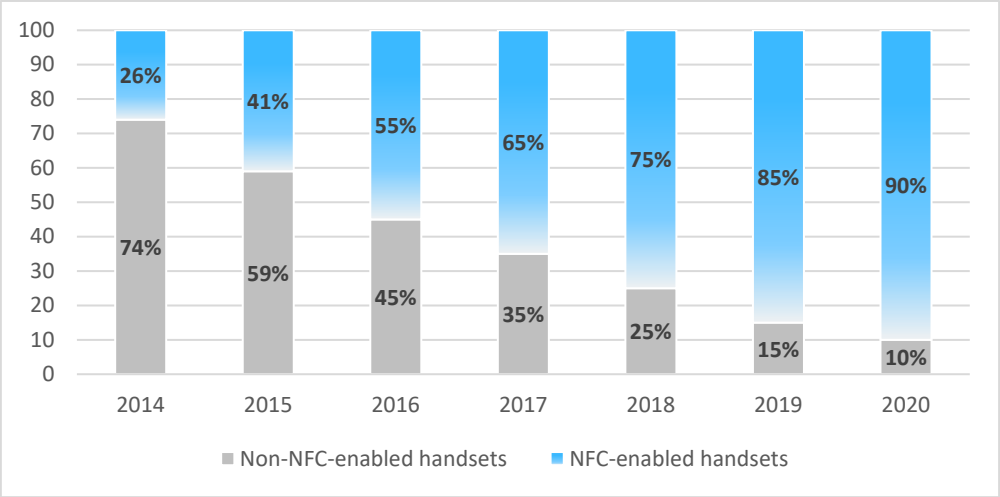


Figure 7. Share of NFC-enabled and non-NFC-enabled cellular handset shipments worldwide from 2014-2020 (adapted from Taylor (2023))

[2] NTAG 424 DNA (NT4H2421Gx) tag developed by NXP (NXP datasheet, 2019)

The NFC technology, as demonstrated in Figure 8b, works in the following order: "the target (NFC tag) is placed in the magnetic field created by the reader (mobile phone), the tag antenna harvest energy received from the mobile device to wake the tag up, and data is then sent to the reader using a standardized format created by NFC Forum called NFC Data Exchange Format (NDEF)" (Lydekaityte, 2020).

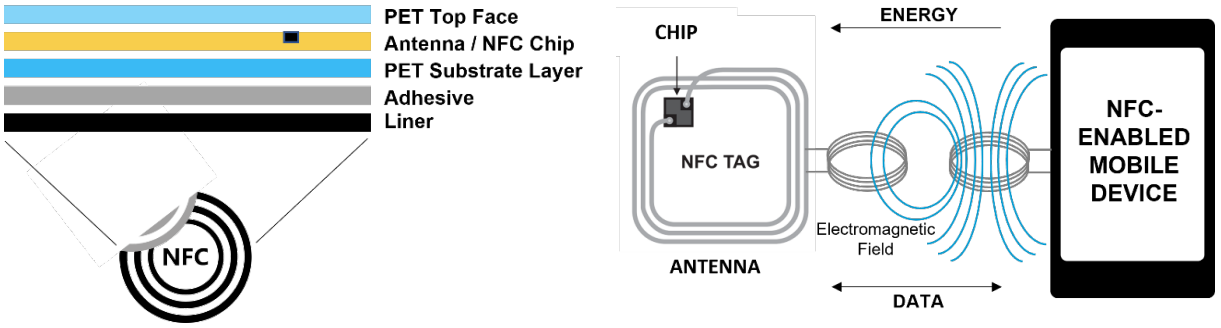


Figure 8. (a) Layers of the NFC sticker that could be utilized for product packaging; (b) NFC systems elements and working principle (adopted from NXP datasheet (2019), Seritag datasheet (2019))

NFC operates in three different modes: card emulation mode, read and write, and peer-to-peer mode (Boes et al., 2015). The NFC forum[3] adds three more modes: host card emulation, secure element-based card emulation, and wireless charging mode. Teh et al. (2014) assert NFC-enabled smart devices have tremendous potential. The benefits of NFC technology are summarized in Table 4.

Table 4. A summary of benefits provided by NFC technology (adapted from Karpavičė et al., 2023, PAPER V)

From a usability perspective	From market perspective	From socio-economic perspective
simple communication setup	combats counterfeiting	increases competition
exceptionally low power consumption	increases economies of scale	Increases financial transparency
convenient way of transferring data	reduces investment risk	offer greater value propositions
fast read capability to scan the NDEF message with only one command	contributes to more transparent and successful business models	contributes to carbon footprint reduction
no need for an external reader	provokes income development	offers price differentiation
ultrathin NFC tags	provides greater client encounters	
no dependency on objects' shape, dimension, materials made from	enables more durable, long-lasting relationships with the consumers	

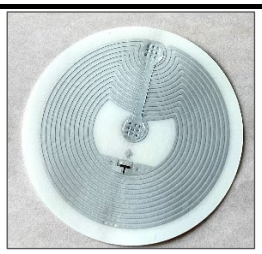
NFC applications are widespread in energy harvesting, monitoring systems, contactless payments, public transportation, IoT, tracking systems, tourism, healthcare, retail, branding, and home appliances (Chandrasekar and Dutta, 2021). Furthermore, the flexibility of the NFC sticker, the improved RF performance, and the decreased thickness of a NFC chip's alleviated the integration process of the NFC tag into various objects despite their shape, dimensions, and materials they are made from, which broadened the range of applications areas even further (Karpavičė et al., 2023, PAPER V). As a result, these improvements in NFC tags altered the traditional NFC system and made it a better fit for the product packaging industry (Karpavičė et al., 2023, PAPER V). The integration of NFC in product packaging surpasses the prevalent practice of inventory control provided by RFID and opens immense engagement possibilities with consumers in the retail landscape (Lydekaityte, 2020). Chandrasekar and Dutta (2021) refer to NFC as the best tool to improve consumer-brand relationships and enhance consumer experience at both pre-

[3] The Near Field Communication (NFC) forum was established in 2004 by Nokia, Philips, and Sony to advance the use of NFC by developing specifications, ensuring interoperability among devices and services, and educating about NFC technology (www.nfc-forum.org).

purchase and post-purchase points. In the pre-purchase phase, consumers can retrieve additional information about the item by simply tapping their phones on its packaging with an embedded NFC tag (Wang et al., 2017). In further detail, such options as stock status, social media and/or comments about the product, the current condition of the packed product (e.g., freshness), supply chain traceability and authenticity of the product, become instantly available to consumers while they shop (Escobedo et al., 2017; Chandrasekar and Dutta, 2021; Forcinio, 2019). After the purchase, the digitalization of products via NFC allows personalized and customized mobile promotions and monetary offers, such as coupons, vouchers, and loyalty points, together with possibilities to connect to help and customer service, order delivery and re-order services, link with groups of shared interests, and other (Singh, 2018; Forcinio, 2019).

Through the course of this PhD research, the following NFC tags have been investigated and experimented with NXP NTAG 424 DNA, NXP NTAG213, and ST25TA02KB. The summary of tags' specifications is given in Table 5. NFC tags used for smart product packaging applications mainly consist of a memory chip and a printed antenna enclosed with several layers of protection, as seen in Figure 8(a).

Table 5. A summary of NFC tag's specifications used in the PhD research

	NXP NTAG 424 DNA	**NXP NTAG213**	**ST25TA02KB**
Picture			
Standard	14443A-2/ -3/ -4 and ISO/IEC 7816-4	ISO 14443 A	ISO 14443 A
NFC Forum type	Type 4	Type 2	Type 4
Data rate	Up to 848 kbit/s	106 kbit/s	106 kbit/s
Memory	416 bytes	144 bytes	256 bytes
Anti-collision	Yes	Yes	Yes
Read	Yes	Yes	Yes
Read/Write	Yes	Yes	Yes
Operating distance	Up to 10 cm	Up to 10 cm	
Features	Anti-counterfeiting, secure login, token generation, AES-128 encryption, SUN authentication	ECC originality signature, 32-bit password protection, scan counter, 7-byte UID Ascii Mirroring	TruST25™ digital signature, 128-bit password protection, 20-bit scan counter, 7-byte UID
Thickness	350 µm	120 µm ± 15µm	120 µm ± 15µm

*NXP NTAG 424 DNA picture is taken from www.smartcardamerica.com

2.8. Technology perception and acceptance of NFC (PAPER V)

A vast amount of research has been conducted in information systems to understand, develop and predict constructs that could impact the adoption of technologies or innovations by individuals (Dutot, 2015). Researchers have developed numerous models and theories that specialize in the acceptance of technology, such as the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975), Theory of Planned Behavior (TPB) (Ajzen, 1991), Technology Acceptance Model (TAM) (Davis, 1989), and Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003).

This study expands the well-established and widely applied Technology Acceptance Model to determine the most impactful factors for NFC technology acceptance for product packaging applications. TAM, presented by Davis (1989), was "one of the first models that offered a theoretical mechanism to explain

technology adoption in IT by proposing that perceived ease of use and perceived usefulness are the two most significant elements in determining the success of an information system" (Karpavičė et al., 2023, PAPER V). Furthermore, TAM postulates that an individual user's attitude toward technology impacts the behavioral intention to use the technology, and the behavioral intention influences the actual technology use (Talantis et al., 2020). Also, TAM attempts to determine the impact of external factors on the above-mentioned internal variables (Museli and Navimipour, 2018). The definitions of the original TAM model variables are presented in Table 6, and causal linkages between these variables are illustrated in Figure 9.

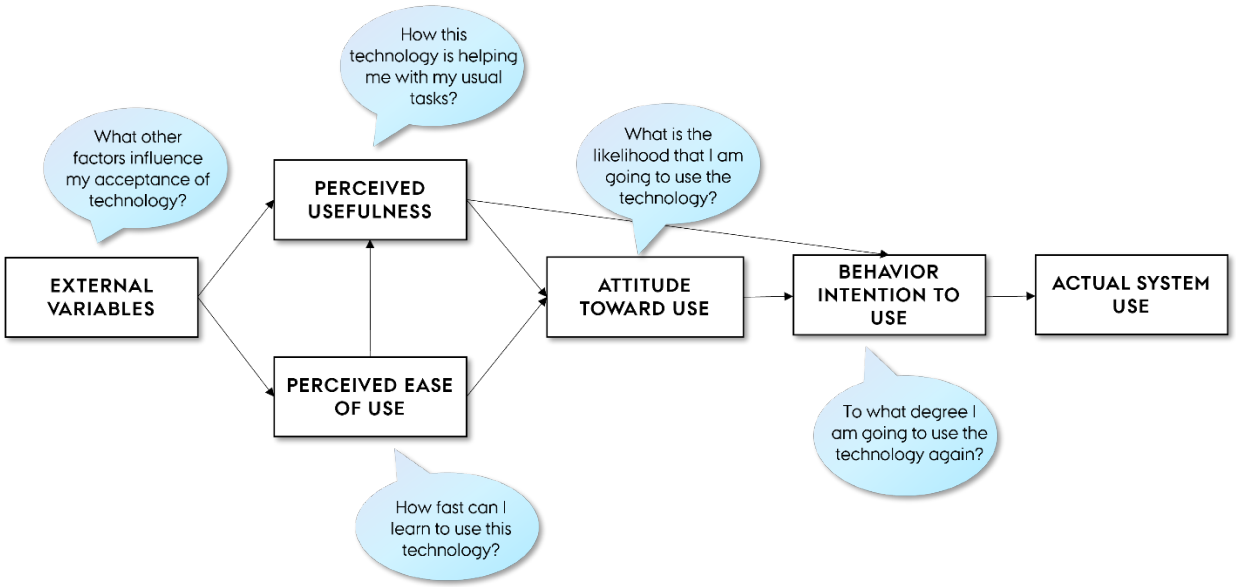


Figure 9. Technology Acceptance Model (adapted from Davis (1989))

Due to TAM's limited ability to capture only utilitarian aspects of ICT systems (Kim et al., 2017), a number of authors have proposed incremental expansions to the original model with the aim of enhancing the model's predictive power by adding new variables to target different aspects of the particular problem (Jamšek and Culiberg, 2020). Davis et al. (1992) developed TAM 2, "where the added variable of perceived enjoyment embodied the hedonic aspects of using a new technology or system related to pure enjoyment and fun" (Karpavičė et al., 2023, PAPER V). Subsequently, Venkatesh and Bala (2008), in the context of e-commerce, presented TAM 3 with the addition of perceived risk and trust of the technology use. Consequently, these extensions of the original model validate its flexibility and feasibility to be adjusted based on recent technology developments (Dutot, 2015).

Table 6. Definitions of TAM model variables

Variable	Definition
Perceived Ease of Use	"the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989, p. 320)
Perceived Usefulness	"the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989, p. 320)
Attitude towards the Use	"a measure of the likelihood that a person will get the given behavior" (Karahoca et al., 2018)
Behavioral Intention to use	a possible action or the tendency of an individual affected by attitude targets (As'adi et al., 2021)
Actual Use	individual's actual use of a given technology (Venkatesh et al., 2012)

Over the last 20 years, a vast number of studies has applied and extended the TAM model to explain and anticipate users' behavior across various contexts, including mobile phones, virtual learning, mobile wallets, interactive self-service technologies in retail, healthcare, and other (Karpavičė et al., 2023, PAPER V).

Accordingly, this PhD study has selected the TAM model to investigate the consumers' acceptance and perception of the NFC technology applied to product packaging.

2.9. Chapter Summary

This chapter has presented the research direction in digital innovation for product packaging, emphasizing the focus on the enhancement of the communication function of the package with the incorporation of NFC technology for improved user experience and product functionality. However, since the incorporation of NFC into packaging design is still not widely practiced, further research is needed to provide a holistic and comprehensive overview of smart interactive packaging as a digital interactive system in relation to the substantial elements of the successful and effective design of such system. Furthermore, the identified research gaps will be addressed in the following chapter.

3 Chapter - Research Design

This chapter presents the methodological choices the author has made to address the objective of this PhD thesis. The chapter opens by linking the philosophical perspectives to the epistemological choices of the research that resulted in applying a design science research approach for the PhD research project. Furthermore, the chapter outlines the conducted research activities during the PhD research and sheds light on the rationales by justifying the selected methods.

Table 7. The relations between the PhD research main questions and research objectives from PAPERS I-V

	PhD Research Questions	Research Objectives
PAPER I	RQ1: How does the emergence of smart packaging impact the traditional concept of the main packaging functions?	1) To examine the traditional 'contain–protect communicate–facilitate convenience' model of the main packaging functions. 2) To revise each component of it in relation to smart packaging applications. 3) To establish a new model of the main packaging functionalities concerning the analyzed data.
PAPER II	RQ2: What are the main peculiarities of smart interactive packaging as a digital interactive system in regard to the interaction design theory?	1) To describe digitally enhanced packaging as a digital interactive system to the interaction design theory. 2) To investigate what are the main elements and steps when designing an effective interactive packaging design based on human-computer interaction, interaction design, user-centered design, and usability theories.
(additional)	RQ3: What potential technologies can be integrated into the smart interactive packaging design?	1) To thoroughly explore the potential technologies such as diverse materials, devices, printed graphics, image recognition technologies, computing systems, and manufacturing techniques for smart interactive packaging
PAPER III	RQ4: What are the main particularities of NFC technology utilized for product packaging?	To investigate the current state-of-the-art and potentials of NFC system, including: 1) the overview of the main characteristics, 2) technological capabilities, 3) benefits, and 4) potential barriers for NFC to become widely accepted.
PAPER IV	RQ5: How do different factors related to technical- and user-oriented barriers affect the consumers' perception and willingness to adopt the NFC technology for product packaging applications?	1) To design the experiment of user interaction with NFC-enabled product packaging 2) To examine the peculiarities of the user interaction with NFC-enabled packaging to find out consumer perception and technology acceptance towards NFC 3) To provide more comprehensive insights regarding barriers to the successful NFC application to a product's packaging
PAPER V	RQ6: What are the most impactful factors for NFC technology acceptance in product packaging applications?	1) To investigate the important variables impacting the adoption of NFC in product packaging. 2) To propose an applicable technology acceptance model. 3) To identify the most impactful variables for the NFC technology acceptance for packaging applications.

3.1. Research Design – Between Design Thinking and Design Science Research

This PhD research applied methods according to the context of Design Thinking and Design Science Research (DSR), with a higher emphasis on the latter. The selection of both research methodologies

was based on their common characteristic to address unsolved problems in an innovative way with the overall objective of examining the usefulness of the designed artifact (Dolak et al., 2013). Consequently, a PhD study by exploring how digital innovation in product packaging enhances the consumer experience and product functionality aims to investigate the struggle of NFC to be widely accepted by the packaging industry, evaluating the usefulness of NFC-enabled product packaging to improve consumer experience and product functionality. Furthermore, the DSR focuses on solving an fundamental business problem, whereas design thinking seeks to understand users' needs and desires (Dolak et al., 2013; Stolterman and Wiberg, 2010). Both proposed problems are addressed in the PhD research, where the Consumer Packaged Goods (CPG) companies and the end user are the main target audience. Furthermore, both methodologies perform an iterative process for artifact design and evaluation, therefore experimentation with users is an integral part of the process (Dolak et al., 2013). As a result, this PhD study considers design thinking as one of the methods of DSR that enables purposeful and value-creating augmentation of the implementation of DSR.

Overall, DSR is a central research paradigm in multiple domains, including architecture, business, engineering, and other IT-related disciplines, for designing novel solutions to relevant problems (vom Brocke et al., 2020). Based on the description of DSR, PhD research seeks to enhance academics' and practitioners' knowledge to create of innovative artifact – NFC-enabled smart packaging, to solve NFC acceptance problems.

Design Science Research Process

The PhD research follows the DSR process and three design cycles to design a meta-artifact and produce design knowledge. First, PhD research began its research activities by identifying the opportunities and problems in an actual application environment (Hevner, 2007). To answer the main research objective, it is essential to combine the current academic knowledge from the scientific literature with the empirical world to expand and deepen the understanding of both the theory and empirical phenomenon (Dubois and Gadde, 2002). In this case, the empirical data collection, through observations and unstructured / semi-structured interviews, was performed at industrial trade fairs, exhibitions, and conferences related to innovations in product packaging, where industry needs, culture, and current smart packaging status were identified. The practice of gathering knowledge from empirical observations at industrial events is well-established and applied (Gębarowski and Siemieniako, 2015; Engblom, 2014; Bettis-Outland et al., 2012; Bathelt and Gibson, 2015).

Second, a vast knowledge base of scientific theories and methods was created via qualitative meta-analysis, systematic and narrative literature reviews, scientific conferences, and designed conceptual product cases that provided a foundation for a rigorous cycle of DSR (Hevner, 2007).

Third, in the design cycle, two types of digital-physical artifacts were designed and experimented with to solve the identified problems from the environment domain by using scientific theories and methods identified in the knowledge base domain. In other words, the design cycle had two iterations, first with the designed NFC-enabled smart poster that explored the technological barriers and user behavior toward NFC technology via usability testing, and second with the designed set of three NFC-enabled packages that investigated the main determinants of NFC technology adoption via usability testing and TAM model.

Followed by the definition of DSR (vom Brocke et al., 2020), the study results are newly designed meta-artifact, i.e., the extended TAM model, and design knowledge of NFC-enabled product packaging that provides a more extensive understanding of how it should be designed by human agents and how it enhances the relevant application context, i.e., achieves enhanced consumer experiences during shopping and consuming/utilizing the product. In addition, the designing process of the meta-artifact was based on a qualitative meta-analysis of 25 primary studies, where the results were quantified and

processed by Multi Criteria Decision Analysis approach proposed by Ortiz-Barrios et al. (2020) with an interval ranking scale from Hair et al. (2019). However, the designed meta-artifact still has to go through the design cycle to fully comprehend its usefulness for the selecting context, which is a concern for future studies. Figure 10 demonstrates the research activities involved in the PhD study that contribute to the three domains of the design science framework proposed by Hevner (2007).

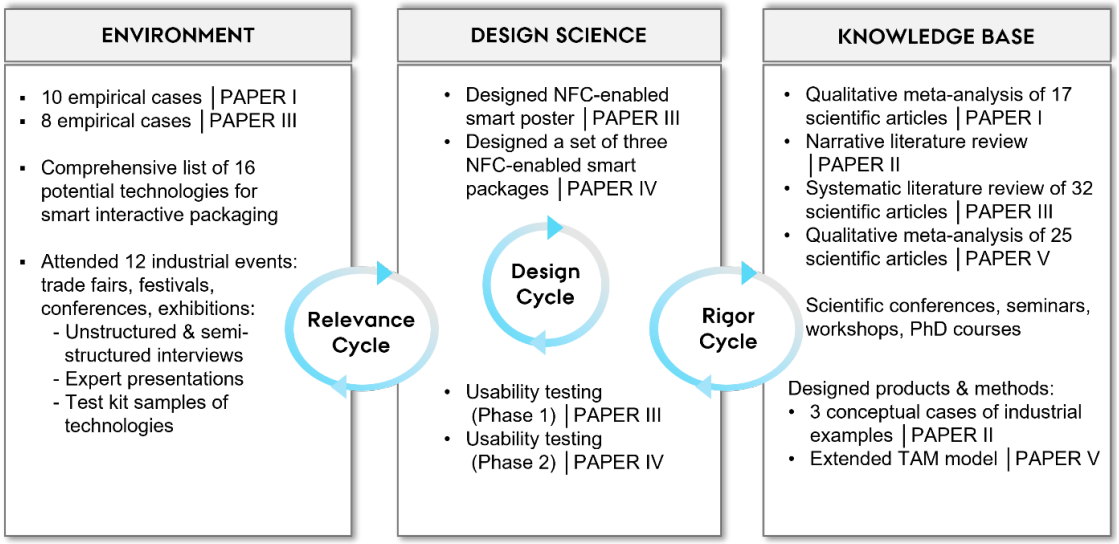


Figure 10. Activities of the PhD research adapted in the design science research framework from Hevner (2007)

3.2. Work Package 1

The research activities in WP 1 provided the author with an understanding of the research gap and problem. Exploration of the current state of smart packaging and its influence on traditional packaging functionalities was performed by conducting the Research Study 1 (PAPER 1), which defined the scope, main objective, and limitations of the PhD project. This study pursues a qualitative meta-analysis, and it is based on an extensive literature review related to packaging science and a set of empirical observations from industrial cases that are further described in the following sections. Table 8 provides an overview of the Research Study 1, whereas the findings are presented in PAPER I.

First, the study employed a qualitative meta-analytic approach to ensure a rigorous methodological position. The main function of a qualitative meta-analysis is to provide a consistent and thorough picture of findings across primary qualitative studies that carry out the same research topic (Timulak, 2009). Meta-analysis is particularly relevant when the researcher aims to bring together data from multiple studies derived from similar research designs (Siddaway et al., 2019). Consequently, Research Study 1 aggregated a group of 17 studies in packaging science research for the purposes of discovering the most commonly identified primary packaging functions and afterward transformed the results into the updated model of the main packaging functionalities. The selection of primary studies was based on theoretical sampling and saturation (Timulak, 2009). During the performance of the meta-analysis, the authors were looking for studies in Scopus and Web of Science that would contribute to the building theory and were addressing the raised research question. A broad range of keyword variations was used to ensure that the scope of the analysis was broad and did not deviate from the context of primary packaging functions. The search was stopped once the new studies did not add any substantial elements to the developed theory, i.e., the model of primary packaging functions. The gathered data was analyzed based on the descriptive-interpretative approach by assigning data into domains, i.e., environmental, marketing, and consumer-oriented strategies, and making categorizations through the comparison of gathered data. The final synthesis of findings was presented in the form of a graphical illustration of a new model of primary packaging functions.

Table 8. An overview of the Research Study 1 (WP 1, PAPER I)

WORK PACKAGE 1 – Research Study 1 (PAPER I)			
Research Questions	**Research Objectives**	**Methodology**	**Data Sources**
RQ1: How does the emergence of smart packaging impact the traditional concept of the main packaging functions?	1) To examine the traditional 'contain–protect communicate–facilitate convenience' model of the main packaging functions 2) To propose an explicit classification of smart packaging types providing clear definitions and differences among them 3) To revise each component of the traditional model of packaging functions in relation to smart packaging applications 4) To establish a new model of the main packaging functionalities concerning the analyzed data	Qualitative meta-analysis Literature review Empirical observation	Scientific literature of thoroughly analyzed 17 studies for packaging functions Empirical cases from 10 technology providers Unstructured interviews with participants of industrial events

Second, it is essential to combine the current academic knowledge from the scientific literature with the empirical world to expand and deepen the understanding of both the theory and empirical phenomenon (Dubois and Gadde, 2002). Therefore, the study utilized a set of 10 empirical observations encompassing industrial cases of smart packaging developed by Digimarc, Ynvisible, Coca-Cola®, WaterIO, Thinfilm, Anheuser-Busch InBev, Saralon GmbH, Steve Haslip, and Harward University. Empirical cases were gathered from unstructured interviews with companies' representatives during industrial events (The 6th Global Packaged Summit and Pack & Gift), product datasheets, technical reports, press releases, whitepapers, and the test kit samples obtained from the participating companies at the industrial conferences. The format of unstructured interviews was selected to form a guided conversation with other participants, i.e., technology providers, and gather rich, in-depth data about existing smart packaging applications without imposing any restrictions on the discussed topic (Wilson, 2014). The interviewees were selected based on the non-probability purposive sampling technique that allows the researcher to select the sample that was the most useful for the research, i.e., the research included only conference participants, who represented companies that were directly related to the smart packaging industry and its collaborators. The interviews took place at the temporary booths of selected companies at the industrial events, and notes were taken to capture respondents' answers. Unstructured interviews are the most useful during the early stages of the research (Wilson, 2014), therefore the author has employed this interview format to try to understand the general issues, increasing trends, and perceptions of smart packaging area during the problem formulation stage of the PhD project. A comprehensive list of attended industrial events is provided in Table 10. The descriptions of collected empirical cases are presented in PAPER I.

The insights from the industrial cases supplemented the knowledge gathered from the literature review regarding smart packaging applications to address the existing research gap and provide an explicit classification of smart packaging types. Subsequently, each element of the traditional model was revised in regard to the technological capabilities of smart packaging, and a new model of the main packaging functionalities was established, see PAPER I.

3.3. Work Package 2

The research activities performed in Work Package 2 aim to explain the conception of smart interactive packaging as a digital interactive system that provides an extended user interface. The research activities are divided into two research studies. The Research Study 2 elaborates on the critical

elements of smart interactive packaging essential for successful and effective human-packaging interaction in relation to selected theories, whereas the Research Study 3 investigates the potential technologies for smart interactive packaging applications for enhanced consumer experience and product functionality. Table 9 provides an overview of the Research Studies 2 and 3, whereas the findings are presented in PAPER II.

Table 9. An overview of the Research Studies 2 and 3 (WP 2, PAPER II)

WORK PACKAGE 2 – Research Study 2 (PAPER II)			
Research Questions	**Research Objectives**	**Methodology**	**Data Sources**
RQ2: What are the main peculiarities of smart interactive packaging as a digital interactive system in regard to the interaction design theory?	1) To describe the digitally enhanced packaging as a digital interactive system in regard to the interaction design theory. 2) To investigate what are the main elements and steps when designing an effective interactive packaging design based on human-computer interaction, interaction design, user-centered design, and usability theories.	Narrative literature review Empirical observation	Scientific literature Three conceptual empirical cases of smart interactive packaging
Research Study 3 (PAPERS I-V)			
RQ3: What potential technologies can be integrated into smart interactive packaging design?	1) To investigate the potential technologies to be attached to a package to improve its communication functionality	Literature review Empirical observations	Scientific literature Unstructured & Semi-structured interviews Empirical cases

Research Study 2

The study conducted a narrative literature review supplemented with three conceptual empirical cases of smart interactive packaging. The need for a literature review arose from the lack of consensus about smart interactive packaging and its perception as a cyber-digital object with enhanced communication capabilities. The literature review was focused on gathering relevant information to provide substance and context to the investigated subject (Xiao and Watson, 2019). Following the nature of the narrative literature review, the selection criteria for the inclusion of the articles were not specified explicitly (Ferrari, 2015). The literature review employed the keywords search on several databases to permit a selection of related articles concerning digitally enhanced physical objects and Human-Computer Interaction, Interaction Design, User-centered Design, and Usability Theories. Furthermore, the three conceptual empirical cases of smart interactive packaging were built to illustrate how the proposed critical elements of enhanced packaging should be employed when designing such objects.

Research Study 3

The research study aims to bridge the gap between academia and society in relation to the current developmental status of emerging technologies that can be applied to product packaging. Throughout PhD research, a broad range of different technologies, advanced materials, and nascent manufacturing techniques have been discovered to utilize for smart interactive packaging potentially. The findings of Research Study 3 were gathered through the mixed methods approach, encompassing data from scientific literature and empirical industrial cases, assembled, and synthesized from unstructured and semi-structured interviews with industry professionals, expert presentations, whitepapers, product datasheets, technical reports, press releases, and the test kit samples obtained from the participating companies at the industrial conferences that are listed in Table 10. The list of potential technologies

has been developed and updated throughout the course of three years of PhD research, and the most recent version of it is presented in Table 3, section 2.6.

Table 10. A summary of participated industrial events during the course of three years of PhD research

Industrial Event	Scope	Relation to PhD research activities
The 6th Global Packaged Summit	The presentation and discussion on the newest developments in the packaging industry	Unstructured interviews (3) Expert presentations Empirical cases
Pack & Gift	The trade fair of packaging promotion and marketing	Unstructured interviews (5) Empirical cases
Printed Electronics Conference (ATV-SEMAPP.DK)	The presentation of latest market data and technology breakthroughs within PE field	Expert presentations (18) Empirical cases
Hannover Messe	The trade fair for Industry 4.0	Unstructured interviews (4) Empirical cases
Printed Electronics Europe 2019 (IDTechEX)	Conference and exhibition on the latest diverse technology capabilities and opportunities of printed, flexible and hybrid electronics	Unstructured interviews Expert presentations (14) Empirical cases
IoT Week Aarhus (IoT Forum and it-forum)	Conference on the latest digital tech and trends for the creation of sustainable, data-driven economies	Expert presentations Empirical cases
AIPIA World Congress 2019	Conference and exhibition of active and intelligent packaging	Semi-structured interviews Expert presentations (8) Empirical cases
Electronics of Tomorrow 2019	The trade fair for the electronics and technology industry	Unstructured interviews Empirical cases
AIPIA World Congress 2020	Conference and exhibition of active and intelligent packaging	Expert presentations (6) Empirical cases
The 12th Global Packaged Summit	The presentation and discussion on the newest sustainable innovations, technologies and developments in the packaging industry	Unstructured interviews (6) Expert presentations (11) Empirical cases
Packaging Design 4 Sustainability	Conference on enabling a circular economy through design methods on material, product and value chain	Expert presentations (5) Empirical cases
The NFC Open Forum	Conference on new developments of NFC technology	Expert presentations (6) Empirical cases
The Industrial event of Innovations Festival	Innovation festival on printed, hybrid, 3D, in-mold, textile electronics	Expert presentations (31) Empirical cases
AIPIA World Congress 2022	Conference and exhibition of active and intelligent packaging	Semi-structured interviews (8) Expert presentations (30) Empirical cases

3.4. Work Package 3

Once the potential technologies for smart interactive packaging were identified and investigated, the Near Field Communication technology was selected for further exploration for its feasibility to be

applied for enhanced packaging. The selection of NFC technology was based on the findings from unstructured interviews and empirical cases gathered from the following industrial events: Printed Electronics Europe 2019 (IDTechEX), IoT Week Aarhus (IoT Forum and it-forum), and AIPIA World Congress 2019. Although NFC technology has already been prominent in the industrial context, there is a lack of scientific research exploring NFC as a branding and marketing tool embedded in a product's packaging.

As a result, the research activities conducted in WP 3 explored the main particularities of NFC technology to be applied to product packaging. Research Study 4 pursues a multi-method research approach combining a systematic literature review focused on scientific publications related to the technological capabilities of Near Field Communication applied in product packaging, a set of empirical observations from industrial cases, and usability testing for investigating user interaction with NFC-enabled smart object (experimentation phase 1). Table 11 provides an overview of the Research Study 4, whereas the findings are presented in PAPER III.

Table 11. An overview of the Research Study 4 (WP 3, PAPER III)

WORK PACKAGE 3 – Research Study 4 (PAPER III)			
Research Question	**Research Objectives**	**Methodology**	**Data Sources**
RQ4: What are the main particularities of NFC technology utilized for product packaging?	To investigate the current state-of-the-art and potentials of NFC system, including: 1) the overview of the main characteristics, 2) technological capabilities, 3) benefits, and 4) potential barriers for NFC to become widely accepted.	Systematic Literature review Empirical observation Usability testing	Scientific literature of thoroughly analyzed 32 studies for NFC capabilities Empirical cases from 8 technology providers Unstructured and semi-structured interviews with participants of industrial events Questionnaire and unstructured interviews with experiment participants

Systematic literature review

The study employed a systematic literature review to systematically evaluate and summarize current knowledge provided from different sources of evidence to establish what is known about the technological capabilities of Near Field Communication applied to the product packaging (Yuan and Hunt, 2009). Following the recommendations from Xiao and Watson (2019), the literature review was performed in three main stages: planning the review, conducting the review, and reporting the findings. First, the research question and the review protocol were developed. Then the literature search followed the keyword-based search approach in the Scopus and Web of Science databases. The keywords for the search were derived from the research question by dissecting it into concept domains together with synonyms, abbreviations, alternative spellings, and related terms (Xiao and Watson, 2019). As a result, the two terms *packag* AND NFC* were used to investigate the titles of the articles. In order to complement and increase the accuracy of the search, a few more diverse combinations of keywords were added, consisting of – *intelligent AND / OR smart AND / OR IoT AND / OR retail* AND / OR market* AND / OR mobile AND / OR consumer AND / OR engag* AND / OR sensor* AND / OR secur* AND / OR label**. The literature search stopped when the same references began to occur, and no new information was obtained. Afterward, in the process of sorting the articles by reading the titles and abstracts, several criteria were applied to narrow down the sample, excluding the papers that were still far from the topic, referred to different meanings of NFC abbreviation, focused on NFC utilization for payment, investigated electronic packaging, and oriented to supply chain operations.

The final list of literature consisted of 32 scientific articles from which data about the technological capabilities of NFC was extracted, analyzed, and synthesized. Since the data is qualitative, the findings were analyzed by establishing descriptive themes and assigning them to the corresponding domain (descriptive-interpretative approach). The findings of the literature review provided a list of 15 explicit capabilities of NFC technology in relation to smart interactive packaging applications.

Empirical observations

Moreover, to expand the understanding of NFC's main characteristics, elements, and working principles, the Research Study collected and analyzed a set of empirical examples from 8 industrial technology providers: Thinfilm, NXP, Toppan, Avery Dennison, PragmatIC, Identiv, Stora Enso, and WISeKey. The analysis utilized information about the examples retrieved from secondary data, i.e., product datasheets, technical reports, press releases, and primary data, i.e., direct observations at companies' presentation area, and unstructured / semi-structured interviews with companies' representatives during the attended industrial events, including Printed Electronics Europe 2019 (IDTechEX) and AIPIA World Congress 2019. Unstructured interviews were selected in order to understand the general issues, trends, and perceptions of NFC technology, whereas semi-structured interviews were based on the questions that emerged from unstructured interviews (Wilson, 2014). The descriptions of collected empirical cases are presented in PAPER III.

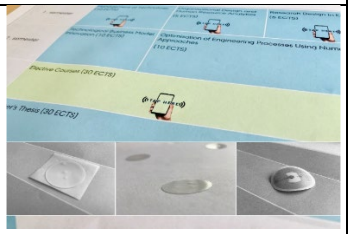
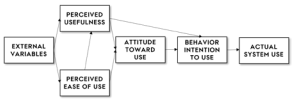
Preliminary usability testing (Phase I)

PAPER III has also presented an overview of the technological barriers of the NFC system to become widely accepted. These results were derived from empirical research guided by scientific experimentation through usability testing. Overall, the research activities in WP 3 and WP 4 are divided into three experimentation phases (see Table 12) related to user experimentation with NFC-enabled packaging. Experimentation Phase 1 is based on a pre-test that only explores a few components of the research study, including initial technology barriers and consumer perception of NFC technology. Experimentation Phase 2 is built as a pilot study that tests the entire study but on a smaller sample size. Finally, based on the findings from the pilot study, the experimentation Phase 3 develops a more comprehensive and exhaustive extended TAM model that will lay the foundation for the future investigation of the acceptance of NFC technology in product packaging.

In user experience research, usability evaluation methods are frequently used to examine the extent to which a product or service can be used by users to achieve the desired goals with effectiveness, efficiency, and satisfaction in a particular context of use (Sonderegger et al., 2016; ISO 9241-11, 2018). The usability testing was selected to provide a better understanding of NFC-enabled smart objects to expose potential problems in the design, discover opportunities to improve the design, and gain a better understanding of consumer behavior and preferences (Alwashmi et al., 2019). During the usability testing, as suggested in the literature (Sonderegger et al., 2016), to evaluate the object, a realistic task scenario was created, where the prospective users were asked to perform a list of tasks using the object while the researcher observed the interaction. The experiment participants were asked to engage with the NFC-enabled smart poster to learn additional information about the study program they were particularly interested in for their future studies. The test instruments were the NFC-enabled smart poster, scripted instructions, and a post-test questionnaire placed on the PhD research website. The usability testing in phase 1 was performed in two settings: with 14 researchers of the EngTech group, where participants were invited to attend the NFC Workshop, and with 9 prospective students at the Open House event held at BTECH, where people came to get more information about the study programs offered at the department. Although the sample size is small, the previous studies have indicated that five subjects are enough to detect issues related to the investigated object in a usability test (Turner et al., 2006; Rubin and Chisnell, 2008; Virzi, 1992). In

addition, Hwang and Salvendy (2010) proposed that the rule of 10 ± 2 is sufficient to disclose 80% of usability problems. The pre-testing of the NFC system provided insights about potential technology- and user-related barriers and an overview of how to design usability testing for user-NFC system interaction that established the basis for the usability testing in Phase 2.

Table 12. A summary of experimentation phases

	Experimentation Phase 1	**Experimentation Phase 2**	**Experimentation Phase 3**
Main research activity	Usability testing (pre-test)	Usability testing (pilot test)	Designing the artifacts for the final usability testing
Research aim	To identify technology issues and opportunities to improve, and gain better understanding of consumer perception for the Phase 2	To explore the influence of system's barriers on the consumers' perception and willingness to accept the NFC technology	To recognize the most impactful factors for NFC technology acceptance in product packaging applications
Experiment artifact	NFC-enabled smart poster	NFC-enabled smart packaging	TAM models
Illustration			
Outcome	Technology- and user-related barriers, basis for phase 2	Explicit experiment design, selected variables impact on NFC technology acceptance	The extended TAM model for NFC-enabled packaging
Data gathering	Observation, questionnaire	Observation, questionnaire based on TAM	Qualitative meta-analysis
Participants	23 (14 EngTech[4] researchers, 9 prospective students)	12 students at BTECH	25 primary studies
Relation to WP and papers I-V	WP 3, PAPER III	WP4, PAPER IV	WP4, PAPER V

3.5. Work Package 4

The research activities conducted in WP 4 continue further experimentation between users and NFC-enabled systems. WP 4 is divided into two research studies. Research Study 5 employs usability testing to explore the influence of technical- and user-oriented barriers on the consumers' perception and willingness to accept the NFC technology (experimentation phase 2), whereas Research Study 6 performs a qualitative meta-analysis to build the extended TAM model to identify the most impactful external determining factors for future experimentation (experimentation phase 3). Table 13 provides an overview of the Research Studies 5 and 6, whereas the findings are presented in PAPERs IV and V.

Usability testing (Research Study 5, Phase 2)

Based on the findings of the experimentation Phase 1 presented in PAPER III, the second usability study was designed to carry out the user experiment, where a product packaging with built-in NFC capabilities was tested with selected participants to track their engagement with the smart interactive

[4] EngTech (Engineering & Technology) – an interdisciplinary research group at the Department of Business Development and Technology, Aarhus University, Herning (https://btech.au.dk/en/research/sections-centres-and-strategic-projects/engtech)

packaging. The study is thoroughly described in PAPER IV. Overall, 12 students at BTECH were involved in the usability testing. The participants were chosen as they reflected the younger demographic with a higher interest in technologies. The sample size was predetermined by the number of complementary sets of packages received from the supplier. Furthermore, Hwang and Salvendy (2010) proposed that the rule of 10 ± 2 is sufficient to disclose 80% of usability problems. The usability testing was conducted at the participants' homes, while the researcher observed the interaction via a web conferencing platform. As Hinchliffe and Mummery (2008) suggested, a combination of usability testing techniques was used for qualitative and quantitative data collection during the interaction: performance measures, direct observation, and subjective user preference (Figure 11). First, the researcher recorded the time taken to complete the task with each package with a stopwatch. Second, participants were required to comment on their interaction with the NFC-enabled package effectively. Third, after the interaction with three packages, participants were asked to evaluate their experience filling up the questionnaire based on the TAM model on a series of five-point scale questions followed by the unstructured interview with the researcher about the interaction with NFC-enabled object. The gathered data were analyzed by applying general descriptive statistics, and the findings were published in PAPER IV. The reliability and validity of the usability testing were ensured in several manners. First, when the initial TAM questionnaire was designed, a pre-test was conducted with two academics specialized in consumer experience and wireless communication technologies and two master students in technology-based business development. Second, the measures utilized in the TAM questionnaire were based on the literature and obtained previously confirmed reliability and validity together with their relevance to the research model. Consequently, the questionnaire included 9 constructs to measure the acceptance of NFC technology in smart interactive packaging: Personal Innovativeness (Agarwal and Prasad, 1998), Intuitive Use of Technology (Blackler et al., 2003), Absorptive Capacity (Mayeh et al., 2016); Perceived Ease of Use, Perceived Usefulness, and Behavior Intention from Davis (1989); and Basic Information, User Convenience, and Optional Questions were developed by the authors. Finally, all items were measured using a Likert scale for all closed-ended questions to reduce the risk of measurement error.

Table 13. An overview of the Research Studies 5 and 6 (WP 4, PAPERS IV and V)

WORK PACKAGE 4 – Research Study 5 (PAPER IV)			
Research Questions	**Research Objectives**	**Methodology**	**Data Sources**
RQ5: How different factors related to technical- and user-oriented barriers affect the consumers' perception and willingness to adopt the NFC technology for product packaging applications?	1) To design the experiment of user interaction with NFC-enabled product packaging 2) To examine the peculiarities of the user interaction with NFC-enabled packaging to find out consumer perception and technology acceptance towards NFC 3) To provide more comprehensive insights regarding barriers to the successful NFC application to a product's packaging	Usability testing	Observations TAM- based Questionnaire (Likert scale) Unstructured interviews with experiment participants Scientific literature
Research Study 6 (PAPERS V)			
RQ6: What are the most impactful factors for NFC technology acceptance in product packaging applications?	1) To investigate the important variables impacting the adoption of NFC in product packaging. 2) To propose an applicable technology acceptance model.	Qualitative meta-analysis MCDA	Scientific literature Semi-structured interviews

	3) To identify the most impactful variables for the NFC technology acceptance for packaging applications.		

Qualitative meta-analysis (Research Study 6, Phase 3)

In relation to the findings from the pilot study, the authors concluded that a more comprehensive and exhaustive TAM model is required to develop a more holistic view of potential determinants of NFC technology acceptance in product packaging than the one used in the Research Study 5. As a result, this Research Study 6 employed a qualitative meta-analysis to develop an extended TAM model that will lay the foundation for the future investigation of the acceptance of NFC technology in product packaging. Consequently, Research Study 6 aggregated a group of 25 primary studies in technology acceptance and interactive consumer technologies domains to identify the determining factors and afterward assess the most impactful variables for the acceptance of NFC in product packaging.

In general, this study followed the same meta-analytic approach described in Research Study 1. The literature search was performed in Scopus and Web of Science research databases using various keyword combinations concerning NFC technology acceptance in product packaging and similar interactive consumer technologies. The research stopped when no new relevant literature was found. The gathered data was analyzed using the descriptive-interpretative approach by assigning data into domains related to seven theoretical models of technology acceptance. 182 found factors were classified into 42 variables that were grouped into 13 categories (see section 4.8.). Then the findings were synthesized into an extended TAM model. Finally, the assessment of the most impactful variables of the NFC acceptance was performed by quantifying results and employing Multi Criteria Decision Analysis with the interval ranking scale.

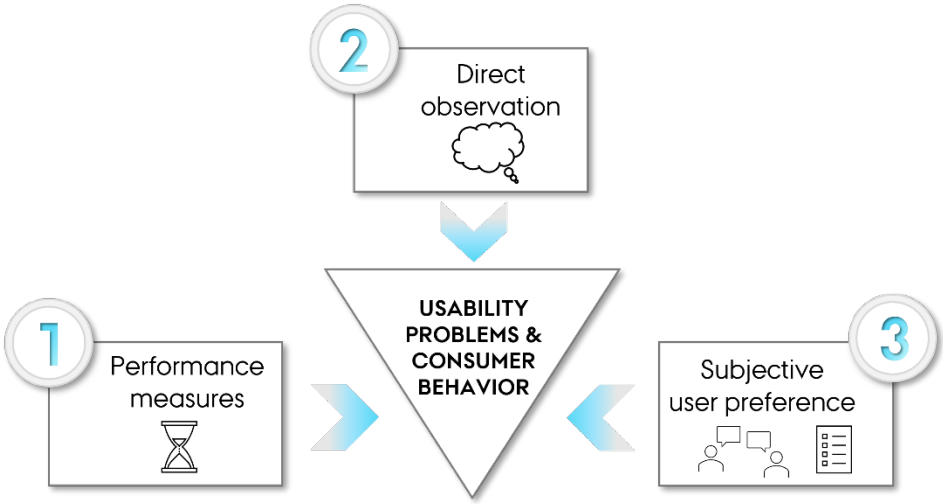


Figure 11. Usability testing techniques (adapted from Hinchliffe and Mummery (2008); elements sources: Microsoft 365 Stock Images and self-created)

3.6. Chapter summary

This PhD project relies on the combination of Design Thinking and Design Science Research paradigms with a higher emphasis on the latter. All research activities are divided into four work packages with thorough descriptions of particular research methods and data collection sources identified for each package. Overall, the research design of this PhD study consists of four work packages and six research studies corresponding to six research questions.

4 Chapter – Research findings

This chapter presents the research results generated from the appended research papers I-V that were developed in the course of this PhD study. A summary of research findings and contributions is provided below in Table 14.

Table 14. Summary of research findings and contributions from PAPERS I-V

	Research Findings	Research Contribution
PAPER I	1) A model of traditional packaging functions encompassing protection, communication, convenience, and containment functionalities. 2) The proposed classification of smart packaging types and clearly defined differences among them, consisting of active packaging, intelligent packaging, ergonomic packaging, and smart interactive packaging.	The proposed model of the main packaging functions takes into consideration the functionalities provided by the smart packaging types. The model consists of four functions, including protection, communication, convenience, and interaction, and demonstrates these functions' relations to the proposed four smart packaging types.
PAPER II	1) The proposed four critical elements of smart interactive packaging design: consumer, task, package, and context. 2) The proposed five-step approach for designing the interaction with digitally enhanced packaging.	1) The proposed perception of smart interactive packaging as a digital interactive system consisting of a human agent, computational agent, and cyber physical agent in relation to the interaction design theory. 2) Expanding the notion of human-packaging interaction by going beyond the pragmatic aspects of physical packaging attributes.
PAPER III	1) An overview of the main components of the NFC system. 2) A comprehensive list of technological capabilities provided by NFC attached to product packaging. 3) A list of consumer-, brand-, and retailer-oriented benefits provided by the NFC-enabled packaging. 4) An overview of potential barriers for NFC to become widely accepted.	The proposed comprehension of smart interactive packaging as an extended user interface – a touchpoint for visual, tactile, and digital interaction with consumers.
PAPER IV	1) Thoroughly described experiment design of user interaction with NFC-enabled product packaging 2) The preliminary analysis of each selected variable influence on NFC technology acceptance. 3) An overview of the technology- and consumer-related barriers that might prevent the successful acceptance of NFC technology applied in the packaging.	A better understanding of how different variables have an impact on consumers' perception and technology acceptance of NFC applied to product packaging.
PAPER V	1) Identification of 42 potential variables, grouped into 13 categories, impacting the NFC technology acceptance in product packaging. 2) The development of the extended TAM model containing 45 variables influencing NFC adoption in product packaging. 3) The recognition of the top 4 internal TAM variables and top 10 external variables that impact the NFC technology acceptance for packaging applications the most.	The developed extended TAM model in combination with other seven prevailing technology acceptance theories and models, including the Multi-level Framework of Technology Acceptance and Use, United Theory of Acceptance and Use of Technology, Protection Motivation Theory, Motivation-opportunity-ability Theory, Uses and Gratifications Theory, and Engagement Theory, that investigates the NFC adoption in product packaging.

4.1. Proposed new model of packaging functions (PAPER I)

PAPER I presented an updated model of the main packaging functions taking into consideration the additional functionalities granted by the smart packaging types. The model consists of four functions: protection, convenience, communication, and interaction. The latter replaced the traditional function of containment. Since the perception of containment is considered as an integral part of the overall concept of packaging (Clarke, 2008) and the ability to hold goods together is a prerequisite for a package (Lindh et al., 2016), it was decided to eliminate this function from the model. Furthermore, the proposed model demonstrates the main functions' relations to proposed smart packaging types, i.e., the type of smart packaging is assigned based on which functionality it enhances.

First of all, **active packaging** enhances the **protection** function. The quality of the packed perishable products is improved by integrating various nanomaterials into package design with higher strength and barrier properties that maintain better resistance to environmental effects (Mlalila et al., 2016). Moreover, active packaging can improve the product's condition by releasing active compounds, such as antimicrobial films, or absorbing substances like O2 scavengers, ethylene scavengers, and moisture regulators (Nandanwade and Nathe, 2013).

Secondly, the development of **ergonomic packaging** induced by environmental concerns has facilitated the design of reusable and purposeful packaging to reduce the waste of packaging materials. Furthermore, ergonomic packaging ensures more **convenience** in consuming or utilizing products, such as one-handed opening, non-slippery packaging materials, air-bubble-sealed materials, and others.

Thirdly, passive packaging only performs **communication** through visual graphical and structural elements of its design, whereas smart **intelligent packaging** encompasses digital-network-enabled elements that store, accumulate, and transmit information (Mlalila et al., 2016). Contrary to active packaging, intelligent packaging does not directly affect the product but monitors the product's condition and environment to inform the user about the changes and current status of goods.

Finally, in comparison to intelligent packaging that only provides information (informs and monitors), **smart interactive packaging** creates two-way communication between the user and the package. It involves the participation of users and their actions to get a response, i.e., the user initiates the interaction by tapping on the package with his mobile device. Consequently, smart interactive packaging is driven by advanced communication systems combined with several enabling technologies.

Figure 12. The proposed model of the main packaging functions and their relation to corresponding smart packaging types (sources of elements: Microsoft 365 Stock Images, self-created) (PAPER I)

4.2. Three main frameworks for designing enhanced product packaging (PAPER II)

The design of digitally enhanced packaging, referred to as the digital interactive system, must address the main aspects of interaction design in order to develop intuitive, effortless, and enjoyable user interfaces. Findings from PAPER II presented three main frameworks that originate from user-centered design, HCI, consumer experience, and usability theories and are essential parts of the design of smart interactive packaging:

1) The four-elements-based framework
2) Interacting agents of digitally enhanced product packaging
3) The five-step approach for smart interactive packaging design

4.2.1. The main four critical elements for digitally enhanced product packaging design (PAPER II)

As mentioned above, the design of digitally enhanced packaging, referred to as the digital interactive system, must address the main aspects of interaction design in order to develop intuitive, effortless, and enjoyable user interfaces. Findings of PAPER II present four critical elements for the digitally enhanced packaging design based on user-centered design, HCI, consumer experience, and usability theories: consumer, task, package, and context (Figure 13).

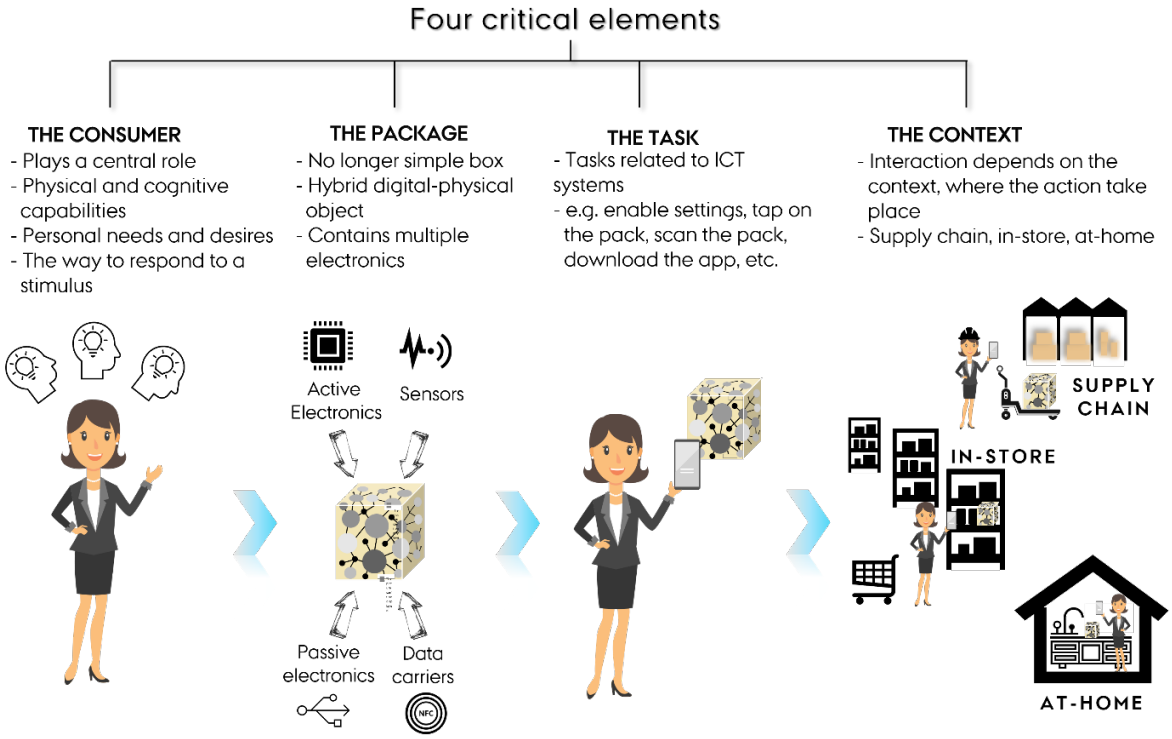


Figure 13. The summary of four critical elements of designing the interaction with digitally enhanced product packaging (sources of elements: www.legoas.co.id, pngtree.com, icon-library.com, www.dreamstime.com, Microsoft 365 Stock Images, self-created)

1) **Understanding the consumer**. First, it is relevant to investigate the target consumers' physical and cognitive capabilities, beliefs, and habits, as well as how they respond to a stimulus (Lorenzini and Olsson, 2019; de la Fuente et al., 2015). Second, the designed artifact must address the user's needs and desires (Stolterman and Wiberg, 2010). Third, the interactive system must provoke stronger emotional and memorable reactions to induce the recurrent use of the technology (Tafesse, 2016).

2) **The Package**. Smart interactive packaging can be embodied with a wide range of communication technologies, therefore the design and the way such devices are integrated affect the human-packaging interaction and must be taken into consideration. Lydekaityte (2019) conceptualized digitally enhanced packaging as "a hybrid digital physical object consisting of Cyber-Physical Systems, Cloud Computing and IoT." According to Petrelli (2017), Cyber-Physical Systems, such as sensors, actuators, and microprocessors, can be attached to everyday objects, and thereby the user will interact not directly with the embedded device but with the interface – the product's packaging.

3) **The Task.** When interacting with smart packaging, there is a set of actions to be accomplished by the user to reach the main goal (de la Fuente et al., 2015). Human-packaging interaction broadens up the traditional functionalities, such as opening, handling, and disposing (Mumani and Stone, 2018), carried out with product packaging by incorporating a wide range of other activities, where users, for instance, have to pick up their mobile device, download the app, scan the package, enabling a particular setting on the device, etc. (Petit et al., 2019).

4) **The context.** Another significant element of successful human-packaging interaction is the identification of touchpoints that are used for users' engagement with the packaging. The first part of the interaction takes place in the distribution system, including warehousing and transportation, where smart interactive packaging monitors and informs about the condition of the packaged goods (Lydekaityte, 2019). For instance, packaging with integrated shock sensors registers accidents during the distribution allowing us to re-evaluate the most incident-free route of transportation (Nilsson et al., 2012). The second part of the interaction occurs in the store when packaging is placed on the shelves and aims to persuade consumers to purchase the product (Wever, 2016). For instance, AR-enabled packaging can induce multisensory effects that might add value to the product and "trigger momentary and instantaneous desire to purchase" (Petit et al., 2019). Finally, after a product is purchased, it lives at the consumer's home, where more tactile-based human-packaging interaction happens while consuming the product creating more emotional and physical connections to the product or the brand (Ryynänen and Rusko, 2015; Tafesse, 2016). At this touchpoint, IoT-enhanced packaging can generate consumption behavior insights to improve consumers' health conditions that may become a building block for greater engagement (Lydekaityte, 2019).

4.2.2. Digitally enhanced product packaging through the lens of the Interaction Design

In relation to the interaction design theory presented by Coiera (2003), PAPER II describes smart interactive packaging as a combination of interacting agents consisting of (i) a human agent, e.g., the smartphone owner who entered the store, (ii) the computational agent, i.e., the smartphone, and (iii) the cyber-physical agent encompassing a physical product packaging and digital network-connected devices.

In order to illustrate both the interacting agents of digitally enhanced packaging and the previously described four-elements-based framework, three conceptual cases of digitally enhanced packaging were created and summarized in Table 15 and visualized in Figures 14 & 15.

Table 15. Fictive packaging cases (adapted from PAPER II)

The Case	The Consumer	The Package	The Task	The Context
Olive oil package with attached NFC tag	Grocery shoppers Olive oil users	Glass bottle NFC tag	Enable NFC settings Download the app (iOS) Find the symbol Tap/scan on the pack Go to the website Explore the track & trace	In-store
Cereal package with attached NFC tag	Grocery shoppers Cereals consumer	Cardboard box NFC tag	Enable NFC settings Download the app (iOS) Find the symbol Tap/scan on the pack Go to the website Get a voucher	At-home
Mouthwash bottle with smart sensors in the lid	Dental hygiene supporters Healthy-live style supporters	Plastic bottle Wireles Capacity sensor IoT	Download the app Enable Bluetooth settings Connect your phone with the bottle via Bluetooth Create a profile Consume the product Track personal profile React to reminders	At-home

*Elements from Microsoft 365 stock images and self-created

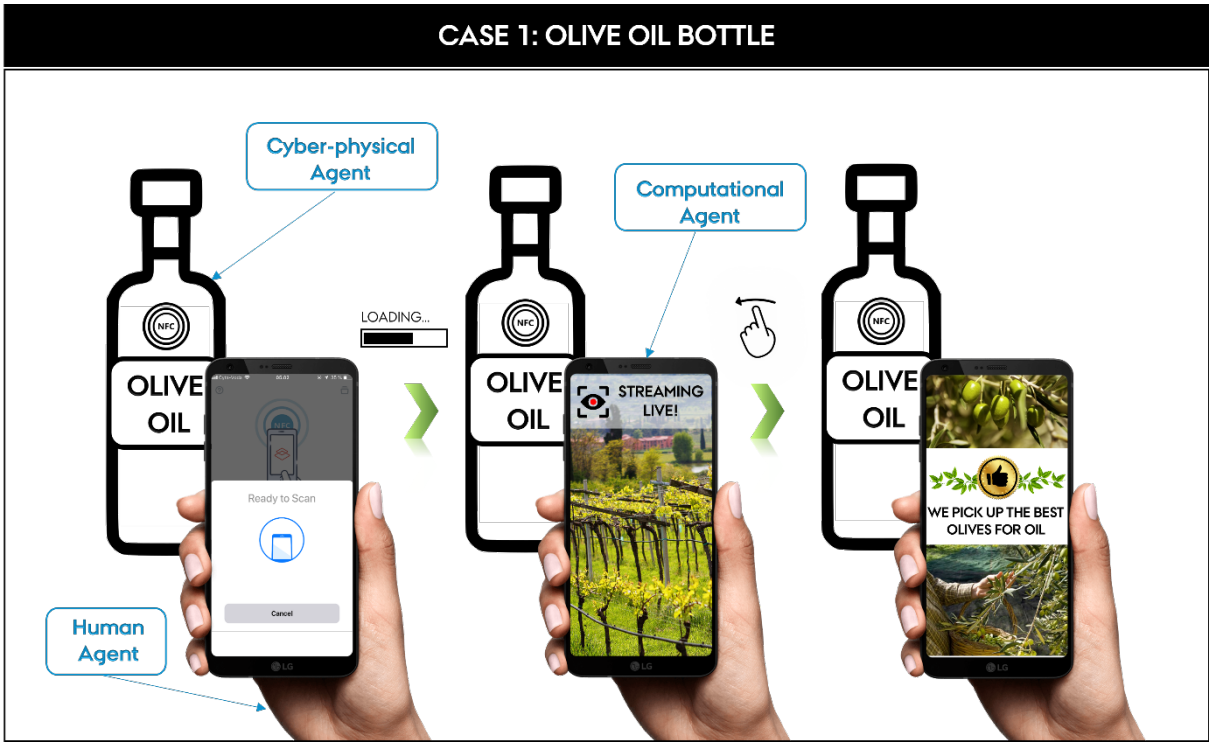


Figure 14. Visualization of first fictional case (elements sources: www.freepngimg.com, www.kevinandamanda.com, www.aljaoliva.com, www.wineries.co.za, www.pngaaa.com, www.iconfinder.com, Microsoft 365 stock images, self-created)

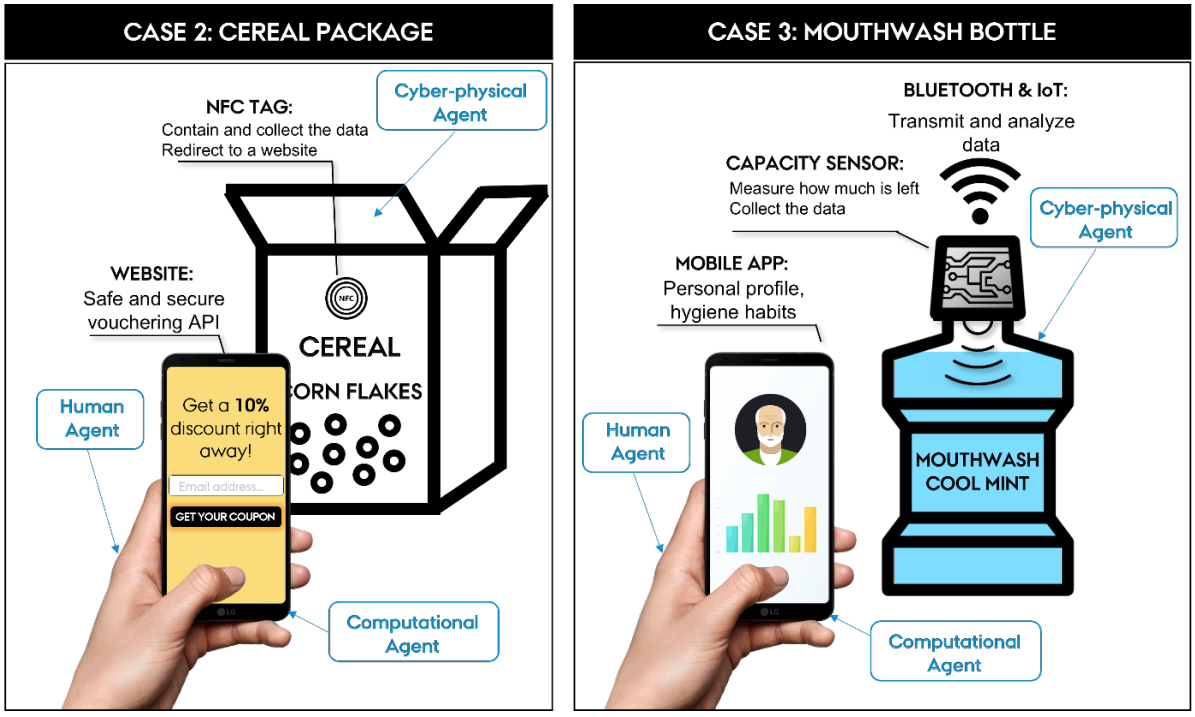


Figure 15. Visualization of second and third fictional cases (elements sources: www.freepngimg.com, www.kevinandamanda.com, www.aljaoliva.com, www.wineries.co.za, www.pngaaa.com, www.iconfinder.com, Microsoft 365 stock images, self-created)

Based on the interaction design theory, the interaction between the human agent and the cyber-physical agent can only be permitted by the computational agent (Coeira, 2003). As in the presented case of an olive oil bottle, a shopper must first interact with his/her smartphone, e.g., download the app, enable NFC settings, unlock the screen, etc., and only then tap with the device on the package. However, the sequence and number of interactions and the nature of the interacting agent might change depending on the type of ICT system embedded in the packaging design. For instance, medicine packaging with a smart label consisting of a printed display, sensors, and data carriers, would turn the label into a computational agent that could collect and display data to the human agent.

4.2.3. The Five Step Approach for Interactive Packaging Design (PAPER II)

The final framework for designing smart interactive packaging presented in PAPER II is the five-step approach that consists of five guidelines for the development of intuitive, effortless, and enjoyable user interfaces through product packaging. The five-step approach is tightly related to the four main elements of the smart interactive packaging presented earlier. These guidelines are based on user-centred design, HCI, consumer experience, and usability theories and refer to the five following concerns to address:

1) Why should the user take action or perform a task?

First, developers must encourage consumers to use the technologies, i.e., download the app or use their phone for a digital packaging experience (Petit et al., 2019). As a result, “to take action, consumers should get a stimulus from the environment, an implied benefit upon completion in the form of a particular reward” (Lydekaityte, 2019). Moreover, several studies have found that the lack of value is the most mentioned obstacle for consumers to adopt innovations (Antioco and Kleijnen, 2010).

2) Is the overall design intuitive and simple to use?
For successful interaction with the system, users must be consciously aware of what activities to perform (Coiera, 2003; Maguire, 2014). For instance, it must be clearly stated where to scan, which app to download, which button to press, etc. Consequently, designers must create simple, fast, and intuitive activities that can be accomplished without any additional skills (Maguire, 2014).

3) What other interaction might appear in the process of accomplishing the main interaction?
The overall interaction space must be examined for the identification of other agents and mediated interactions that may be needed to perform for the main interaction to succeed (Coiera, 2003). As the number of mediated interactions increases, it is vital to keep the user motivated throughout all the steps to reach the final goal (Coiera, 2003).

4) What other internal and external resources are needed for accomplishing the interaction?
Developers must consider and build all the internal and external elements of the interactive system that support the main interaction. For example, creating and printing a QR code on the package that allows downloading the app for NFC tag reading. However, all the internal and external resources come with their own tasks, cost, and limitations (Coiera, 2003). Thus, "the implied benefit upon the completion has to be greater than the cost of resources" (Lydekaityte, 2019).

5) What other attitudes, intentions, and motivations of the user must be incorporated into the overall design?
The design of interactive ICT systems must take into account the cognitive attributes and peculiarities of human agents who will be using them (Coiera, 2003). User-centered design is the focal point in the design process that requires an in-depth investigation of users' attitudes, motivations, intentions, and inspirations (Coiera, 2003).

4.3. The list of technological capabilities of NFC system (PAPER III)

PAPER III presented a thorough investigation of NFC's technological capabilities related to the enhancement of the communication function of product packaging. In the PAPER III study, technology capabilities are understood as digital capabilities and affordances that refer to characteristics, functions, and abilities related to the environment surrounding the digital artifact, i.e., smart interactive packaging, and enabled or supported by something or someone (Maier and Fadel, 2009). Overall, 16 technological capabilities were found and grouped into four categories: data and information services, security services, promotional services, and others. A more thorough description of each category is provided below.

4.3.1. Data and Information Services

As discussed in the theory section, the NFC tag consists of a memory chip and antenna, therefore the technological characteristics of the chip largely influence the overall NFC tag performance, such as how much data can be stored, how fast the data exchange can happen, is it possible to encrypt the data and other. This category consists of the following four technological capabilities: data storage, data collection, data logging, and data transmission.

Table 16. Definitions of technological capabilities of NFC: data and information services (adapted from PAPER III)

Technological capabilities	Descriptions
Data storage	- To store encoded/written data in heterogeneous formats - Chip characteristics: Read/Write memory 144-888 bytes, comply to ISO/IEC 14443 - Links to URL: the most common type of stored data in NFC tag that redirects the user to specific content on the internet, e.g., additional product information, proof of legitimate distribution, product origin, and other
Data collection	- To collect data autonomously using sensing devices that monitor the surrounding environment of the packaging under different conditions - The collected data is uploaded securely into the cloud - There are various types of smart sensors that can be incorporated into NFC IC
Data Logging	- To allow manual or autonomous data entry by human agents (e.g., feedback) - Mostly occurring in the retail and at-home touchpoints for marketing purposes - Used for instantaneous feedback, streamlined data collection, and capturing real-time consumer interaction with products
Data Transmission	- To transmit, read or exchange NDEF data between devices upon the initiated request from the human agent - To enable data transmission, the NFC tag has to be positioned in the RF field created by the reader (mobile device), allowing the transmission rate of up to 848 kbit/s - NDEF is a standardized data format used to exchange information between devices and consists of NDEF Messages and NDEF records

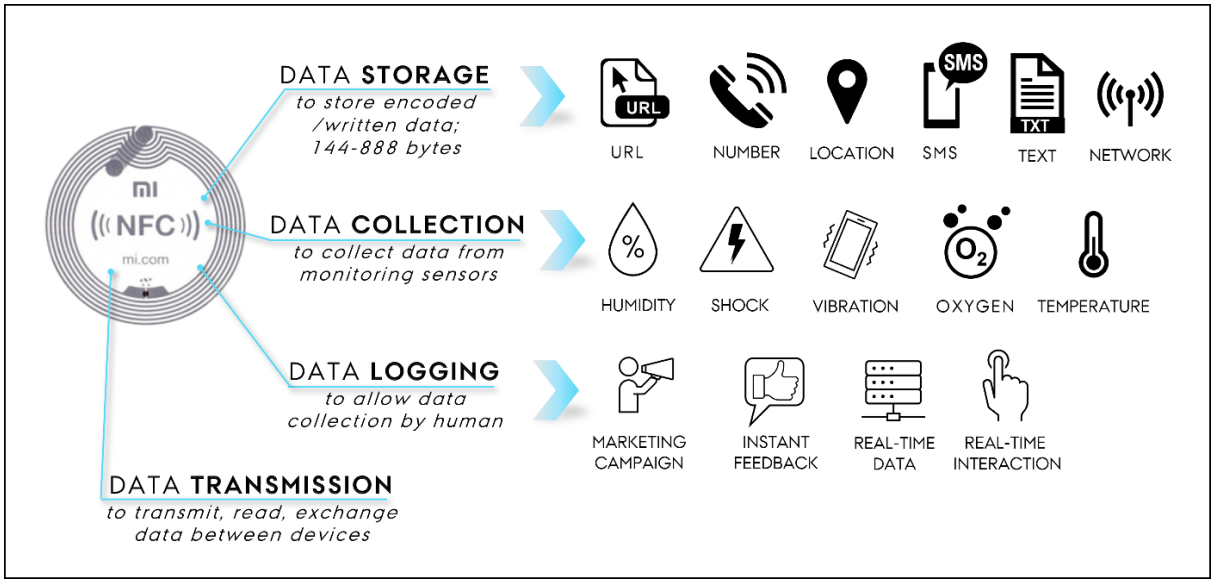


Figure 16. NFC capabilities: Data and information services (sources of elements: NFC logo from Saeed et al. (2013), icons from Microsoft 365 Stock Images and self-created)

4.3.2. Security services

Counterfeit products are the major threat to e-commerce, estimating up to 5-7% of world trade goods and a global economic value of over $865 billion (Saeed et al., 2013; Schilling et al., 2016). Therefore, the attachment of NFC tags to product packaging allows consumers to determine the legitimacy of a product already in store (Saeed et al., 2013). In general, PAPER III presented four ways to ensure stored, collected, or logged data security in the NFC system, including identification, validation and redirection, authentication, and encryption. In Table 17, the security-related capabilities are listed

based on their complexity and the strength of offered protection ranging from identification to encryption.

Table 17. Definitions of technological capabilities of NFC: security services (adapted from PAPER III)

Technological capabilities	Descriptions
Identification	- To store a unique identifier that provides the capability to be uniquely identified through the Internet - NDEF on the NFC tag stores unique (serialized) identifiers in Unique Resource Identifier (URI) or Unique Identifier (UID) formats
Validation and Redirection	- To protect and control product identities giving each item a persistent, addressable web-based presence - E.g., these processes link products to manufacturers' digital platforms, NXP created NFC solutions use RESTful APIs to allow straightforward and instant integration into brand owners' business intelligent systems
Authentication	- To provide a simple and secure way to verify the genuineness of the product (if the item is a product it claims to be) - NFC tags can detect counterfeits, grey-market products, and tampering by assuring that only requests from authentic tags redirect to the brand's webpage - Anti-counterfeiting: EPC standard used to track the physical location of a tag and upload the data on the cloud that allows detecting product diversion with a simple scan Tampering: NFC system can prevent forged re-labeling, refill fraud, pierced protective cork foil, and other fraudulent events occurring in the supply chain
Encryption	- To secure data with secret keys and provide trust provisioning services/cryptography - Each NFC tag possesses a secret encrypted value that can not be read by anyone who does not have a decryption key - It uses an encrypted challenge-response protocol based on symmetric, asymmetric, or public key cryptography - NFC can encrypt all critical data, protect access to target URLs, detect valid/invalid authentication requests, protect the master secret against vicious attacks, and other

Figure 17 illustrates all four described security capabilities provided by NFC in a fictional olive oil case demonstrating the main differences among them.

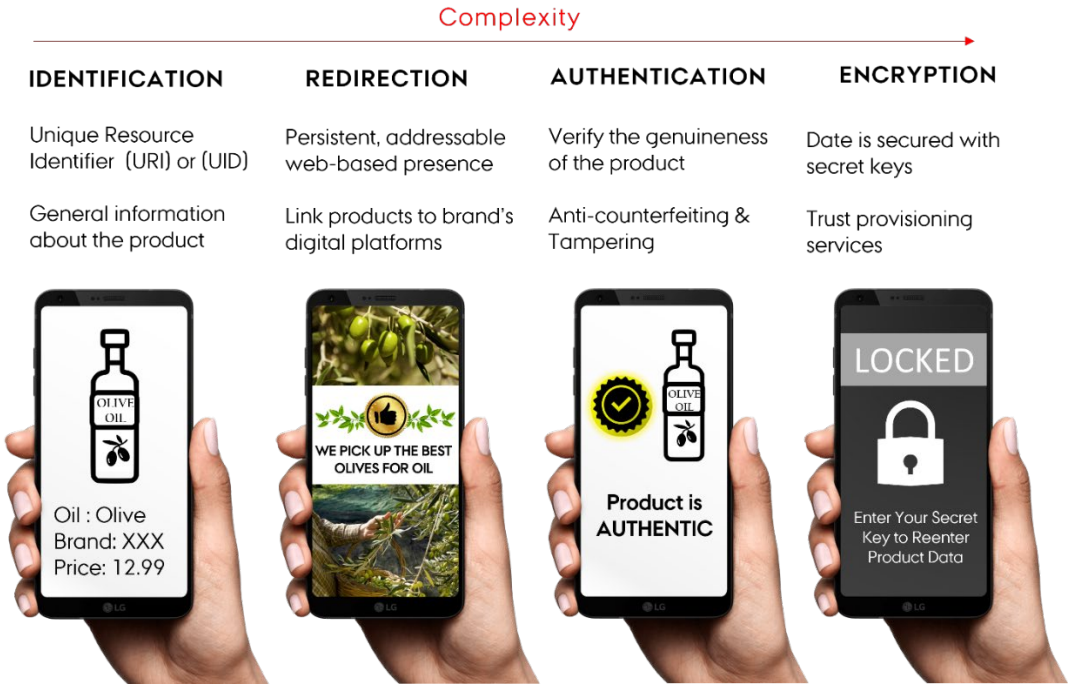


Figure 17. NFC capabilities: Security services (sources of elements: www.freepngimg.com, www.aljaoliva.com, www.wineries.co.za, www.onlinewebfonts.com, Microsoft 365 Stock Images and self-created)

4.3.3. Promotional services

NFC technology offers diverse opportunities for retailers and brands to interact with their consumers for promotional purposes (Wang et al., 2017). Such engagement with digitally enhanced and network-connected products allows instant consumer feedback and streamlined data collection that, in turn, benefits brands with real-time perceptions and foresight about their products and services (Abhishek, 2016). PAPER III divided the promotional services of NFC into four groups: coupons and vouchers, loyalty, bonus and memberships, location-based services, and social networks. Each group is explained in Table 18.

Table 18. Definitions of technological capabilities of NFC: Promotional services (adapted from PAPER III)

Technological capabilities	Descriptions
Coupons and Vouchers	- To diffuse, distribute, source, validate, redeem, and manage coupons and vouchers based on location or personalization
Loyalty, Bonus, and Memberships	- To implement better customer loyalty programs by automatically accumulating points, providing discounts, special offers, priority reservations, product samples, etc. - The system requires loyalty, bonus, and membership cards to be stored on the device
Location-based services	- Location-based promotional offers: award consumers with diverse incentives based on their location (couponing, advertising, in-store marketing, mobile marketing) - Personalized location-based promotions: based on the user's previous visits, forwards time-stamped promotions to impact purchase decisions when entering the store - Working principle: when a registered buyer carrying an NFC-compatible device with a personalized promotion app comes to a close range to NFC-enabled products, the tag is activated, its UID is collected, and a special offer is sent to the shopper - Transparent tracking in the supply chain: enables traceability solutions to provide real-time supply chain visibility
Social networks	- To link users with social media to receive first-hand experiences and recommendations from others - A person's buying decision is dependent on suggestions and opinions from others that can reduce or increase the perception of a product

4.3.4. Other capabilities

Finally, the other technological capabilities summarized in PAPER III are related to a peer-to-peer operating mode of NFC technology and are subdivided into the following: energy harvesting, network access, and device pairing capabilities (Table 19).

Table 19. Definitions of technological capabilities of NFC: Other capabilities (adapted from PAPER III)

Technological capabilities	Descriptions
Energy harvesting	- To enable data transmission and also power up embedded sensors to read their data - Working principle: passive NFC tag obtains energy from RF that is generated by electromagnetic field induced by the active NFC reader (mobile device)
Network access	- To provide a login to Wi-Fi or get connected to a Bluetooth by a tap
Device pairing	- To securely and automatically pair two devices without searching for a connection or typing a code

EXPERIMENTATION PHASE 1

4.4. The results from experimentation with NFC (PAPER III)

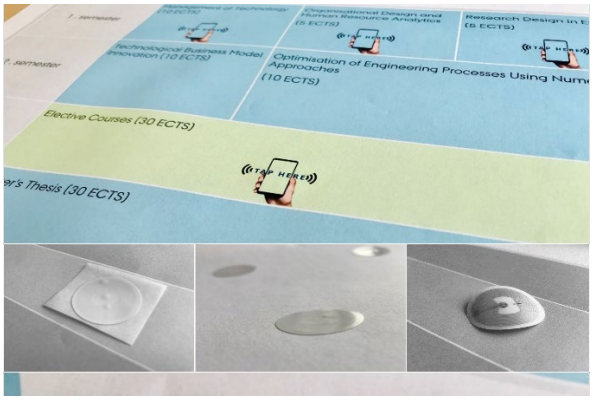
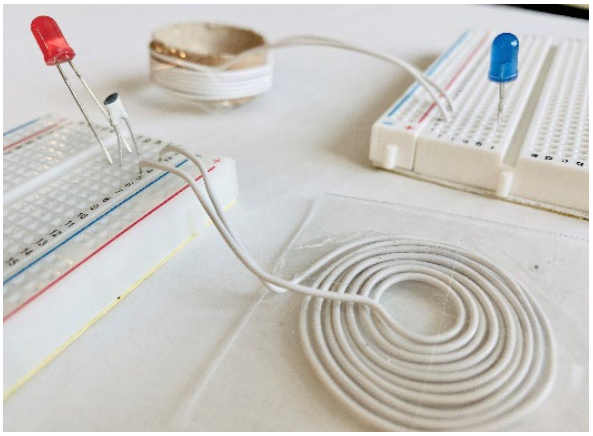
PAPER III has also presented an overview of the technological barriers of the NFC system to become widely accepted. These results were derived from the initial experimentation with NFC tags in Phase 1, that consisted of three elements:

1) ***Smart interactive packaging lab***, where a handful of examples of different enabling technologies, including smart NFC systems, smart identification, and security systems, augmented reality, diverse electronics, and printed sensors, were gathered from various smart technologies-related industrial events, such as AIPIA World Congress 2019, Printed Electronics Europe 2019, and Hannover Messe 2019 (Figure 18). Furthermore, a printer Brother Label Printer CZ-1005 - VC-500W was obtained for customized label production, together with a conductive ink pen and glue for self-printed NFC antenna fabrication.
2) ***PhD research web page*** (www.interactivepackaging.dk) that contained general information about smart interactive packaging, the research scope, and aims, carried out and ongoing projects including conferences, publications, experiments, industrial events for data collection, and similar. Moreover, the web page was also created to embed the digital content for the developed fictive experiment artifacts and redirect to surveys for data collection from the conducted experiments.
3) ***Preliminary testing of the NFC system*** to investigate the working principle of NFC technology and the initial response from the users. Based on the results from PAPER III, which provided a list of potential technological capabilities of NFC, two of them were selected to test: validation and redirection and energy harvesting. The descriptions of each experiment element are provided in Table 20. The first experiment was performed during the open house event at the Department of Business Development and Technology, where visitors were asked to try out the NFC technology in order to retrieve information about the study program and courses from the interactive poster. Once the interaction was achieved, they were asked to rate their experience on the survey built on the PhD research website. The same smart poster has been used several times in workshops during the teaching sessions held by the PhD student. The second test was the NFC-enabled system that powers up the integrated LED.

Figure 18. Objects for initial experimentation with smart interactive packaging (Phase 1)

The pre-testing of NFC systems provided insights about potential technological and user-related barriers and an overview of how to build such experiments for an effective user - NFC technology interaction that laid out the foundation for Phase 2.

Table 20. Preliminary testing of NFC systems (Phase 1)

NFC-enabled Smart Poster	NFC Experiment Details
	NFC tags: - NTAG213 from NXP - Diameter: 29 mm, Memory: 180 Byte - 13.56 Mhz / ISO 14443 A - White PET Plastic NFC Encoding: - App: NXP TagWriter - URL: links to diverse materials about master program in TBBD offered at BTECH, AU Poster: - A3, 90 gsm - Digital printing, Xerox AltaLink C8045
	NFC- powered system consisting of: - Capacitor with 68pF capacitance - Inductor with 2uH inductance - Low power LED - Self-made coil of 10 loops, 13Mhz - 400 tie-points Breadboard NFC reader: - NFC-compatible mobile device with an installed NXP reader app

4.5. Technology-centered barriers of NFC adoption (PAPER III)

Although NFC's benefits and enhanced technological capabilities have been recognized the researchers and developers, the technology is still not widely accepted by the end-users and brand owners (Pal et al., 2015). It might be related to the economic benefits of implementing the technology into the business model, consumer willingness to accept it, or technological obstacles that hinder effective and successful interaction with the NFC technology. Regarding the latter, PAPER III combined the results from the preliminary tests carried out in Phase 1 and the findings from the literature review and presented a list of technological barriers impacting the engagement with NFC, including:

1) ***The stability of the regulated voltage by the NFC chip.*** It is influenced by the powering time and the position of the mobile device when it is brought close to the passive NFC antenna. Since the NFC chip requires a certain amount of the induced electromagnetic field to ensure the regulated power supply, the active device – passive NFC tag position is significantly important (Escobedo et al., 2017). If the mobile phone and the passive NFC tag are placed incorrectly (i.e., too far from one another), no power supply is harvested to activate the passive tag. According to Escobedo et al. (2017), only a minor displacement is allowed to obviate deactivation. Based on the results from the initial tests, the position between a smartphone and a passive NFC tag was the most occurring issue for successful interaction, mainly because of unawareness of where the active NFC component is embedded in the mobile device. If the mobile phone and the tag were in the wrong range (too far from one another), there was no power supply to activate the tag. It was one of the most occurring problems during testing because it is difficult to know where precisely the reader is placed in

the mobile phone. Especially if people have never used their smartphones to interact with NFC-enhanced objects. For instance, iOS-supported devices tend to possess NFC readers implanted on the upper part of the device, whereas Android-supported devices contain NFC readers fixed in the middle. Moreover, it is not only the location of the NFC reader that affects the reading performance but also, based on findings from Barge et al. (2020), distinct smartphone models exhibit considerable differences in the maximum reading distances.

2) ***Transmission speed.*** Since NFC has a lower transmission speed than other networking technologies, it intercommunicates with other wireless networks, such as Bluetooth or Wi-Fi, that are capable of large files transfer (Cerruela García et al., 2016). At the moment, the highest data transmission speed, up to 848 kbit/s, is offered by NXP NTAG 424 DNA (NXP Datasheet, 2019). However, the majority of NFC tags built for consumer communication in fast-moving consumer products operate at 106 kbit/s data rate. Consequently, the performance of the validation and redirection technological capability highly depends on the network user is connected. During the preliminary testing, some participants were able to download the data quite fast, while for others, it took a while, which greatly affected the patience of those participants to continue the experiment.
3) A limited number of devices that support NFC. NFC compatibility is only available on certain models of smartphones. However, new generation mobile devices are being equipped with NFC technology built-in, likewise other wireless technologies, such as Wi-Fi or Bluetooth (Chandrasekar and Dutta, 2021). As a result, the number of NFC-compatible devices is continuously increasing. The up-to-date list of NFC-enabled smartphones and tablets is provided by www.shopnfc.com[5].
4) Inconsistency among different devices and operating systems. The overall NFC system lacks consistency and integrity among various mobile devices and operating systems. Mobile devices developed by different manufacturers activate NFC technology in different ways. Preceding models of smartphones with earlier versions of operating systems require third-party applications to read the NFC tag. For instance, every iPhone since iPhone 6 has a built-in NFC chip, but only iPhone and newer models allow reading the NFC tags using a specific mobile application. Furthermore, starting with iPhone XS and iOS 13, the smartphones are able to write and read NFC chips in the background, i.e., no additional app is required (www.digitalcitizen.life). On the other hand, NFC initiation with devices supporting Android mobile operating system is less complicated and straightforward. Based on the results of the preliminary tests, all the devices supporting the Android OS did not need any additional application to install in order to read the tag. However, the other problem that occurred during the experimentation was the need to update the operating system of the phone because the app required the newest version. Unfortunately, this requirement stopped the interaction permanently, and participants refused to continue.
5) Battery saving mode. People tend to switch off various settings on their smartphones and apps that connect the mobile device with a service provider to prolong the battery life (Hemchand, 2016). As a result, the user must perform several intermediate steps to enable interaction with NFC technology. Based on the findings from PAPER II, the additional unforeseen steps might increase the participant's risk of quitting and stopping the interaction because too much effort is required.
6) Privacy settings. Similarly, to the previously described issue, it is common to switch off permissions always to track users' activities, such as their geographical location, on mobile devices regarding privacy concerns (Hemchand, 2016). Therefore, users are asked to enable

[5] https://www.shopnfc.com/en/content/7-nfc-compatibility

different settings before interaction with the NFC tag. However, during the experiments, some participants raised concerns about their privacy, that decreased their interest in engaging with the NFC system.

EXPERIMENTATION PHASE 2

4.6. The experimental framework for user-packaging experiment (PAPER IV)

The experimentation results from Phase 2 were summarized in PAPER IV. Overall, the Phase 2 experiment was conducted on a small scale with students at the Department of Business Development and Technology. The study carried out a user experiment, where a product packaging with built-in NFC capabilities was tested with selected participants to track their engagement with the smart interactive packaging. The experimentation was designed taking into consideration the frameworks and models developed in previous papers (PAPER I, PAPER II, PAPER III):

- In relation to PAPER I, the experimentation employed smart interactive packaging with enhanced communication function through the embedded wireless technology – Near Field Communication.
- The design of the physical and digital artifacts of the experiment followed the three frameworks presented in PAPER II, considering the four main elements of the smart interactive packaging, the five-step approach for the design, and all the interacting agents and mediated interactions that took place in the overall interaction space.
- Finally, based on the findings from PAPER III, two main technological capabilities related to security services were selected to investigate, including validation and redirection, and authentication. Furthermore, the design of the experiment aimed to overcome all the technological barriers presented in PAPER III and facilitate user interaction with the smart interactive packaging.

In the following sections, the main elements of the experimentation of Phase 2 are provided with a more comprehensive explanation of their relation to other papers.

4.6.1. Physical and digital artifacts of the experimentation

Physical and digital artifacts of the experiment described in PAPER IV consisted of a set of three NFC-enabled cardboard packages, an instruction sheet for explaining the NFC working principle, and diverse digital content for each package.

A set of three NFC-enabled cardboard boxes

A set of three cardboard packages with built-in NFC capabilities was the central part of this experiment (Table 21). Packages were 10×10×20 cm and made from single-wall white corrugated cardboard. NFC stickers with the NXP NTAG213 chip were attached to the inner part of the package. Each package was built with a different NFC digital capability to test during the experiment:

1) Package No. 1, with an embedded link to video content on YouTube, was without any graphics or identification mark of where the NFC sticker was. The intent of this manipulation was to confirm the research hypothesis that the identifying sign and additional information of the embedded technology allow users to interact with the system more intuitively. The hypothesis was initiated by the results from Museli and Navimipour (2018) that argue if the consumers have prior knowledge of technology (such as how the identification sign of the NFC looks like), the interaction would be more intuitive, and thereby the intention to adopt the technology would increase. The integration of the identification mark is related to the step two and step four in the proposed five-step approach for designing smart interactive packaging (see section

4.2.3.) – the clearly defined area to tap with their phone and the necessary external resource the company has to invest in in order to notify consumers about the innovations in their products' packaging.

2) Package No. 2 contained no graphical elements, only the identification mark of NFC that was printed on the front of the package. The package was built with the intent to investigate the impact the identification mark has on the interaction with the NFC system in comparison with Package No. 1. The package provides validation and redirection capability and sends the user to the PhD research website (www.interactivepackaging.dk).
3) Package No. 3 is a fictive cosmetic product with corresponding graphical elements and the NFC identification mark. Recently, it has been found that 80% of consumers claimed they care about the authenticity of the product, especially when buying luxury goods (Digimarc, 2022). As a result, the ability to check the genuineness of the product before the purchase can be understood as a reward that might facilitate the decision to buy the product. Furthermore, Violino et al. (2019) argue that NFC simplifies the identification and authentication processes that refer to the safety and quality of the packaged products that, in turn, build consumer trust in the manufacturer. The secured trust in the brand owner can contribute to the continuous usage of the product (Candy and Costello, 2008). Consequently, the package was built to test if the provided context and intrinsic incentives for consumers increase their interest and willingness to use the interactive system.

Summaries of all built NFC-enabled packages are provided below in Table 21.

Table 21. A summary of three NFC-enabled cardboard packages (Adapted from PAPER IV)

Information	Package No. 1	Package No. 2	Package No. 3
Description	Corrugated cardboard package without graphics or NFC sign	Corrugated cardboard packaging without graphics but with a sign of NFC	Corrugated cardboard packaging with graphics of a specific cosmetic product and with a sign of NFC
NFC chip	NXP NTAG213, 144 bytes, ISO 14443 A	NXP NTAG213, 144 bytes, ISO 14443 A	NXP NTAG213, 144 bytes, ISO 14443 A
NFC sticker	120 µ ±15 µm thickness, 29 mm diameter	120 µ ±15 µm thickness, 29 mm diameter	120 µ ±15 µm thickness, 29 mm diameter
NFC capability	Validation and redirection	Validation and redirection	Authentication
NFC tag data	YouTube video of NFC technology (link)	PhD research website (link)	Authentication mock-up for the packaged product (link)
Picture			

Figure 19. Experiment instructions for NFC interaction depending on the type of a smartphone (elements sources: pixabay.com, Microsoft 365 Stock Images and self-created)

An instruction sheet of NFC working principle

An instruction sheet of explanation of how NFC technology works was built and distributed to the experiment participant before interacting with the packages to address most technical discrepancies to reduce the uncertainty of the technology as much as possible and facilitate the first steps of interaction. The user-NFC interaction begins with identifying the type of operating system the device works on and if it is needed to download a third-party app to read the tag. Moreover, one of the most occurring issues during NFC interaction is the stability of the regulated voltage. As written earlier, if the mobile phone and the tag are in the wrong range, there is no power supply to activate the tag. Therefore, it is of utmost importance to get consumers acquainted with the exact placement of the NFC reader in their devices, especially those who interact with NFC for the first time. An instruction sheet of the NFC working principle is provided in Figure 19.

Digital content for each package

Finally, each NFC tag attached to a package contained different digital content. NFC tag stickers are produced by the manufacturer in a blank state, therefore to program the tag, specialized software, and hardware is required. All three NFC tags are encoded with different URLs using the NXP TagWriter app. Package No. 1 redirects the user to the YouTube video about NFC technology. The NFC incorporated into Package No. 2 contains a link to the PhD research website (www.interactivepackaging.dk). Package No. 3 is equipped with the NFC tag with an authentication capability for the fictive cosmetic product. The digital mock-up to confirm the product's genuineness was created and placed on the PhD research website.

Figure 20. Graphical visualization of URL links embedded in each package NFC chip (elements sources: freepngimg.com, screen-prints from interactivepackaging.dk and YouTube, and self-created)

4.6.2. Experiment process

The process of the experiment is summarized in Figure 21, including every stage in researcher-participant communication and participant-packaging interaction during pre-experimental, experimental, and post-experimental activities.

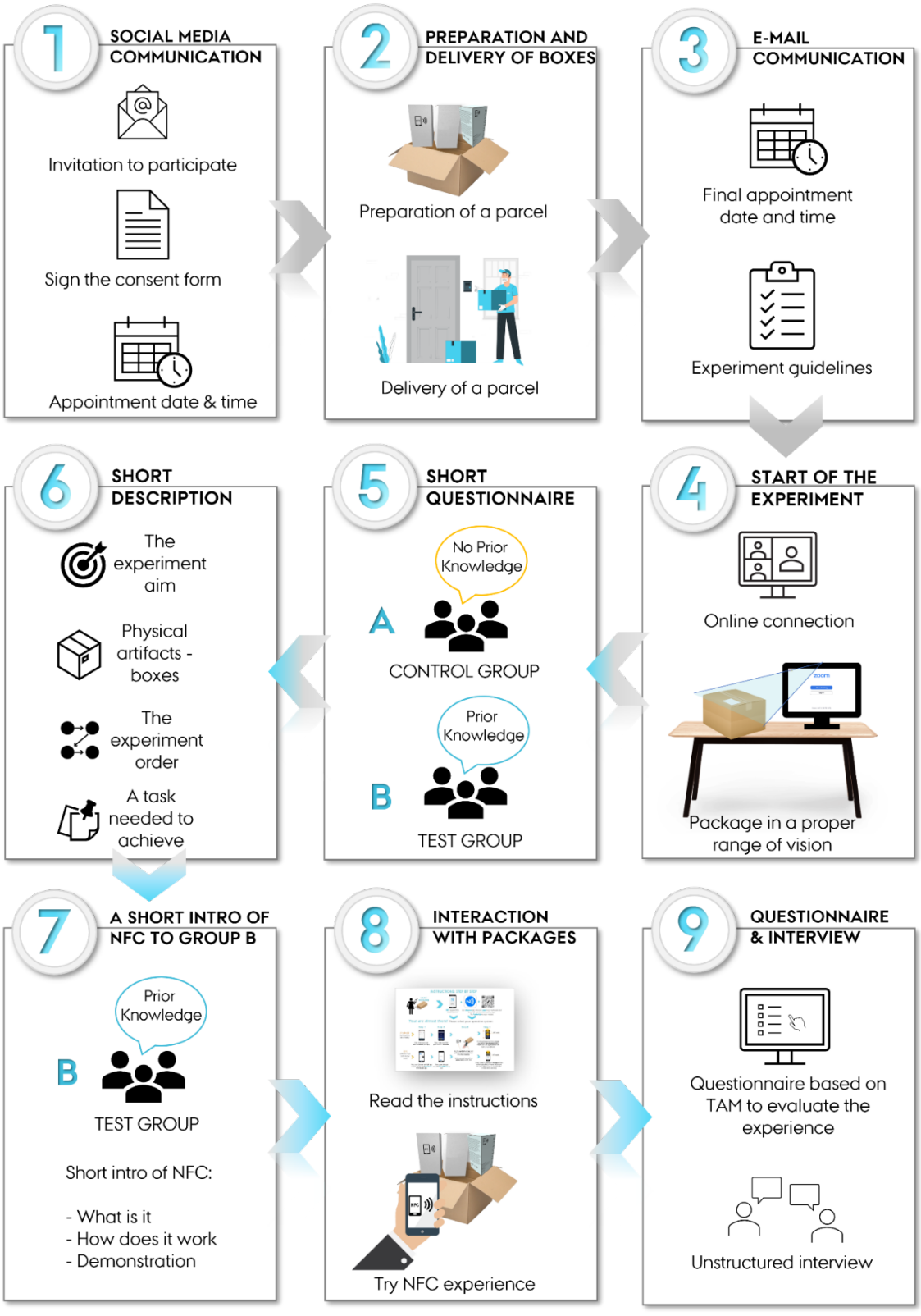


Figure 21. Experiment Process Steps for Phase 2 (elements sources: www.indiamart.com, www.freepik.com, www.pngfind.com, www.zoom.us, southernutahcares.com, Microsoft 365 Stock Images and self-created)

4.6.3. Insights from user-packaging interaction in Phase II (PAPER IV)

Several observations from the experiment regarding the main user-packaging interaction, where participants were asked to initiate NFC tags placed on packages, are given below:

- More than half of the participants were unaware of the embedded NFC reader in their mobile devices. It indicates that consumers lack knowledge not only about the technological innovations implemented around them but also about the technological capabilities of their devices. As a consequence, an improved individual's absorptive capacity might facilitate a better understanding and acceptance of NFC technology (Pham and Ho, 2015).
- Although all the experiment participants had already used NFC before for wireless payments, only a few of them knew the exact name of the technology. It could be understood that people are not concerned about the peculiarities of the technologies around them and are only interested in how to use them in practice, such as tapping on the payment machine with a credit card. As a result, consumer education and knowledge are integral parts of technology adoption (Tiekstra et al., 2021).
- Overall, it was found that there is an essential incoherence among different devices and operating systems and the way they initiate the NFC interaction. According to Davis (1989) and Venkatesh et al. (2016), the acceptance of new technologies significantly depends on the system's complexity and the efforts needed to succeed. For some users whose personal innovativeness level is low, initiating the NFC interaction would be too time-consuming because of the need to install the third-party application or upgrade their current operating system. As a result, more research is needed to investigate whether the NFC system's complexity negatively affects consumers' perception and adoption of the technology.
- The results from the experiment confirmed the importance of consumer awareness of where the NFC reader is integrated into the mobile device. It took longer for participants to succeed in their first interaction since they had to test several different locations on their smartphones. However, the subsequent interactions went faster and smoother, with 72.7% of participants confirming that the NFC system is rapidly learnable after the first time. In addition, all the participants agree and strongly agree that the provided instructions helped them understand how to properly use the NFC technology. Correspondingly, the perceived ease of use of NFC technology might positively affect the consumer's intention to use the technology.
- A significant relation was observed between the identification sign of NFC and the duration of interaction initiation. The latter was reduced from 5 minutes for Package No. 1 to less than one minute for Package No. 2 and Package No. 3, indicating that the interaction with NFC swiftly becomes more intuitive with the presence of the identification sign. As a result, all the participants agreed that the identification mark helped them to use the NFC intuitively.
- Experiment participants recognized NFC as a beneficial tool for faster access to product information. Approximately two-thirds of participants agreed that the ability to check a product's authenticity through NFC technology increases the possibility of purchasing the product. However, further research is needed to investigate other intrinsic and extrinsic means of motivation that would trigger users' intent to interact with NFC once they notice it on the product package.

In addition, some participants were concerned with the security aspect of enabling the NFC feature on their smartphones. Consumers and businesses are concerned about their personal and sensitive data held on third-party servers that contain large amounts of data and can be accessed at any time and geographic location (Ratten, 2015). This anxiety about security concerns might conflict with consumers regarding whether it is safe to interact with NFC technology.

EXPERIMENTATION PHASE 3

4.7. The list of identified and classified factors influencing the adoption of NFC (PAPER V)

This PhD study has selected the TAM model to investigate the consumers' acceptance and perception toward the NFC technology applied to product packaging. TAM aims to determine the influence of external factors on the original variables, i.e., Perceived Ease of Use, Perceived Usefulness, Attitude Toward the Use, Behavioral Intention to Use, and Actual Use of technology (Museli and Navimipour, 2018). Especially since NFC technology is still not widely accepted by consumers, it is of the utmost importance to identify and investigate the factors facilitating NFC adoption for product packaging. Overall, in PAPER V, 169 variables were gathered from the investigated 25 studies that later were classified into 42 constructs assigned into 13 categories. In further detail, the classification of variables to 13 categories was based on their descriptions and the theories they were derived from. Constructs from seven prevailing technology acceptance theories and models were used to build those categories, including the Technology Acceptance Model, Multi-level Framework of Technology Acceptance and Use (Venkatesh et al., 2016), United Theory of Acceptance and Use of Technology (Venkatesh et al., 2003), Protection Motivation Theory (Rogers, 1975), Motivation-opportunity-ability Theory (MacInnis et al., 1991) and Uses and Gratifications Theory (Katz et al., 1974), and Engagement Theory (Kearsley and Shneiderman, 1998). The descriptions of the five original variables of the TAM model have already been given in the theory section, thereby Table 22 shortly describes the rest 37 variables.

Table 22. Definitions of identified variables

Variable	Definition
Perceived Credibility	
Perceived Security and Privacy	privacy as "willingness to provide personal information to trans-act on the Internet." (Dinev and Hart, 2006, p. 65) security as concerns the level of protection against threats provided by the technology (Aldughayfiq and Sampalli, 2021)
Perceived Trust	"the individual's intention to act in a certain way and reflects the security that one party has in the other one" (Dutot, 2015, p. 47)
Individual Attributes	
Knowledge and Experience	"as people's perceptions of what or how much they know about a product, based on their subjective interpretation making" (Daoud and Trigui, 2019, p. 360)
(Personal) Innovativeness	"the willingness of an individual to try out any new information technology" (Agarwal and Prasad, 1998, p. 206).
Decision confidence	"the degree of certainty that people have about the appropriateness of their decisions" (Romano et al., 2022, p. 1225).
Optimism	"how consumers felt about the benefit of technologies in their daily consumption activities" (Castillo and Bigne, 2021, p. 891)
Technology readiness	"people's propensity to embrace and use new technologies for accomplishing goals in home life and work" (Parasuraman, 2000, p. 308).
Need for cognition	a personality trait that describes the need for activity or stimulation with cognitive efforts often shaped by external influences, during socialization and interaction of learning experiences (Cacioppo and Petty, 1982)
Discomfort	"an individual's anticipation of lacking the sense of mastery of the new technologies and being overwhelmed by them" (Chang and Chen, 2021, p. 4)
Insecurity	"a distrust of new technologies and skeptical attitude toward their abilities to work correctly" (Chang and Chen, 2021, p. 4).
Individual Beliefs	
Self-efficacy	user's confidence in their ability and skills required to perform a task (Demoulin and Djelassi, 2016)

Technology Availability	the degree to which "an individual believes that technical infrastructure exists to support the use of the system" (Dutot, 2015, p. 48)
Price Value	encompasses presumed monetary value (Pham and Ho, 2015), time and emotional efforts need to use the technology (Museli and Navimipour, 2018), and the importance placed on the price (Romano et al., 2022)
Time Pressure	a person's predisposition to consider time as a scarce resource (Romano et al., 2022)
Technology Attributes	
Technology Accessibility	"concerns how accessible the technology is, i.e., is the technology spread worldwide, is it prevalent and standardized" (Karpavičė et al., 2023, PAPER V)
Interactivity	"the degree to which the user perceives that the interaction or communication is two-way, controllable, and responsive to their actions" (Mollen and Wilson, 2010, p. 921)
Mobility	"involves interactions within individuals and artifacts within a given space" (Kourouthanassis et al., 2010, p. 279), and "the extent of user awareness of the mobility value of mobile services and systems" (Park et al., 2014, p. 6)
Intuitive	"able to understand something by using feelings rather than by considering the facts" (Teh et al., 2014, p. 488).
Facilitated Navigation	"process of exploring the interactive environment in alternative ways to seek out product-related information" (Childers et al., 2001, p. 515)
Trialability	"the degree to which an innovation may be experimented with on a limited basis" (Karahoca et al., 2018, p. 745)
Performance	the probability that NFC technology will not work as expected and will not give the intended benefits (Liébana-Cabanillas et al., 2020)
Social Context	
Social Influence and SN	"the extent to which consumers perceive that important others (e.g., family and friends) believe they should use a particular technology" (Venkatesh et al., 2012, p.159)
Social presence	"the degree to which one perceives the presence of participants in the communication" (Calefato and Lanubile, 2010, p. 287)
Motivation	
Motivation	the users' wants and needs to achieve specific goals with the technology (Faisal et al., 2022)
Satisfaction	means of emotional response and cognitive judgment (Han et al., 2016)
Perceived Enjoyment	"the degree to which the activity of using technology is perceived to be enjoyable in its own right apart from any performance consequences that may be anticipated" (Davis et al., 1992, p. 1113)
Perceived Value	"the consumer's overall assessment of the utility of a product based on perceptions of what is received and what is given" (Zeithaml, 1988, p. 14).
Perceived Quality	"the consumers' judgment about the superiority of a product" (Zeithaml, 1988, p. 5)
Control	"the fact that an individual can choose the timing, content and sequence of communication (Boudkouss and Djelassi, 2021, p. 1628).
Time-Saving	The ability to facilitate convenience and save time (Boudkouss and Djelassi, 2021)
Information seeking	"as using social media to seek out information or to self-educate" (Whiting and Williams, 2013, p. 364)
Image	"the degree to which use of an innovation is perceived to enhance one's image or status in one's social system" (Moore and Benbasat, 1991, p. 195)
Facilitating Conditions	
Facilitating Conditions	"as the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system." (Venkatesh et al., 2003, p. 453).
Perceived Compatibility	"the status of an innovation that is perceived as being consistent with the existing values, past experiences and needs of potential adopters" (Karahoca et al., 2018, p. 745)
Individual Experience	
Gamification	the process of using video game elements in non-gaming systems to improve user experience and engagement to encourage participation (López-Martínez et al., 2020)
Focused attention	"represents the individual temporal and environmental dissociation derived by the total absorption in the performed task" (De Canio et al., 2021, p. 925)
Engagement	"as both the act of emotionally involving users and the state of being in gear and interacting directly with a system (O'Brien, 2010, p. 345)

4.8. The proposed extended TAM model (PAPER V)

In PAPER V, once the external variables of the TAM model were identified and categorized, the extended TAM model was developed (see Figure 22). The extended TAM model encompasses the following:

- 37 external variables gathered from 25 investigated studies.
- 5 original variables from Technology Acceptance Model.
- 3 additional external variables proposed by the authors in PAPER V that were omitted by investigated studies.

The proposed extended TAM model also depicts all supported structural relationships between external and internal (original) variables compiled from 25 investigated studies that were confirmed to have a positive impact on the technology acceptance of NFC.

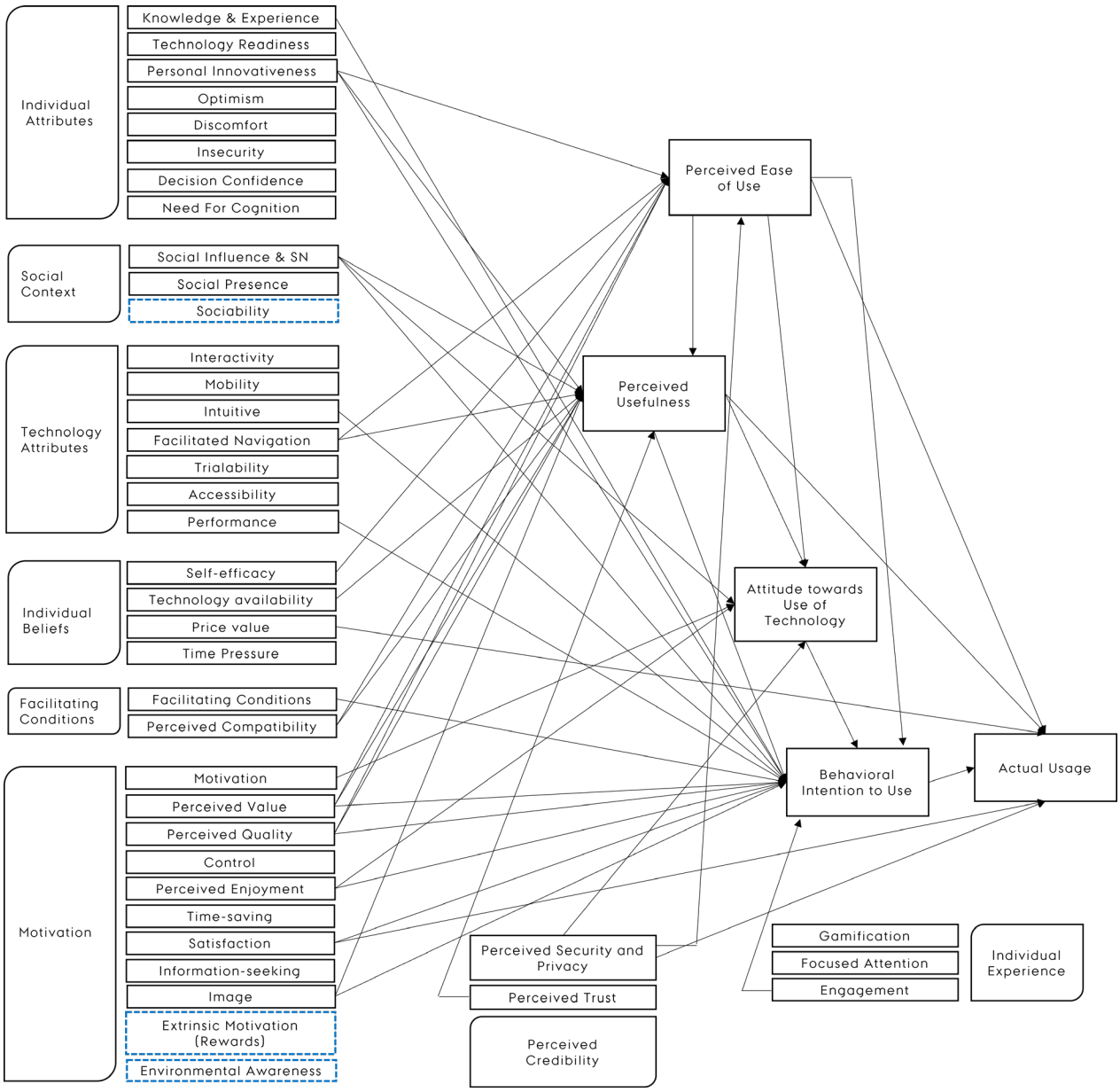


Figure 22. extended TAM model for NFC-enhanced product packaging; rectangles – indicate variables, diagonal corners rounded rectangles – indicate categories, line arrows – indicate the supported structural relationships from 25 studies, blue dashed rectangles – indicate the proposed additional variables (Karpavičė et al., 2023, PAPER V)

4.9. The selection of the most influential variables for the maturity level of NFC for product packaging (PAPER V)

In PAPER V, the investigation of the most influential variables for NFC technology acceptance in product packaging has been conducted by quantifying the results and employing Multi-Criteria Decision Analysis (MCDA) together with an internal scale. First, 42 variables were examined by the following four criteria presented in Table 23, calculating corresponding criteria rates for each variable.

Table 23. Descriptions of criteria used in MCDA (adapted from PAPER V)

Criteria	Explanation	Formula
C I: The rate of the variable occurrence	The number of investigated articles that uses the variable as a potential factor for NFC adoption	$R1_{k_x} = \sum_{i=1}^{n} a_{art}$
C II: The rate of variable dependencies	The number of hypotheses of one variable's dependency on the other in the investigated articles	$R2_{x\_dep} = \frac{n_{hyp\_x}}{n_{hyp\_all}} \times 100$
C III: The rate of supported hypotheses in relation to all propositions made	The number of accepted hypotheses for each variable that support structural relations between variables based on the results from structural equation modelling (SEM) performed in investigated studies *(path coefficients, p-values)*	$R3_{x\_hyp\_sup} = \frac{n_{x\_hyp\_sup}}{n_{x\_hyp\_all}} \times \frac{k_x}{25}$
C IV: The rate of the strength of the supported hypotheses	The magnitude of the supported hypotheses by assessing the mean values of path coefficients of structural relationships	$R4_{x\_h\_str} = \frac{\sum_{i=1}^{n} k_i}{n}$

Second, each calculated rate was attributed to the equivalent rating score on the ordinal (for C I) and interval (C II, C III, C IV) scales. The intervals of the rates for assigning to the ranking scale are provided in PAPER V. The criteria rates and ratings for the top 15 variables in each criterion are provided in Table 24. The complete results of the MCDA analysis encompassing all 42 variables can be found in PAPER V.

Table 24. The criteria rates and ratings for the top 15 variables (adapted from PAPER V)

	Var	*C I R1*	*Rating 1-10*	*Var*	*C II* $R2_{x\_dep}$	*Rating 1-10*	*Var*	*C III* $R3_{x\_hyp\_sup}$	*Rating 1-10*	*Var*	*C IV* $R4_{x\_h\_str}$	*Rating 1-10*
1.	PU	19	7	PEoU	13,8	10	PU	0,53	9	ATT	0,72	9
2.	PEoU	18	7	PU	12,6	9	BI	0,43	8	SAT	0,66	9
3.	BI	16	6	PSC	7,5	6	PEoU	0,39	7	BI	0,53	7
4.	ATT	10	4	PCOM	5,7	4	ATT	0,32	6	PEJ	0,52	7
5.	PSC	10	4	PEJ	5,7	4	PEJ	0,25	5	PU	0,48	6
6.	PEJ	8	4	PQ	5,7	4	SI	0,23	4	KE	0,43	6
7.	SI	8	4	INN	5,0	4	PQ	0,21	4	MOT	0,42	6
8.	PQ	6	3	SI	4,4	3	PSC	0,20	4	PEoU	0,41	6
9.	AU	5	3	ATT	3,1	3	PV	0,20	4	PV	0,41	6
10.	INN	5	3	INTR	3,1	3	FC	0,16	3	PQ	0,39	5
11.	PV	5	3	PV	3,1	3	SE	0,12	2	SE	0,34	5
12.	FC	4	2	IM	2,5	2	INN	0,10	2	ENG	0,33	5
13.	PRV	4	2	KE	2,5	2	PRV	0,08	2	NAV	0,29	4
14.	INTR	3	2	NAV	2,5	2	SAT	0,08	2	INTT	0,24	3
15.	KE	3	2	BI	1,9	2	DC	0,04	1	TA	0,24	3

Finally, the final score for each variable was calculated by multiplying each criterion rating by the

corresponding weight of the criterion. The formula for the final score calculation is given below:

$$FS_x = Rating_{R1_{kx}} \times 0.25 + Rating_{R2_{x\_dep}} \times 0.25 + Rating_{R3_{x\_hyp\_sup}} \times 0.25 + Rating_{R4_{x\_h\_str}} \times 0.2$$

The calculated final scores of the top 14 external variables that impact NFC technology acceptance for product packaging applications the most are provided in Table 25. Based on the PAPER V findings, the original TAM variables, including PU, PEoU, BI, and ATT, were found to be the most influential regarding NFC adoption. The other ten most impactful external variables were PEJ, PSC, PQ, PV, SI, SAT, INN, KE, PCOM, and SE, belonging to Motivation, Perceived Credibility, Social Context, Individual Attributes, Individual Beliefs, and Facilitating Conditions categories.

Table 25. The list of most impactful variables of NFC technology acceptance for product packaging (PAPER V)

Place	Total score	Variable	Category	Variable Type
1.	7,75	Perceived Usefulness	Perceived Usefulness	TAM variable
2.	7,50	Perceived Ease of Use	Perceived Ease of Use	TAM variable
3.	5,75	Behavioral Intention to Use	Behavioral Intention to Use	TAM variable
4.	5,50	Attitude Towards the Use	Attitude Towards the Use	TAM variable
5.	5,00	Perceived Enjoyment	Motivation	External variable
6.	4,25	Perceived Privacy and Security	Perceived Credibility	External variable
7.	4,00	Perceived Quality	Motivation	External variable
8.	4,00	Perceived Value	Motivation	External variable
9.	3,50	Social influence and SN	Social context	External variable
10.	3,25	Satisfaction	Motivation	External variable
11.	3,00	Innovativeness	Individual attributes	External variable
12.	2,75	Knowledge and experience	Individual attributes	External variable
13.	2,50	Perceived Compatibility	Facilitating Conditions	External variable
14.	2,50	Self-efficacy	Individual Beliefs	External variable

*ECT – Expectation Confirmation Theory

5 Chapter - Discussion

The PhD dissertation aims to understand the proposed research objective of **how digital innovation in primary product packaging can enhance CPG consumers' experiences and product functionalities**. The PhD research has identified that there is a scarce amount of research on smart interactive packaging as a digital interactive system. The ambition of this study has been to extend the current body of knowledge of smart interactive packaging within interaction design, human-centered design, and technology acceptance domains since the current comprehension of enhanced packaging is heavily fragmented and nearly non-existent. Furthermore, the author aims to provide a set of discernments for successful and efficient smart interactive packaging design based on the findings from PAPERS I-V.

This chapter presents the synthesis of the main research findings disseminated in the appended papers by introducing an updated four-main-element framework of smart interactive packaging design and elaborating on its connection to results from appended studies. Moreover, although sustainability was not explicitly defined within the scope of this research, this concept has been obscurely and implicitly occurring throughout the entire journey of the PhD research. As a result, this chapter discusses sustainability's relation to carried out studies. The chapter also addresses the theoretical and practical implications, followed by the limitations and related future research.

5.1. Answering research question

As presented in PAPER II, digitally enhanced and network connected product packaging can be understood as a digital interactive system consisting of digital and physical elements that enable it to expand the traditional human-packaging interaction and enhance the consumer experience. In order to answer the main research objective, smart interactive packaging has to be comprehensively investigated through the lens of interaction design principles allowing to distinguish the critical elements of successful and engaging user interaction that would, in turn, would be able to enhance consumer experience and product functionality. The four critical elements framework presented in PAPER II has been used to illustrate the coherence and conjunction of the appended research papers. Table 26 contains a summary of this section.

The consumer

The quality of human-packaging interaction highly depends on an individual's physical and cognitive capabilities (Lorenzini and Olsson, 2019). PAPER V listed the determining variables of Innovativeness, Knowledge & Experience, and Self-efficacy belonging to the individual attributes and beliefs categories as the top 10 external factors of NFC technology acceptance in product packaging (see Table 25). Individuals with a higher level of innovativeness might be more willing to interact with new technologies and develop more positive perceptions about them (Liébana-Cabanillas et al., 2020). Likewise, the decision-making process of whether to interact with the technology or not highly depends on an individual's prior knowledge and experiences with that system (Bettman and Park, 1980). Therefore, the more knowledgeable about the digital interactive system individuals are, the more willing they will be to perform continuous interaction with it (De Canio et al., 2021). Consequently, when designing smart interacting packaging, the developers must address the level of personal innovativeness and the possessed prior knowledge and experience of their target audience. These results concur with the findings from PAPER IV, concluding that consumers lack knowledge about the technologies around them, thus, consumer education and knowledge are inherent parts of technology adoption (Pham and Ho, 2015). Businesses have to make an effort to educate their consumers about the embedded technologies in their products and how to use them.

Moreover, only consumer awareness of the incorporated technologies might not facilitate engagement with smart objects. Based on the findings of PAPER V, motivation is one of the most influential categories of NFC technology acceptance, listing Perceived Enjoyment, Satisfaction, and Perceived Value in the top 10 impactful external variables (see Table 25). As stated in PAPER II, the interactive system has to trigger stronger emotional and memorable reactions to maintain the continued use of technology, therefore perceived enjoyment and satisfaction are substantial intrinsic factors for consumer motivation to engage with a digital interactive system for entertaining and exciting interplay (As'adi et al., 2021). The NFC-enabled system with potential connectivity and interactivity is able to grant consumers a degree of enjoyment, pleasure, and fun (De Canio *et al*., 2021). Findings from PAPER III agree with the statements and claim that attached wireless communication technologies to product packaging create unique experiences and entertaining tools for shoppers to engage with. Furthermore, the individual's desire to engage with the ICT system is driven not only by utilitarian intrinsic factors but by hedonic extrinsic factors as well. PAPER V concludes that "the continuous and enhanced use of the interactive system is also driven by an implied benefit upon completion in the form of a specific reward, such as customized offers, gaming tokens, or extra loyalty points". Therefore, extrinsic motivation elements in the form of diverse rewards must be incorporated into the smart interactive packaging design.

Furthermore, Perceived Privacy and Security was also assessed as the top 10 external most impactful factor of NFC technology acceptance. The developers have to be particularly careful not to overstep the personal boundaries of individuals and not to interfere with their willingness to share personal information over the internet or raise security concerns and risks from the use of the internet (Dinev and Hart, 2006; Nor et al., 2011). The information about the interaction's security and privacy has to be well communicated and guaranteed.

The package

As stated in PAPER II, product packaging with embodied communication technologies becomes a hybrid digital-physical object with abilities to detect, track, communicate, and apply scientific logic due to the incorporated passive and active electronics and smart materials. As a result, the users will no longer only interact with the physical packaging material, such as cardboard, plastic, or glass, but also with the attached technologies (Petrelli, 2017). Thus, it is significantly important for developers to obtain a complete overview of potential technologies that could be embedded in the packaging design. Research Study 3 presented a comprehensive list of potential technologies for smart interactive packaging applications that could be taken as a point of departure when beginning the transformation from passive to interactive packaging. Furthermore, PAPER III presented an exhaustive list of technological capabilities of NFC attached to product packaging, expanding the traditional perception of primary packaging functionalities, specifically the communication function of packaging.

Consequently, the performance and technical characteristics of the embedded technologies become additional points for consideration when designing smart interactive packaging. PAPERS III and IV concluded with a list of potential technology-centered barriers impacting the success of user-packaging interaction, including the position of the active device – passive NFC tag, transmission speed, device compatibility with NFC, the current status of the device's operating system, and other. As a result, the computational device possessed by the user also becomes a part of the digital interactive system since no interaction would happen without the presence of a user's personal mobile device. The developers have to be aware of personal technologies owned by their consumers and whether they can effortlessly and intuitively initiate the interaction.

PAPER IV presents an in-depth description of the design of smart interactive packaging that can be seen as an example of what relevant digital and physical element designers should take into consideration when creating enhanced packaging applications.

Finally, based on the analysis performed in PAPER V, Perceived Quality (of the information provided by the smart object) is one of the ten most impactful factors of NFC technology acceptance. The user's judgment about the product's excellence directly influences the technology's perceived value (Han et al., 2016; Zeithaml, 1988). Therefore, the developers have to maintain proper information diagnosticity, ensure information availability and reliability, and provide information integration and consistency (Daoud and Trigui, 2019; Aldughayfiq and Sampalli, 2021; Park and Kim, 2021). Furthermore, the other seven external variables were included in the extended TAM model for investigating the adoption of NFC technology in packaging, including Technology Accessibility, Interactivity, Mobility, Intuitiveness, Facilitated navigation, Trialability, and Performance. More thorough descriptions of each determinant can be found in PAPER V.

The task

The third critical element of smart interactive packaging design stated in PAPER II is a set of actions that have to be accomplished by the users to reach the final aim (de la Fuente et al., 2015). Since the smart interactive packaging is supplemented with a wide range of additional elements, the list of traditional human-packaging activities broadens, and users are asked to perform various mediated interactions (tasks) with the package (Petit et al., 2019). PAPER III presented a list of initial insights into technology-oriented barriers impacting the success of user-packaging interaction related to additional actions needed for changing various settings of the mobile device, obtaining third-party apps, and updating the mobile device's operating system in order to be able to interact with the embedded technologies. Afterward, a more comprehensive insight into activities during the user-packaging interaction was provided in PAPER IV in the form of an instruction sheet of the NFC working principle and the steps of the experiment process related to the interaction with NFC-enabled packaging. Based on PAPER IV findings, the experiment participants agreed that providing instructions with the predefined course of action helped them successfully finish their interaction with the product package. Therefore, until NFC technology will become widely known and adopted, there is a substantial need for provided instructions for consumers on how to interact with NFC-enabled packaging. Furthermore, the identification mark of NFC placed on the package facilitates and expedites the interaction leading to a positive outcome. As a result, every NFC-enabled product packaging must contain an identification sign of where the users are expected to tap on their mobile devices.

The context

The final significant element of smart interactive packaging design is the context, where human-packaging interaction occurs. The design of enhanced packaging has to take into consideration the environment and its surroundings, where users will engage with the package. Regarding PAPER III, the selection of technological capability to be implemented in NFC highly depends on the context where the user will interact and benefit from the package, i.e., the nature of technological capability determines the touchpoint of interaction and vice versa. Moreover, PAPER V listed Social Influence and Social Norms, and Perceived Compatibility belonging to social context and facilitating conditions categories as the top 10 external factors of NFC technology acceptance in product packaging (see Table 25). Social influence addresses the user's intention to use the technology based on the influence of other people (Chen and Chang, 2013). As a result, the willingness to interact with the NFC-enabled packaging in store might be increased due to the group-engaging activities. Facilitating conditions are defined "as the degree to which an individual believes that an organizational and technical infrastructure exists to

support the use of the system." (Venkatesh et al., 2003). Therefore, for a successful user-packaging interaction, brands and retailers must ensure that the necessary resources are provided to the user, such as the quality of the Wi-Fi connection or a link to download a NFC reading app.

Table 26. Descriptions of criteria used in MCDA (adapted from PAPER V)

THE CONSUMER	THE PACKAGE	THE TASK	THE CONTEXT
Relations to findings from other appended papers: ▪ PAPER I: a comprehensive list of packaging features and sub-functions regarding the consumer-oriented strategy ▪ PAPER III: a list of consumer-oriented benefits for motivation to engage with smart interactive packaging ▪ PAPER IV: consumer education and knowledge are inherent parts of technology adoption ▪ PAPER V: in a list of the top 10 most impactful external variables related to consumer: - Innovativeness - Knowledge & Experience - Self-efficacy - Perceived Enjoyment - Perceived Value (extrinsic rewards) - Satisfaction - Perceived Privacy and Security	Relations to findings from other appended papers: ▪ PAPER I: expanded the notion of primary packaging functionalities due to embedded smart technologies ▪ Research Study 3 (RQ3): a list of potential for smart interactive packaging applications ▪ PAPER III: a thorough list of technological capabilities of NFC attached to the packaging ▪ PAPER IV: an in-depth description of the design of smart interactive packaging, including relevant digital and physical elements ▪ PAPER IV: insights into technology-related barriers impacting the success of user-packaging interaction ▪ PAPER V: in a list of the top 10 most impactful external variables related to the package: - Perceived Quality	Relations to findings from other appended papers: ▪ PAPER III: insights into technology-oriented barriers impacting the success of user-packaging interaction related to additional actions needed for changing various settings, obtaining third-party apps, updating the OS ▪ PAPER IV: a comprehensive list of activities during the user-packaging interaction to successful completion of the task, including: - Instruction sheet of NFC working principle - Steps of the experiment process related to the user-packaging interaction	Relations to findings from other appended papers: ▪ PAPER III: the selection of technological capabilities depends on the context of the packaging that will be used ▪ PAPER V: in a list of the top 10 most impactful external variables related to context: - Social influence and Social Norms - Perceived Compatibility

5.2. Theoretical implications

Since PhD research is highly based on a meta-analytic approach, a number of theoretical implications have been established to address the identified research gaps in the theory section. First of all, drawing on the current model of the primary packaging functions (Rundh, 2005; Loucanova et al., 2017; Lindh et al., 2016; Underwood, 2003), the PhD research proposed an updated model considering the impact of technological capabilities and affordances provided by the smart packaging types. The need for a new model of the primary packaging functions is driven by the obsolete perception of the main packaging roles considering only the static passive product packaging. Furthermore, the PhD research also proposed a distinctive classification of smart packaging types, clearly identifying the differences among them, since the literature on smart packaging contains discrepancies and inconsistencies in smart packaging descriptions. Finally, the proposed classification of smart packaging functions and the proposed updated model of packaging functions were merged together to demonstrate the coherence between them.

The motivation for PhD research was driven by the scarce amount of research on smart interactive packaging and its comprehension as a digital interactive system. In the literature on packaging science, packaging was still mainly understood as a static and passive part of a product. Therefore, PhD research

distinctly elaborated on the perception of smart interactive packaging as a cyber physical object through the lens of human-computer interaction, interaction design, user-centered design, and usability theories. In relation to these theories, smart interactive packaging consists of three interacting agents, namely human agent, computational agent, and cyber-physical agent, and four critical elements, including consumer, package, task, and context, that are significantly important to address when designing enhanced consumer engagement through the product packaging. Furthermore, the PhD research expanded the traditional understanding of human-packaging interaction by reflecting on the complex relationship between user behavior and enhanced packaging, i.e., where people are asked to perform various mediated interactions with the package (Petit et al., 2019).

PhD research identified the lack of research on NFC applicability to product packaging, none of the existing studies has investigated NFC technology as a potential tool for consumer enhancement and engagement in store and at home. The research related to NFC is limited to only a small number of studies investigating NFC as a way to communicate information from sensors for monitoring and tracking applications (Escobedo et al., 2017; Zhang et al., 2017; Li et al., 2018; Nguyen et al., 2019; Barandun et al., 2019). As a result, the PhD study proposed a comprehensive overview of smart interactive packaging as an extended user interface – a touchpoint for visual, tactile, and digital interaction with consumers driven by the digital capabilities and affordances of NFC technology.

Finally, the PhD research proposed an extended TAM model in combination with seven other prevailing technology acceptance theories and models, including the Multi-level Framework of Technology Acceptance and Use, United Theory of Acceptance and Use of Technology, Protection Motivation Theory, Motivation-opportunity-ability Theory, Uses and Gratifications Theory, and Engagement Theory, to investigate the technology acceptance of NFC in product packaging. The proposed model can also be used to examine the adoption of other smart consumer interactive technologies, such as Augmented Reality, mobile applications, or QR codes. Since the model consists of 45 variables classified into 13 groups, multiple variations of the model are possible.

5.3. Empirical implications

Based on the PhD research findings, several empirical implications are discussed in relation to the successful development of smart interactive packaging applications. First, the enhanced packaging design must be highly oriented toward the consumer. Businesses have to rethink their packaging policies, manufacturing processes, and consumer outreach in order to become more consumer centric. The current situation, where the most central department that focuses on creating value for consumers is marketing, has to change and become holistically applied across the entire departments of the company. It is essential to influence the leaders in companies to have packaging on the agenda. For enhanced human-packaging interaction, consumers need incentives to take their mobile devices out of their pockets and initiate the interaction. Furthermore, appropriate infrastructures must be established and supported. As a result, the consumer motivation to act could be induced by creating personalized, secure, transparent, and sustainable interactions with product packaging. By combining hardware and software, businesses are able to create a unique communication channel allowing for new types of storytelling and one-of-a-kind “phygital” user experiences. Furthermore, as expressed earlier, consumer education on how to engage with technologies highly influences their willingness to interact.

Due to the digital transformation induced by the embedded computing devices into packaging design, the packaging becomes an analog proposition of a digital world. Consequently, smart interactive packaging creates a new channel to transform products into a digital platform and opens a new dimension to the collection and delivery of data, which can then be used to enable new product development, provenance, authentication, supply chain security, and consumer engagement. Due to the digital transformation, packaging provides a possibility to connect with the consumers at the item

level even after it has been bought and brought to the consumers' homes. Smart interactive packaging allows brands to engage with their consumers at the point of use, building real-time data to make fact-based decisions, such as automatic order of products that are about to run out.

On the other hand, while attempting to create satisfying interactions for consumers, businesses have to ensure that some sort of commercial value is created for their operating model as well and that a built digital experience becomes an additional source of income besides the physical product price. In other words, businesses have to find new ways of monetizing the data based on developed digital user-packaging interaction. Furthermore, the implementation of connected packaging reduces the scalability and the financial incentives to produce counterfeits and, thereby, permits brands to operate fully transparently by storing product data on the blockchain, where information can be constantly and automatically updated and shared among supply chain stakeholders. As a result, connected packaging can help to drive business goals.

5.4. Limitations and further research

Although this PhD project has identified several prerequisites to answer the research objective and thereby provided a number of theoretical and empirical contributions, the study is not without limitations.

First, the research scope was limited to investigate only the primary product packaging that is in direct contact with the end user at the point of purchase and at the point of consumption or utilization, i.e., in-store and at-home environments. The secondary and tertiary packaging for the rest of the supply chain operations were not taken into consideration or discussed in this research. However, the majority of the identified technologies operates and provides benefits throughout the entire supply chain. Further, the study only considered the smart interactive packaging type that focuses on the enhancement of the communication and interaction functions. No in-depth exploration of other smart packaging types was performed in relation to a vast number of existing studies on these topics. Also, the research particularly underlined the smart interactive packaging's ability to enhance consumer experience and product functionality with less emphasis on business benefits and induced business model innovation.

Second, the research is highly oriented toward the consumer element. Based on the presented four elements framework of smart interactive packaging design, most research activities conducted were related to consumer experience and packaging design, having a lesser emphasis on interaction tasks and context where the interaction takes place. Further research is needed to explore all the mediated interactions, i.e., additional steps, more comprehensively to identify where consumers struggle the most in the human-packaging interaction in order to eliminate the design flaws and facilitate engagement. Moreover, performed research activities via usability testing did not address the impact of the context where the user-packaging interaction takes place. Therefore, further research is needed to test the designed artifact of smart interactive packaging in the real-world environment, i.e., in the store.

Third, the research concluded with the meta-artifact – the designed extended TAM model for investigating the adoption of NFC technology in packaging and did not provide empirical evidence for the experimentation phase 3. However, to answer the research objective to the full extent, the completion of the final design cycle is needed. Therefore, further studies can utilize the proposed extended TAM model for investigating the adoption of NFC or any consumer interactive technology in-store performing a more profound statistical analysis of the findings by examining the reliability of the measurement and structural models.

6 Chapter - Conclusion

In this PhD thesis, the digital innovation in product packaging for enhanced consumer experience and product functionality has been explored and explained, providing the holistic understanding of smart interactive packaging as a digital interactive system that goes beyond the long-established perception of human-packaging interaction and grants access to an extended user interface. Overall, the synthesis of five appended papers provided an extended summary, addressing the main research objective.

The PhD study has introduced an updated model of the main packaging functions taking into consideration the additional capabilities and affordances imparted by the development of smart packaging types. The proposed model consists of four functions: protection, convenience, communication, and interaction. The latter replaced the long-standing functionality of containment. The authors argue that the concept of containment is in line with the definition of packaging that stems from the noun “container”, which is a synonym for the noun “package”. Furthermore, the developed model demonstrates how the main functions are related to proposed smart packaging types, i.e., the type of smart packaging is assigned based on which functionality it enhances. As a result, the emergence of new enhanced forms of packaging changed the traditional comprehension of the packaging role and its functionalities, opening a broad range of opportunities for diverse stakeholders in the supply chain.

Moreover, the PhD research has addressed smart interactive packaging as a “non-conventional” element of computer and mechanical systems and refers to it as a digital interactive system consisting of a human agent, computational agent, and cyber-physical agent, i.e., a physical world object with embedded electronics. In relation to the theory of interaction design, it is essential to design ICT systems comprehensively, elaborating on the critical elements of the digital interactive system and addressing the main design concerns originating from human-computer interaction, user-centered design, and usability theories.

Furthermore, numerous technologies can be incorporated into product packaging for enhanced consumer experience and product functionality. Therefore, this PhD thesis presented an overview of the most nascent materials, devices, computing systems, and manufacturing techniques that can be embedded, attached, laminated, incorporated, or directly printed onto the packaging design, and thereby, contribute to the emergence of new forms of packaging. The comprehensive list of potential technologies for smart interactive packaging can be taken as a point of departure when initiating the transformation from passive to interactive packaging.

Particularly, in this PhD study, the potentials of NFC technology for product packaging applications have been thoroughly explored. The conducted research elaborated on NFC’s technological capabilities and benefits related to enhanced consumer, retailer, and brand experiences, as well as identified potential technology- and consumer-oriented barriers that might hinder the coherent interaction with the NFC system.

The identified technical- and user-related barriers negatively impacting consumer interaction with NFC technology have laid the foundation for user experimentation through usability testing with NFC-enabled product packaging. The experiment activities were divided into three phases, where the pre-test and pilot test were performed, followed by the proposition of a theoretical model of technology acceptance for further studies. The results from the experiments shed light on potential variables determining the consumers’ perception and willingness to adopt the NFC technology in product packaging applications.

The PhD dissertation concluded with the developed extended TAM model and the assessment of the most impactful variables of NFC technology acceptance in product packaging applications based on a

meta-analysis of the primary studies. The most influential external variables belong to the following categories: motivation, perceived credibility, social context, individual attributes and beliefs, and facilitating conditions. As a result, the successful and engaging human-packaging interaction is significantly driven by intrinsic and extrinsic motivational incentives the users can obtain from the interaction. Furthermore, the secure, private, and trustworthy collection and processing of personal data have to be ensured and clearly communicated to the user. The prior experience and knowledge, as well as the cognitive capabilities of individuals, highly impacts their willingness to interact with enhanced packaging.

Finally, advances in smart interactive packaging enable brands to interact with consumers in novel and revolutionary ways both at the point of purchase and at the point of consumption or utilization of the product at home. New insights provided by the PhD research of consumer packaging as a digital interactive system are expected to have substantial implications for brand owners and retailers that target to uplift their consumer engagement and create memorable, long-lasting connections that would facilitate the recurrent use of their products. Packaging is no longer received as a separate part of the product, with embedded computing systems, packaging becomes an integral part of it, therefore the added digital capabilities and affordances from integrated technologies at the same time increase the number of product functionalities as well. Smart interactive packaging is expected to bring strategic value for businesses by creating new forms of interaction t with purchased goods through embedded digital innovations that might turn into unique business models for improved consumer experiences and product functionalities.

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Appended papers

PAPER I:

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PAPER I

Smart packaging: Definitions, models and packaging as an intermediator between digital and physical product management

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Smart packaging: definitions, models and packaging as an intermediator between digital and physical product management

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ABSTRACT

The purpose of this paper is to examine the traditional 'contain–protect–communicate–facilitate convenience' model of the main packaging functions, to revise each component of it in relation to packaging strategies and smart packaging applications, and to establish a new model of the main packaging functionalities concerning the analysed data. The scientific approach of this paper is twofold: it is based on an extensive literature review focused on articles related to packaging science and on a set of empirical observations from industrial cases of enhanced packaging with a higher emphasis on interactive packaging. The key findings of this paper are the two principal purposes of smart interactive packaging: (1) to enhance the product's functionality or experience in order to serve its primary initial purpose more effectively and (2) to improve consumers' experiences through engagement and entertainment in both the retail and the usage environment. This paper proves its originality by considering shifts in technological opportunities in packaging to assure a broader range of design options in packaging and engagement, thereby leaving packaging as static item. Also, bridging the general consumer experience between digital marketing and physical shopping using packaging is a novelty in retailing and brand management. This research is in its early stages and limitations are given from the modest proliferation of smart and interactive packaging into empirical contexts. New technologies of packaging and the design decisions are expected to have significant practical implications for brand and retail managers as well as consumers.

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Introduction

The history and development of packaging began with the primary need for containment (Clarke 2008). From its earliest forms as leaves, hollowed-out tree limbs, straw, and skins, packaging has developed, become more sophisticated, and improved to meet the specific needs of product handling (Raheem 2013). Consequently, packaging has become an integral and inseparable part of every product-based company's business model (Chan, Chan, and Choy 2006). In traditional terms, conventional packaging was intended as a means of containment, protection, and preservation (Loucanova,

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Supplemental data for this article can be accessed here

Kalamarova, and Parobek 2017). Generally, according to the previously mentioned theorists, packaging has always served its practical function of holding goods together and protecting them during the supply chain until the goods reach the end user. However, the importance of packaging has increased over the last decades. Increased industrial utilisation and advanced technologies have influenced the change and enhancement of primary packaging functions (Nandanwade Priyanka and Nathe Parag 2013). Due to recently developed nanoscale-nature substances and composites, the two main packaging functions of 'protect' and 'preserve' have been significantly improved, whereas high-performance computing devices have enhanced the 'communication' function. Therefore, the traditional passive packaging is facing alternatives and more advanced forms of packaging are being introduced to the market and becoming an improved asset for brand and consumer communication (Lydekaityte and Tambo 2018). Generally, smart packaging is divided into three main categories: active packaging, intelligent packaging, and interactive packaging (Loucanova, Kalamarova, and Parobek 2017; Schaefer and Cheung 2018).

As the history and development of packaging shows, technology is the key driver of and contributor to the growth of the enhanced packaging industry. Nonetheless, this development is also highly stimulated by the growing interest in sustainable development (Bradley, Castle, and Chaudhry 2011). Likewise, since the industry is moving from the information age to the communication and interaction age, traditional marketing and advertising approaches are becoming less effective. Therefore businesses prefer live consumer interaction and engagement with their brand, which can be achieved well through the product's packaging, especially when packaging is kept in consumers' homes and thus becomes part of their lives (Sudbury-Riley 2014).

Consequently, the key driver of the emergence of enhanced packaging is the need to develop more innovative and intelligent approaches to packaging due to growing competitiveness, rising ways of digital interaction, changes in consumer behaviour and demand, increased interest in product security, increased consumer awareness of environmental impacts, and others. Therefore the purpose of this research is to examine the traditional 'contain–protect–communicate–facilitate convenience' model of the primary packaging functions in order to revise each part of it in relation to packaging strategies and smart packaging types. It is essential to (1) determine, refine, and assess the main packaging functions, (2) investigate environment-, marketing-, and consumer-related packaging strategies, and (3) define the most common types of smart packaging. Consequently, the main contribution of this study is an established new model of the main packaging functionalities with respect to the investigated packaging strategies and the capabilities of smart packaging types.

In brief, the importance of this research relies on its contribution to the literature of packaging science by identifying the existing gaps and presenting a revised model of the roles of packaging. It also connects to current discussions and theorising in packaging subfunctions related to the environment, marketing, and consumers, which results in new forms of (digital) smart packaging being introduced to the market not only to enable brands to engage with their consumers better but also to develop new business models. As a result, practitioners might benefit from this research by revising their packaging strategies and preparing for the years to come. Furthermore, this study investigates the state of the art of digital transformation from passive packaging to Internet-connected, which leads to novel consumer experiences and interactions with products/brands through the packaging.

Methodology

At the moment, the model of the primary packaging functions is well established from a passive packaging perspective and either does not include or only to some extent covers the phenomenon of smart packaging, as seen in the following literature (Underwood 2003; Rundh 2005; Ampuero and Vila 2006; Ford, Moodie, and Hastings 2012; Ryynänen and Rusko 2015; Lindh et al. 2016). Since the majority of research is carried out concerning active and intelligent packaging applications (Mumani and Stone 2018; Asgari, Moradi, and Tajeddin 2014; Raheem 2013; Biji et al. 2015; Brockgreitens and Abbas 2016; Loucanova, Kalamarova, and Parobek 2017; Wyser et al. 2016; Bradley, Castle, and Chaudhry 2011), the scientific literature has only considered the influence of these types of packaging on the model of the main packaging functions. However, the improved functionality provided by ergonomic and interactive packaging is not discussed on a research level. Therefore this study emphasises the potential of smart interactive packaging in regard to both design-based and technology-based interaction. For instance, much literature (Sudbury-Riley 2014; Westerman et al. 2013; Underwood 2003; Rundh 2005; Ford, Moodie, and Hastings 2012; Ryynänen and Rusko 2015; Ampuero and Vila 2006) has researched the design-driven improvements of enhanced packaging, whereas only some (Unander, Nilsson, and Oelmann 2007; Shah, Prajapati, and Agrawal 2010; Olsmats 2017) include the feasibility of enabling technologies incorporated into packaging design. As a result, this work encompasses and investigates every aspect of interaction created by various graphical, structural, or technological approaches with a greater emphasis on the last. Furthermore, the study examines smart packaging applications with enhanced functionality at the point of purchase in the retail environment and at the point of utilisation in the consumer's home.

The main outcome of this paper is expected to be a new model of the main packaging functions based on the investigated packaging features and sub-functions retrieved from marketing-, environmental-, and consumer-oriented strategies regarding smart packaging applications.

This paper is based on an extensive literature review focused on articles related to packaging science and employs a set of empirical observations, listed in Table 1, from industrial cases of every type of enhanced packaging, with a greater emphasis on interactive packaging. These cases have been developed in terms of data collection from unstructured interviews with companies' representatives during industrial events, product datasheets, and technical reports, press releases, and test kits provided by the companies. It is essential to combine the current theoretical knowledge from the scientific literature with the empirical world in order to expand the understanding of both theory and empirical phenomena (Dubois and Gadde 2002).

Moreover, this study pursues a meta-analytic approach to ensure a rigorous methodological position. This is relevant when the researcher wishes to bring together the data from many studies derived from similar research designs (Siddaway, Wood, and Hedges 2019). One of the functions of the meta-analytic method is to identify patterns across primary qualitative studies (Levitt 2018) which is directly linked to the main purpose of this study, that is, to determine repetitive keywords related to packaging functionalities, features, and strategies in the existing literature on packaging science (Table 1).

Table 1. The summary of observed empirical cases of smart packaging technologies.

Empirical cases of smart packaging	Short description of the cases	The developer
WikiCells packaging	Packaging shells for food to be consumed together with the product it contains	Harward University
Hangerpack	Cardboard packaging for shipping clothes that transforms to a hanger	Steve Haslip
SaralLight®, Saralllu®, SaralOLED® and SaralSecurity®	Cardboard packaging with printed electronic devices, as LED, circuits, batteries, sensors, touch pads for enhanced consumer experiences	Saralon GmbH
Ribbon Magic Bow campaign	Bottle's label that can be transformed into a ribbon for marketing and branding campaign	Coca-Cola®
Beer Packaging	Cardboard packaging that transforms to a board game with bottle caps used as game tokens to enhance product consuming experience	Corona
OpenSense™ and SpeedTap™ NFC tags	Wireless communication tags for packaging to prevent refills, counterfeiting, facilitate authenticity and combat grey markets	Thinfilm
Smart Cap	Bottle lid with integrated sensors, tags, batteries, LED and etc. to measure the liquid capacity and inform the user, e.g. to stay hydrated	WaterIO
Right moment campaign	Cans with printed thermos-chromatic ink to inform users when is the best time to consume the product	Coca-Cola®
Electrochromic displays (EC)	Packaging with EC displays combined with motion, temperature, touch or proximity sensors improves track&track, cold chain, and security	Ynvisible
Digimarc Barcode	The machine-readable Digimarc Barcode contains data about the product for better transparency, brand protection, consumer loyalty	Digimarc

In order to accomplish the set aims of this research, this work is planned as follows. Firstly, this paper approaches the traditional 'contain–protect–communicate–facilitate convenience' model of packaging functions and collects the data from the various related works in the scientific literature to identify both common and more contemporary roles, features, and strategies of retail packaging. The analysis is given in Appendix 1 and Figure 1. Then, this study

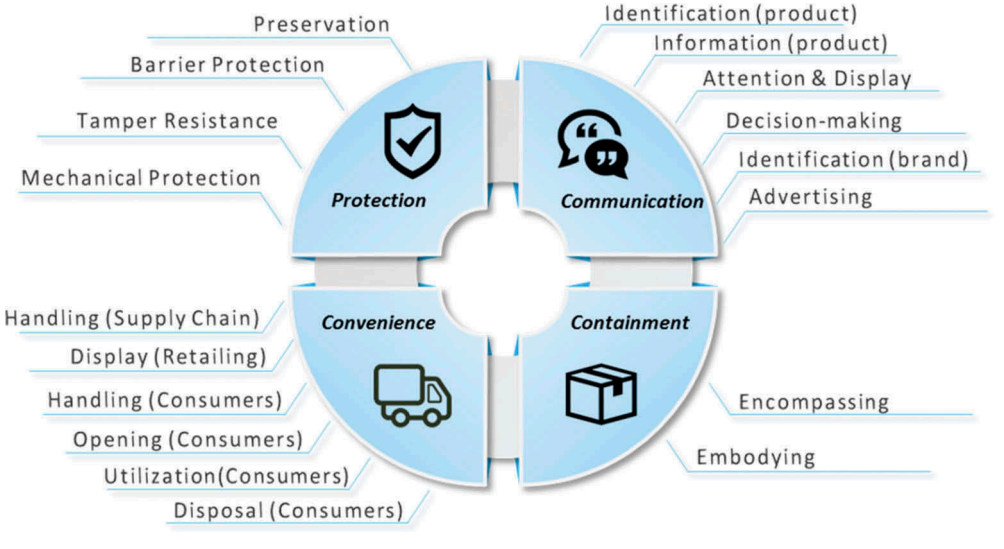

Figure 1. Model of the main functions and features of traditional primary packaging.

investigates the influence of environment-, marketing-, and consumer-related concerns linked to the primary product's packaging based on the keyword analysis of the scientific literature presented in Tables 2–4. Moreover, in the discussion section, this study creates a link between (i) researched features and sub-functions of packaging strategies, (ii) primary packaging functions, and (iii) smart packaging, arguing that there is a strong correlation between all these factors. Finally, the new model of the main packaging functions in relation to smart packaging is proposed and illustrated in Figure 2.

Theoretical background

In this section, descriptions of the primary packaging functions will be given. This section includes a brief historical overview from passive to smart packaging including active, intelligent, ergonomic, and interactive packaging, with a stronger emphasis on the last.

The main functions of passive traditional packaging

Generally, traditional packaging has always served a practical function of holding goods together and protecting them during the supply chain until the product reaches the end user. In the literature, research (Loucanova, Kalamarova, and Parobek 2017; Ampuero and Vila 2006; Underwood 2003; Lindh et al. 2016; Mumani and Stone 2018) has dealt with packaging functions and roles classification in several ways. For instance, considering conventional packaging, Lindh et al. (2016) identified from the literature three main packaging functions: to protect, to facilitate handling, and to communicate. Ampuero and Vila (2006), on the other hand, describe packaging as a container that not only holds, protects, and preserves the goods inside but also identifies the product and facilitates handling and commercialisation, and therefore the term 'convenience' during logistics, retailing, and consumption was added to the traditional perception of packaging. Moreover, Underwood (2003) expands the definition of product identification and states that the traditional role has been to contain, protect, and deliver the product to the retail shelf as well as to attract consumers' attention, impart a strong, distinctive brand identity, and communicate the brand's value. All the otjer functionalities can be more generally defined as the communication function of the packaging (Mumani and Stone 2018). Although several authors include the preservation function in the traditional packaging model, Lindh et al. (2016) argue that preservation is a part of the protection function and applies only to food-containing packaging. To summarise, the packaging functions most commonly mentioned by the authors include protection, communication, convenience, and containment, which aligns with statements provided by Loucanova, Kalamarova, and Parobek (2017), Paine (1991), Robertson (2005), Yam, Paul, and Joseph (2005), Paine (1991), and Robertson (2005). A great example to reflect upon the main functions is a typical carton of milk: the plastic-lined paperboard provides an effective barrier that both protects the milk from the outside environment and keeps it fresh. The carton box communicates with the end user with printed branding, nutritional, and consumption information. Finally, the carton has an easy-to-open lid designed for smooth pouring that offers convenience. Brief descriptions of the main four functions of the packaging are giving below together with Figure 1.

Table 2. Packaging features and sub-functions regarding the environmental strategy of packaging.

Features	Sub-functions and sub-features of Packaging	References
1. Nature of packaging materials	Ecological, biodegradable, recyclable,	Loucanova, Kalamarova, and Parobek (2017)
	produced from friendly materials	Clarke (2008)
	renewable, reusable, reasonable	Raheem (2013)
	biodegradable, sustainable, biocompatible pack materials	Bradley, Castle, and Chaudhry (2011)
		Brockgreitens and Abbas (2016)
	biodegradable materials	Nilsson et al. (2012)
	utilize renewable biodegradable materials	Nilsson et al. (2012)
	environment impact by production and material sources,	Rundh (2005)
		Rundh (2005)
	ensure recyclable materials	Lindh et al. (2016)
	develop renewable materials for sustainability requirements	Nilsson et al. (2012)
		Rundh (2005)
	recyclable, lightweight, degradable materials	Underwood (2003)
	minimal use of hazardous substances	
	reducing or eliminating the use of harmful chemicals	
	risk assessment to human and environment	
	ecologically-, environmentally-friendly 'green' packaging	
2. Facilitated Recycling	Facilitate recycling	Loucanova, Kalamarova, and Parobek (2017), Bradley, Castle, and Chaudhry (2011)
	reduce, reuse, recycle	
	recyclability, disposal	Clarke (2008), Nilsson et al. (2012)
	adopt recycling systems	Raheem (2013), Lindh et al. (2016)
	recycling, composting and disposal	Olsmats (2017)
	support recycling industry by using secondary materials	Brockgreitens and Abbas (2016)
		Nilsson et al. (2012)
	reuse and recycle materials, recycling	Unander, Nilsson, and Oelmann (2007)
	appropriately handled and treated at their end of life	Rundh (2005)
		Mumani and Stone (2018)
	good disposal; reopen;	
	increase tendency to recycle empty packages	
3. Waste of materials	Product waste reduction, reduced use of resources	Lindh et al. (2016)
		Nilsson et al. (2012)
	reducing the number of packaging levels	Unander, Nilsson, and Oelmann (2007)
	minimize packaging waste	Rundh (2005)
	address and reduce food waste, reduce material use	Mumani and Stone (2018)
		Mumani and Stone (2018)
	reduce waste by reusing, reduce waste through the entire SP	Olsmats (2017)
		Asgari et al. (2014), Olsmats (2017), Brockgreitens and Abbas (2016),
	good reusal; increase tendency to reuse empty packages	Bradley, Castle, and Chaudhry (2011)
	adopt re-use systems	
	reduce waste	
4. Environment impact	Reduce environment damage, environment pressure	Loucanova, Kalamarova, and Parobek (2017)
		Bradley (2011)
	environmental footprint	Brockgreitens and Abbas (2016)
	concern pollution	Nilsson et al. (2012)
	growing societal concerns about environmental issues	Mumani and Stone (2018)
		Rundh (2005)
	ecological cues, preserve the environment	Underwood (2003)
	increase environmental performance, LCA	Raheem (2013, Bradley (2011), Brockgreitens and Abbas (2016),
	ecological cues (structural, informational, graphical)	
	environmental impact	
5. Sustainable Develop-ment	Sustainability development	Lindh et al. (2016)
	adopt sustainable practices	Brockgreitens and Abbas (2016)
	adopt green marketing strategy, sustainable packaging	Nilsson et al. (2012)
		Unander, Nilsson, and Oelmann (2007)
	env-friendly packaging, eco-labelling	Mumani and Stone (2018)
	efficiently manage sustainability	

Table 3. Packaging features and sub-functions regarding the marketing strategy of packaging.

Features	Sub-functions and sub-features of Packaging	References
1. Attracting attention	Attention	Loucanova, Kalamarova, and Parobek (2017)
	attract attention on the shelf	Ford, Moodie, and Hastings (2012)
	perceived attractiveness of packaging and brand	Ford, Moodie, and Hastings (2012)
	have visual impact on consumer attention, appearance	Rundh (2005)
	draw attention	Ryynänen and Rusko (2015)
	attract attention	Ampuero and Vila (2006), Mumani & Stone (2018)
	attract attention, attract users	Underwood (2003)
	visual attention	Clarke (2008)
	create appeal, presentation	Ford, Moodie, and Hastings (2012)
	encompass aesthetic appeal of pack	Mumani and Stone (2018)
	appeal to users to help product compete with others	Asgari, Moradi, and Tajeddin (2014)
	products presentation	
2. Compe-tition	Unforeseen competition on shelf	Clarke (2008)
	competitive advantage, distinguish from competitors	Ford, Moodie, and Hastings (2012)
	contribute to competitive advantage, matter of competitive adv.	Rundh (2005)
	create and sustain competitive advantage	Rundh (2005)
	provide commercial advantage in the competitive arena	Rundh (2005)
	competitive advantage created by consumer-oriented packaging	Ryynänen and Rusko (2015)
	competition strategy, strategic decision taking competition	Ampuero and Vila (2006), Mumani & Stone (2018)
	help product to compete with others	
3. Communi-cation	Brand communication	Loucanova, Kalamarova, and Parobek (2017)
	communicate brand imagery	Ford, Moodie, and Hastings (2012)
	marketing communication, support market communication	Rundh (2005)
	on point of sale communication, communication medium	Ampuero &Vila (2006)
	communicate brand and product values	Mumani and Stone (2018)
	communicate different messages that affect user perception	Mumani and Stone (2018)
	communicate efforts applied by producers	Underwood (2003)
	achieving sustainability affecting user's perception	Underwood (2003)
	promotional communication, communication vehicle	Underwood (2003)
	communicate product positioning	Ryynänen and Rusko (2015)
	an element of mass-communication in the marketplace	
	everyday negotiation with packaging	

(*Continued*)

Table 3. (Continued).

Features	Sub-functions and sub-features of Packaging	References
4. Promotion and advertising	Promote the product, brand promotion, advertising,	Ford, Moodie, and Hastings (2012)
	promote customer choice, promotion, brand-building	Rundh (2005)
	promotion	Loucanova, Kalamarova, and Parobek (2017)
	sales promotion, promotion, advertising	Ampuero and Vila (2006), Underwood (2003)
	promotional communication, sales promotion	Underwood (2003)
	advertisements, advertising, brand-building mass-media	Unander, Nilsson, and Oelmann (2007)
	advertising	Mumani and Stone (2018)
	perform advertising functions	
5. Marketing, merchandise	Marketing requirements	Loucanova, Kalamarova, and Parobek (2017)
	increase market share	Clarke (2008)
	market, merchandise	Raheem (2013), Biji et al. (2015)
	new product development to open new markets	Bradley, Castle, and Chaudhry (2011)
	the fifth 'p' of the marketing mix	Ford, Moodie, and Hastings (2012)
	effecting marketing medium	Ford, Moodie, and Hastings (2012)
	sell the product through the packaging	Ford, Moodie, and Hastings (2012)
	function as a marketing tool, strategic marketing tool	Ford, Moodie, and Hastings (2012)
	create new market position, marketing tool, marketing strategy	Rundh (2005)
	marketing communication	Rundh (2005)
	marketing strategy, strategic decisions of the marketing mix	Ampuero and Vila (2006), Ampuero &Vila (2006)
	facilitate commercialisation	Mumani and Stone (2018)
	efficiently manage marketing,	Mumani and Stone (2018)
	represent an opportunity to enhance market value of product	Underwood (2003)
	direct marketing, marketing communication,	Underwood (2003)
	3D marketing communication vehicle tangible in nature	Underwood (2003)
	a heightened role in the marketing mix	Ryynänen and Rusko (2015)
	silent salesman, silent salesman decisive feature	Lindh et al. (2016), Asgari (2014) Olsmats (2017), Shah, Prajapati, and Agrawal(2010)
	marketing	

(*Continued*)

Table 3. (Continued).

Features	Sub-functions and sub-features of Packaging	References
6. Product perception	Facilitate recognition	Underwood (2003)
	communicate product positioning, positioning strategy	Ampuero and Vila (2006), Ampuero &Vila (2006)
	communicate product values	Clarke (2008)
	differentiate itself (product) from others (products)	Ford, Moodie, and Hastings (2012)
	distinguish from competitors	Ford, Moodie, and Hastings (2012)
	aid in product differentiation and positioning	Ampuero and Vila (2006), Mumani & Stone (2018)
	increase effective differentiation	Rundh (2005)
	represent an opportunity to enhance market value of product	Underwood (2003)
	reinforce packed products concept	Bradley, Castle, and Chaudhry (2011)
	relate to product performance	Rundh (2005)
	new product development to open new markets, innovation	Rundh (2005)
	create new market position	
	contribute to innovativeness by new solution	
7. Brand	Brand communication	Loucanova, Kalamarova, and Parobek (2017)
	branding experience and communication	Clarke (2008)
	branding	Lindh et al. (2016)
	reflect brands message and identity	Olsmats (2017)
	communicate brand values, brand imagery, identity, promotion	Ford, Moodie, and Hastings (2012)
	brand evaluation	Ryynänen and Rusko (2015)
	live experience between consumer and brand	Ampuero and Vila (2006),
	consumer-brand relationship, brand-building role	Underwood (2003)
	symbolic brand benefits to users	Underwood (2003)
	brand strategy	Underwood (2003)

Table 4. Packaging features and sub-functions regarding the consumer-oriented strategy of packaging.

Features	Sub-functions and sub-features of Packaging	References
1. Intent to purchase	Encourage to buy a product	Olsmats (2017)
	influence purchase, purchase intent	Ford, Moodie, and Hastings (2012)
	intent to purchase, intent to recommend	Ryynänen and Rusko (2015)
2. Decision-making at the store	Consumer decision-making process	Loucanova, Kalamarova, and Parobek (2017)
	visual attributes affect the purchase decision	
	play in consumer decision making	Mumani and Stone (2018)
	buying decisions	Ford, Moodie, and Hastings (2012)
	purchase decision	Rundh (2005)
	moments of true; influence the point of purchase, increase purchase decisions directly in the shop	Ryynänen and Rusko (2015) *Ampuero and Vila (2006)* Underwood (2003)
	in-store decision making; buying decisions at the store	
3. Consumer preferences	Consumer's preferences	Mumani and Stone (2018)
	support user-centered package design	Mumani and Stone (2018)
	increase sales by tailoring design to consumer preferences	Ford, Moodie, and Hastings (2012) Rundh (2005)
	affect customer value	Ampuero and Vila (2006)
	consumer behaviours	
4. Consumer perception	Affect users perception	Mumani and Stone (2018)
	communicate different messages that affect user perception	Mumani and Stone (2018) Ford, Moodie, and Hastings (2012)
	associate psychological values	Rundh (2005)
	change product perception	Ryynänen and Rusko (2015)
	perceived value has an impact on brand evaluation	
5. Consumer-Packaging communi-cation & interaction	Everyday negotiation with packaging	Ampuero and Vila (2006), Ampuero and Vila (2006), Ampuero and Vila (2006), Ford et al (2012)
	provide visual sales negotiation when purchasing and using a product, on point of sale communication	Mumani and Stone (2018)
	build consumer relationships through possession, usage	Ampuero and Vila (2006) Ampuero and Vila (2006)
	human-packaging interaction	
	packaging lives at home;	
	become intimate part of consumer life	
6. Consumer-Brand communi-cation & interaction	A live experience between consumer and brand	Ampuero and Vila (2006), Underwood (2003)
	create and enhance consumer-brand relationship	Olsmats (2017) Ampuero and Vila (2006), Ford et al (2012)
	reflect brands message and identity	Ryynänen and Rusko (2015)
	communicate brand and product values	
	communicate brand imagery	
	brand evaluation	
7. Consumer loyalty	Cement consumer loyalty	Clarke (2008)
	enhance long-term customer loyalty	Rundh (2005)
	build consumer loyalty programs	Nilsson et al. (2012)
8. Consumer segments	Customer segments	Loucanova, Kalamarova, and Parobek (2017)
	target specific consumer groups	Ford, Moodie, and Hastings (2012)
9. Consumer experience	Enhance consumer experience (fulfilment)	Clarke (2008)
	increase customer satisfaction	Ryynänen and Rusko (2015)

Protection function to maintain quality and safety

In general, according to Olsmats (2017), the protection function is used to obviate various deteriorative and contaminating effects of the packaging's external environment. This function aims to maintain the quality and safety of packed goods during distribution, storage, and transportation (Shah, Prajapati, and Agrawal 2010). Rundh (2005) concurs

Figure 2. Proposed model of the main packaging functions in relation to the capabilities and features of smart packaging types.

with these authors and highlights that packaging protects the product during movement and withstands robust physical handling during distribution and storage. Generally, there are several types of methods of providing such protection. Firstly, there are physical, barrier, and thermal types of protection. Packaging has to be designed to ensure mechanical strength and shatter resistance (Raheem 2013) in order to prevent damage from external effects (Mumani and Stone 2018). According to Olsmats (2017), this includes protection against mechanical shock, vibration, electrostatic discharge, compression, and temperature. Moreover packaging has to be impermeable to light, moisture, bacteria, gases, and vapours; that is, it has to act as a barrier to various physical, chemical and microbiological attacks (Rundh 2005). Secondly, packaging has to provide security and therefore tamper-evident packaging is an efficient method of protecting manufacturers, retailers, and consumers from product tampering, pilferage, and theft (Olsmats 2017).

Preservation function to maintain quality and prolong shelf-life

Preservation aims to maintain product taste and texture, to preserve food against spoilage, and to prolong its shelf life (Asgari, Moradi, and Tajeddin 2014). Many products we enjoy today would not exist without the possibility of preservation (Clarke 2008). Regarding food packaging, various chemicals, agents, and composites are added to polymeric films not only to preserve the food but also to maintain quality, reduce food waste, and increase efficiency. In addition, Asgari, Moradi, and Tajeddin (2014) affirm that technologically preserved products are easier to transport and handle since they are less sensitive to environmental conditions and have a longer shelf-life. As a result, they help reduce the amount of waste. However, in this work, the preservation function is considered as a part of the protection function and is not distinguished as a separate role of packaging.

Communication function to identify, inform, and advertise

Underwood (2003) describes packaging as a means of communication to deliver messages about the product through various graphical cues that affect consumers' perceptions. The package design communication may transmit such messages for various purposes. Based on the collected literature, the main aims of the packaging communication function are to (i) identify the product, (ii) inform about the product, (iii) attract attention, (iv) persuade the consumer to purchase the product, (v) identify brand values, and (vi) advertise and promote the product and the brand. First of all, the packaging is a part of a product, and thus it becomes a powerful vehicle for product identification, presentation, and display (Ampuero and Vila 2006; Ford, Moodie, and Hastings 2012). From the very first moment the consumer takes a glance at the packaging, it instantly imparts recognition of the packed good (Rundh 2005). Then, graphical communication by the packaging also creates differentiation and visually distinguishes the product from others (Ampuero and Vila 2006; Underwood 2003). Moreover, product identification is tightly related to product perception. Therefore Ampuero and Vila (2006) and Ryynänen and Rusko (2015) refer to packaging's capability to communicate, denote, and justify the quality of the product.

Secondly, communication is an information transmission asset, and thus packaging communicates various informative messages to consumers during the entire life-cycle of the packaging. Several authors agree (Asgari, Moradi, and Tajeddin 2014; Brockgreitens and Abbas 2016; Wyser et al. 2016) that in the purchase situation, packaging contains such information that affects the consumer decision-making process to buy the product, such as the expiration date, nutritional value, flavour, health, wellness, or level of sustainability. Then, packaging further communicates additional messages to the user once the packaging is bought and brought home, that is, in the usage situation. Usually, it informs the consumer how to properly handle the packaging with regard to transportation, storage, opening, and disposal (Asgari, Moradi, and Tajeddin 2014; Olsmats 2017; Mumani and Stone 2018). Authors also emphasise that packaging also plays an instructive role and provides detailed product-related information concerning how to consume and utilise the goods inside the package.

Thirdly, in the retail environment, visual awareness is critical to attract consumers' attention, which in turn may result in the momentary and instantaneous desire to buy the product. Consequently, to maintain the company's competitive advantage, various forms

of visual communication are utilised directly on the package exterior. First, Ryynänen and Rusko (2015) state that packaging triggers a direct conversation with consumers through various graphical and structural attributes like colour, typography, illustrations, and form and shape of the packaging. Then symbolic negotiation takes place regarding whether to buy the product or not. The visual and tactile interplay between the consumer and packaging produces emotions and associations that further influence and frame the consumer's perception of the product (Mumani and Stone 2018) and reinforce brand benefits (Underwood 2003). To sum up, packaging communicates visual attributes to attract attention and influence the consumer's perception of the product and its quality, which persuades the consumer to purchase the product.

Underwood (2003) claims that packaging conveys a strong distinctive brand identity and contributes to the total understanding of the corporation. Ryynänen and Rusko (2015) and Ampuero and Vila (2006) concur with the author and add that packaging also communicates brand cues, features, and brand personality via structural and visual elements such as colour, shape, and graphics. As a result, the packaging is an enabling tool to develop brand image (Ford, Moodie, and Hastings 2012) and reflects the overall quality and value of the brand (Underwood 2003).

Finally, besides being expected to provide the user with some additional information about the packaging and its content, the communication function of the packaging has also recently become a great marketing tool to merchandise the product and promote the brand at the point of sales display (Nilsson et al. 2012). The packaging exterior acts like an advertisement function and directly translates promotional communication to consumers right at the store shelf. This aspect of the packaging communication function will be more thoroughly discussed in the next main section.

Convenience function to facilitate handling, logistics, and consumption

The other packaging function is to facilitate convenience not only in delivering the product to the retail shelf but also in the consumer's home once the good has been purchased. Consequently, convenience has to be ensured regarding logistics, retailers, and consumers. Firstly, Rundh (2005) states that packaging serves in the distribution system. Olsmats (2017) and Lindh et al. (2016) add that packaging affords convenient handling including storage, transportation, distribution, warehousing, and stacking. Secondly, packaging also affects how products are put on display for sale in the retail environment (Shah, Prajapati, and Agrawal 2010). Thirdly, Mumani and Stone (2018) emphasise that the consumer's satisfaction is highly dependent on the package's attributes that, in turn, might provide benefits at both the point of purchase and after-purchase contact points. Consequently, it is intended that consumers should be able to handle their bought products without significant problems. The package has to possess features that impart convenience during (i) handling at home, (ii) opening and re-opening, (iii) consumption and utilisation of the packed product, and (iv) disposal (de la Fuente et al. 2015). Once the product is purchased, it begins its journey to the consumer's home including handling, transportation, and storage. Thus a nice fit with hand size, portability, rigidity, and easy-fit storability are the key features to meet these needs (Underwood 2003). Moreover, a package should be designed to provide easy access to the product, and therefore it has to facilitate easy opening, reclosing, reuse, or resealing (Rundh 2005; Lindh et al. 2016). Functionality and smooth operation during consumption

and utilisation of the packed product are also included in the so-called lived experience between the consumer and packaging (Ryynänen and Rusko 2015; Underwood 2003). Finally, the last experience is the disposal stage, where packaging has to provide a clear declaration how to dispose of it (Rundh 2005).

Containment function to enclose, envelop, and hold products together

In general, packaging is commonly referenced as a source of containment (Underwood 2003) that encloses and holds goods together (Ampuero and Vila 2006; Ryynänen and Rusko 2015; Olsmats 2017). However, the inclusion of containment as one of the main packaging functions is questionable at the moment. For instance, Lindh et al. (2016) refer only to three clusters of packaging functions: protect, communicate, and facilitate convenience. The containment function is not considered as a separate packaging function.

From passive to smart packaging

In the literature (Nandanwade Priyanka and Nathe Parag 2013), traditional packaging, also called passive packaging, is defined as a covering material that encompasses insulating, protective, and ease-of-handling qualities, and serves the basic principles of protection, preservation, communication, and handling convenience. However, the development of advanced technologies such as nanomaterials, printed electronics, the Internet of Things (IoT) as well as increased industrial utilisation of packaging have influenced a change of the primary role of packaging. Due to recently developed nanoscale-nature substances and composites, the two main packaging functions of 'protect' and 'preserve' have been significantly improved, whereas the 'communication' function has been enhanced by high-performance computing devices. Therefore, the traditional passive package is facing alternatives, and more advanced forms of packaging are being developed on the market and becoming an improved tool for store and consumer communication. Kontominas (2015) claims that enhanced packaging might completely replace traditional packaging in the near future.

Brockgreitens and Abbas (2016) describe smart packaging as any packaging that incorporates advanced technologies to enhance the primary functions of the package or adds new functionalities in comparison to conventional packaging. Nandanwade Priyanka and Nathe Parag (2013) add that smart packaging not only improves major functions but also responds to stimuli created by the packaged product or its environment and then reflects the change in an efficient manner in order to preserve, protect, facilitate convenience, or communicate with the consumer or any participant in the supply chain. Furthermore, smart packaging can be based on any chemical, electrical, electronic, mechanical, or digital-network-connected technology or any combination of them. Regarding the function that smart packaging enhances and the way in which this improvement is achieved, smart packaging can be classified into active packaging, intelligent packaging, ergonomic packaging, and interactive packaging.

According to Biji et al. (2015), active packaging interacts directly with the packaged products to improve and maintain their quality and to extend their shelf-lives. In other words, active packaging keeps the internal packaging environment favourable for the product and aims to maintain it. The development of active packaging has led to advances in various areas including delayed oxidation in fresh foods, controlled

respiration rate in horticultural products, and microbial growth and moisture migration in dried products (Biji et al. 2015).

Although intelligent packaging is also related to the food industry, it does not directly affect the product but monitors either the condition of packaged goods or the environment surrounding the package in order to inform the user about the changes and current status of goods (Biji et al. 2015). More comprehensively, intelligent packaging is a system that is capable of performing intelligent functions such as detecting, sensing, recording, tracing, communicating, and applying scientific logic in order to facilitate decision-making to prolong shelf-life, improve safety and quality, provide information, and alert people about possible issues (Loucanova, Kalamarova, and Parobek 2017; Te Kulve and Rip 2011). Biji et al. (2015) name three main intelligent packaging systems: sensors, indicators, and Radio Frequency Identification (RFID) tags. In relation to packaging functions, intelligent packaging enhances the 'communication' function of traditional packaging and communicates changes to the consumer.

Meanwhile, ergonomic packaging embraces the convenience function for manufacturers, retailers, and consumers. Firstly, it makes the package easier to transport, store, use, and discard. Secondly, ergonomic packaging also facilitates handling, sealing, and dispensing of the packaged product for end-consumers (Brockgreitens and Abdennour 2016). A great example is packaging with an air bubble in the seal. Popping the bubble ruptures the seal and separates the layers. Therefore users of any age and dexterity can then easily and quickly open the package.

Finally, with regard to the packaging concept, intelligent packaging with integrated sensors and indicators only provides information without any action being performed by the user, whereas interactive packaging is based on reciprocal actions and therefore creates two-way communication between the user and the package (Wyser et al. 2016). In other words, interactive packaging involves the participation of users, or more precisely, their actions, to get a response from design-based or technology-based interactive packaging systems. Even though interactive packaging can contain food and beverage products its aim is not to preserve the products but to enhance consumers' experience and engagement with the products or the functionality of products. As a result, the Consumer Packaged Goods (CPG) industry is especially interested in employing interactive packaging in its infrastructure. According to Wyser et al. (2016), the development of interactive packaging has been influenced by several factors related to enabling technologies, marketing, branding, and, most importantly, consumer demand and behaviour. Nilsson et al. (2012) state that recent advances in printed electronics, augmented reality, IoT, Near Field Communication tags (NFC), and standardisation of communication protocols allow packaging to become interactive through digital services accessible on the Internet that increase the design freedom for new applications, especially with the rapid employment of the IoT, which is emerging as a third and significantly bigger wave in the development of the Internet (Yoon, Petrov, and Liu 2015). Ryynänen and Rusko (2015) concur and claim that the development of interactive packaging benefits businesses on several levels or in several environments: the supply chain, the retail environment/pre-purchase situation, and the use environment/post-purchase situations.

The key driver for the smart packaging boom is the need to develop more innovative and intelligent approaches to packaging due to growing competiveness, consumer demand and experience, protection and preservation of the packaged product, increased

regulatory requirements, increased interest in security, and others. Consequently, in order to maintain and improve its main functions, a package should be designed to address the current economic-, environmental-, marketing-, and consumer-related concerns that highly impact the contemporary understanding of the role of smart packaging. The following section will review and revise this model based on the influence of the four mentioned concerns and will thereby present a final model of smart packaging functions based on economic-, environment-, marketing-, and consumer-oriented packaging strategies.

Analysis

Packaging functions and features

The increased range of external pressures that has strongly induced packaging innovation has also influenced the increased number and diversity of packaging elements and features. In general, every package possesses graphic, structural, and verbal elements such as form, size, material, colour, brand, and producer (Agariya et al. 2012). Various technology- and design-based improvements applied to such elements result in additional enhanced features of packaging. Lindh et al. (2016) define packaging features as prominent or distinctive qualities or characteristics of packaging that enable it to fulfil its functions. Features are highly dependent on the type of product the package contains and therefore different types of packaging possess different features. On the other hand, despite the increase of packaging features, packaging functions are more permanent, general, and comprehensive; that is, a packaging feature is a part of the packaging functions that makes it possible to accomplish an assigned duty, activity or specific role, like communication or protection (Lindh et al. 2016). As a result, businesses that wish to develop more innovative and intelligent approaches to their products' packaging are creating and adding extra features to packaging in the form of changed graphical, structural, and verbal elements that, in turn, improve the main packaging functions. For instance, a changed structural element such as an air bubble in the seal of flexible packaging facilitates a feature of easy opening that successfully improves the convenience function of packaging. From the literature point of view, esearch(see Appendix 1) has dealt with several ways of classifying the main packaging functions and roles. Interestingly, some of the functions were repeated, while others were mentioned only by a few sources or were identified not as functions but as features or possible strategies for how to develop a package. In order to find out the most common roles and features of both passive and enhanced packaging, a great number of articles were investigated to compare and collate data, which is presented in the table in the Appendix 1. The table is divided into four sections regarding the main packaging functions: containment, protection, convenience, and communication. Each section consists of sub-functions and features provided by other researchers.

Packaging strategies

Besides packaging features and functions, packaging strategies also play a significant part in packaging innovation. Sun Pharmaceutical Industries came up with a packaging solution

where a medicine bottle lid is transformed into a magnifying glass, which makes it easier to read the instructions and other information given on the package. In other words, such packaging innovation was induced by consumer-oriented concern, which is further referred to as one of the packaging strategies. Therefore, this work takes into consideration four of the most commonly addressed packaging strategies considering economic-, environmental-, marketing-, and consumer-related matters (Ford, Moodie, and Hastings 2012) and collects a great number of packaging features and sub-functions related to them.

Environment-related concerns and environmental strategy

As the history and development of packaging shows, technology is the key driver and contributor to the growth of the packaging industry. Nonetheless, the growing interest in sustainability also has a significant influence on the development of the package. In the past decades, production capacity has increased drastically. In parallel, growing consumption has led to increased amounts of solid waste, use of resources, and environmental impacts. According to the Netherlands Institute for Sustainable Packaging, a European citizen opens on average seven pieces of packaging a day, which adds up to 157 kilos of packaging waste per person per year, accounting for almost 40% of the total household waste. Therefore, the sustainable production of packaging is critical. According to Lindh et al. (2016), packaging has great potential to contribute to sustainable development if considered early in the product development process or communicated clearly regarding functions and features in the decision-making around packaging. Mumani and Stone (2018, 10) concur and add the matter of consumers' and governments' increasing awareness of the environmental impact of packaging: 'reducing the negative impacts of packaging on the environment is consistent with users' tendency to protect the environment and is therefore considered as creating a competitive advantage'. Consequently, consumers' preferences are highly affected by the possible impacts of packaging on the environment. Therefore packaging becomes the main source of media that can communicate the efforts made by producers to achieve sustainability and thereby have an impact on consumers' perceptions (Mumani and Stone 2018).

Recently, growing environmental pressure has induced the packaging industry to address environment-related issues and create, change, or design new or current features of the packaging. Based on the data in Table 2, five packaging features with the following sub-functions of packaging are described to address the packaging characteristics regarding environmental concerns:

(1) *To utilise ecological, biodegradable, recyclable, renewable, reusable, sustainable, and biocompatible packaging materials that will increase the environmental performance of the packaging*. One way to follow up on the increasing environmental concerns, addressed by more than half of the investigated literature, as seen in Table 2, is to employ more sustainable materials for packaging. Moreover it is vital to reduce or eliminate the use of harmful chemical elements in packaging materials and to assess the risk to humans and the surrounding environment, especially for packaging that contains nanomaterials.
(2) *To facilitate and promote recycling and disposal systems by increasing consumers' tendency to recycle empty packages*. It is important to appropriately handle and treat packaging at the end of its life. At the moment, the paperboard and paper

recycling industry is well-established and steady, and therefore packaging has to contain the right visual-graphical and verbal-informational cues not only to refer to the eco-friendliness of the packaging but also to motivate consumers to embrace the proper recycling practices, such as folding or squashing paperboard packaging boxes before discarding them in a paper-recycling container. Mumani and Stone (2018) affirm that such consumer motivation will have a positive impact on reducing environmental pressure.

(3) *To facilitate, enable, and adopt Reduce, Reuse, & Repurpose systems for packaging in order to address waste reduction*. On the other hand, recycling is the last resort in a truly circular economy, because by returning a product to its constituent materials, a company loses all energy, labour, and expenses that went into creating the product in the first place. Therefore businesses first have to consider the adoption of the Reduce, Reuse, & Repurpose framework in their infrastructure. The matter of waste reduction might be addressed from two perspectives: regarding packaging resources and the packed product. The former is related to the reduced use of packaging materials, reduced number of packaging levels, efficient transportation solutions, and others. Meanwhile the latter concerns the reduction of product waste and how packaging can prolong a product's shelf-life and maintain its quality. Furthermore, packaging that can be reused or repurposed by consumers can significantly affect waste reduction, and thus it is relevant for companies to investigate potential packaging design efforts for such actions (Mumani and Stone 2018).

(4) *To reduce the environmental impact of packaging to preserve the environment and appease growing societal concerns about environmental issues regarding products' packaging*. In general, environmental impacts are related to effects on the planet such as depletion of natural resources, mining and deforestation, climate change, atmospheric emissions, energy consumption, water consumption, and solid waste (Franklin Associates 2017). The growing societal concerns regarding environmental impacts have prompted businesses to increase their environmental performance (Rundh 2005; Nilsson et al. 2012). According to Mason (2010), consumers are becoming more educated on sustainability and increasingly interested in their impact on the environment; that is, they would rather buy more sustainable products than regular (non-sustainable) ones. Due to this, companies have started to integrate various environmental certifications into their business models based on responsible environmental behaviours, such as ISO certifications for waste management, Forest Stewardship Council (FSC) certification for the best forest management, Planet Promises, and others.

(5) *To efficiently manage sustainability development and adopt sustainable practices in the overall packaging design*. On the other hand, the facilitation of sustainability cannot be fully accomplished only by switching to sustainable materials. Sustainable development of the overall packaging design has to take into consideration environmental, social, and economic impacts throughout the life-cycle of the packaging. In fact, the environmental impact discussed above is just one part of sustainable packaging development. Lindh et al. (2016) claim that there is a narrow view of sustainable packaging if it mainly deals with issues of packaging

materials rather than having a systems perspective that also encompasses the packaged goods.

To conclude, all five named packaging features and sub-functions lean upon the environmental strategy that is able to mitigate the environmental impact or facilitate overall sustainable development of the packaging. Moreover, these strategies are tightly related to the main functions of packaging. For example, in order to preserve food against spoilage, the biodegradable polymer polylactic acid (PLA) could be selected instead of traditional polyethylene terephthalate (PET), which is non-renewable, when a lower environmental impact would be considered as a possible beneficial outcome. Thus, the selection of sustainable packaging material is dictated by an environmental concern that possesses a more strategic nature rather than dictated by a function.

Marketing-related concerns and marketing strategy

Traditionally, advertising was considered as the main marketing method (Ford, Moodie, and Hastings 2012). However, since industry is moving from the information age to the communication and interaction age, traditional mass media marketing and advertising approaches are becoming less efficient because of decreased effectiveness regarding consumers, reduced advertising budgets, and the increased prime cost of the product due to additional expenses of advertising (Clarke 2017; Ampuero and Vila 2006). As a result, industry has to come up with other potential marketing media. According to Underwood (2003), one marketing element that has been largely disregarded in the communication of brand symbolism is product packaging. Overall, it is the packaging that catches the consumer's eyes first (Asgari, Moradi, and Tajeddin 2014). In fact, it was evaluated that 73% of experiment participants rely on packaging regarding their purchase decisions at the supermarket (Ampuero and Vila 2006). Ampuero and Vila (2006) also state that this function has increased due to the implementation of self-service sale systems that have moved packaging to the foreground in capturing attention. Loucanova, Kalamarova, and Parobek (2017) concur and state that packaging already forms the product, and therefore its size, shape, design, colour, or font have a significant influence on the consumer decision-making process and, in turn, affect the merchandising of the product. Moreover, if the packaging is designed to reflect the experience of the brand through both graphical and physical designs, it will greatly encourage potential buyers to purchase a product (Loucanova, Kalamarova, and Parobek 2017). In this sense, packaging plays the role of a 'silent salesperson', where companies concentrate their efforts on sales promotion at the point of purchase (Ampuero and Vila 2006). Ford, Moodie, and Hastings (2012) emphasise the preeminent value of packaging not only for its profound advertising capabilities but also for its benefits for all forms of marketing. As a consequence, packaging is becoming one of the most effective marketing communication tools. Therefore the current interest of businesses regarding packaging innovation should be oriented to offer consumers packaging that will be adjusted to transmit the main principles of the marketing strategy.

In order to integrate marketing communications into a product packaging design, packaging has to possess relevant features. As a result, the following packaging features regarding this strategy were retrieved from the literature and are given in Table 3, where they are divided into seven sections. Every investigated feature consists of a number of

sub-functions that packaging has to accomplish within the frame of a specific given feature. The following sub-functions of packaging, based on the data listed in Table 3 regarding the marketing strategy, are summarised below:

(1) *To create a positive aesthetic appeal and attract the attention of consumers at the point of purchase*. First of all, packaging is an essential means of product display and presentation. Therefore its first interaction with a consumer is based on visual experience. Mumani and Stone (2018) claim that the visual graphical and structural attributes of packaging are dominant factors in catching a consumer's attention. Various design changes and improvements regarding shape, size, colour, typography, graphic elements, and others might strongly affect users' perceptions and their further decision-making. Ampuero and Vila (2006) refer to such matters as the positioning strategy of packaging concerning how the brand wishes to present its products and itself to the public.

(2) *To create, contribute to, and sustain a competitive advantage in the competitive arena of the similar products*. At the moment, especially in highly competitive markets, businesses are looking for new approaches to enable them to stand out and increase their competitive advantage over others. Ford, Moodie, and Hastings (2012) state that in an overloaded consumer goods market, the best way to maintain and increase competitive advantage is through the development of innovation in packaging. Rundh (2005) concurs, addressing packaging as a part of the strategic value of the company's marketing strategy; that is, a competitive advantage can be obtained by appropriate packaging design solutions related to marketing requirements.

(3) *To communicate different messages in relation to brand and product values and marketing-, consumer-, and environment-oriented strategies to affect consumers' perceptions*. Packaging is considered as a significant communication medium since it can reach the highest amount of consumers and has the closest connection with them at the crucial point of purchase (Ampuero and Vila 2006). In general, the communication function of packaging relates to the transmission of information. Consequently, the marketing-oriented information provided by a bright colour, unusual shape, or popular brand and transmitted to the buyer will have an impact on his or her perception and later on his or her purchase decision. In relation to the marketing strategy, packaging can transmit various positive cues concerning the brand and product values, quality, and imagery (Westerman et al. 2013). Furthermore, packaging is a great promotional tool to communicate efforts applied to achieve better sustainability to increase consumers' awareness and, in turn, affect their decision-making.

(4) *To promote and advertise the product and brand to increase sales*. Once the packaging design was well-established, industry acknowledged the growing importance of packaging to be able to sell products from the shelf (Ford, Moodie, and Hastings 2012). In comparison to traditional advertising, packaging can reach a broader audience and better position brand values. Consequently, funds traditionally allocated to brand-building advertising are increasingly being directed to sales promotion at the point of purchase provided by product packaging (Underwood 2003).

(5) *To function as a marketing tool to sell a product, create new market positions, facilitate commercialisation, and enhance the market value of a product*. Based on the investigation given in Table 3, it has become apparent that packaging is an integral part of a business's marketing strategy. The majority of the investigated literature to some degree refers to packaging as a marketing tool. Underwood (2003) highlights the heightened role of packaging in the marketing mix due to multiple market factors such as decreased effectiveness of traditional advertising and consumer trends such as in-store decision-making and mobile lifestyles. Furthermore, Ford, Moodie, and Hastings (2012) suggest that packaging should be considered as the fifth 'P' of the marketing mix.

(6) *To facilitate recognition and differentiation of the product, reinforce its concept and perceptions of it, and contribute to new product development*. According to Underwood (2003), it is essential that businesses identify the core essence and value of the product and estimate the degree to which packaging can improve or at least effectively communicate that value to consumers. In order to accomplish these actions, packaging first has to provide a clear identity of the product and effective differentiation from others by employing previously described visual attributes (Ampuero and Vila 2006). Secondly, Mumani and Stone (2018) add that packaging can be associated with an opportunity to improve the market value of a product if the appearance of the packaging is improved. In this case, the improvement of packaging directly relates to the product's performance and overall concept (Rundh 2005). Underwood (2003) emphasises that innovative packaging features can enhance the functionality of a product; that is, a potential design change of a package feature might influence the product usage and utilisation such as by providing easy opening or easy-fit storability. The improved packaging functionality, in turn, facilitates the decision-making process to purchase a product (Loucanova, Kalamarova, and Parobek 2017). Finally, packaging innovation contributes to new product development and opens new markets (Bradley, Castle, and Chaudhry 2011).

(7) *To reflect brand messages, cues, identity, and values to build and enhance consumer–brand relationships*. The packaging also acts as a communication vehicle to transmit symbolism related to the overall understanding of the brand (Underwood 2003). From the consumer's point of view, packaging serves as a tangible symbol of a product and thereby of a brand as well, and therefore the appearance and quality of packaging also expresses the personality of a brand. Furthermore, packaging then stimulates the consumer's sensory perceptions and redirects them to possible positive outcomes; for example, a picture of a freshly baked pie on the packaging induces an appetising perception and an emotional connection between the consumer and packaging/brand/product is built and firmly fixed. Consequently, packaging is one of the building blocks for the successful creation, maintenance, and enhancement of consumer–brand relationships.

To conclude, the marketing strategy is also tightly related to consumer-oriented concerns that are addressed in the next section. All seven given packaging features and sub-functions lean upon the marketing strategy, which can create, maintain, and enhance the product, consumer, and brand experiences. Moreover, the marketing strategy is

tightly related to the communication function of packaging due to its inherent tangible form; that is, consumers communicate with the packaging from the moment it has caught their attention until disposal.

Consumer-related concerns and consumer-oriented strategy

The development of packaging has been influenced by several factors related to technologies, marketing, branding, environmental impact, and, most importantly, consumer experiences and engagement. According to Landi (2015), the right technological solutions not only help companies increase productivity, safety, and efficiency but are also able to enhance consumer service. Consequently, during the last decade, the entire packaging industry has become increasingly interested in consumer-oriented matters. Mumani and Stone (2018) add that greater efforts have recently shifted toward improving human–packaging interaction. If in the beginning packaging served as a box to contain and protect the goods inside, over the years more functions have been added and enhanced according to demand by consumers. Ford, Moodie, and Hastings (2012) emphasise that packaging has the potential to increase product sales if it is tailored to consumer preferences. Wyser et al. (2016) contribute and claim that innovation in packaging is driven by observable changes in consumer demand and behaviour from which industry has the opportunity to predict future trends in the packaging market. Consumer engagement and communication is one of the main characteristics and features that packaging must possess. Furthermore, the development of consumer-oriented packaging, especially for CPG industries, is imperative due to the fact that packaging is interacting with consumers within and outside the retail environment; that is, packaging communicates with consumers at the point of purchase and at the point of product utilisation at home (Ford, Moodie, and Hastings 2012).

As a result, ten features of packaging with regard to the consumer-oriented strategy are given in Table 4 with the following sub-functions regarding the consumer strategy:

(1) *To encourage and influence the intent to purchase the product based on visual aspects of its packaging*. The previously described marketing strategy sub-function to attract attention at the point of purchase is tightly related to the consumer strategy sub-function of promoting intent to purchase. All design-based and technology-based improvements of the packaging appearance aim to get the attention of buyers and encourage them to purchase the product. Ryynänen and Rusko (2015) refer to this sub-function as the first step in consumers' symbolic negotiation with packaging at the point of purchase.
(2) *To affect, influence, and facilitate the consumer decision-making process at the point of purchase*. This is closely connected with the first marketing sub-function of creating an aesthetic appeal. The time gap between the buyer noticing the package and the decision to purchase the product is a few seconds. In this short but crucial moment, the packaging is the key factor that has a great chance to persuade the consumer to grab it (Ampuero and Vila 2006). As a result, consumers' aesthetic preferences regarding packaging design directly affect the imagery of the product and thereby influence the purchase decision (Westerman et al. 2013).
(3) *To affect consumer value by supporting consumer-centred packaging design based on consumer preferences*. In order to accomplish the first two sub-functions –

influence intent to purchase and affect decision-making – the packaging design has to be tailored to meet consumers' preferences, usually by monitoring and tracking changes in their behaviour towards packaging. Consumer preferences usually refer to physical packaging functionalities (Mumani and Stone 2018).

(4) *To communicate different messages that affect consumers' perceptions of the product and the brand*. The first consumer perception is usually formed at that crucial moment of decision-making and is mainly affected by the packaging functionality, sustainability, cleanness, and other visually attractive elements (Mumani and Stone 2018). Then, if the product is purchased, packaging features continue to have an impact of the consumer's perception during product consumption and utilisation and are associated with psychological values related to both product and brand (Ford, Moodie, and Hastings 2012).

(5) *To communicate and interact with consumers when they are purchasing and utilising the product at home to build the consumer–packaging relationship*. According to Ryynänen and Rusko (2015), symbolic consumer negotiation with packaging differs depending on the point of purchase and when the product is utilised or consumed. In order to build strong consumer–packaging relationships, these two moments have to possess different features but still satisfy consumers. In the first moment, packaging has to attract attention through highly observable visual elements when buyers examine the packaging to obtain the information they need, whereas in usage situations the packaging has to fulfil its functionality. Packaging developers have to consider packaging as an intimate part of consumer life (Ampuero and Vila 2006).

(6) *To communicate brand imagery, messages, identity, and values to create and enhance the consumer–brand relationship*. This coincides with the last marketing strategy sub-function that was described briefly above.

(7) *To build and enhance long-term consumer loyalty, which, in turn, will drive consumption*. The development of packaging based on consumers' preferences might result in enhanced long-term consumer loyalty if the potential desirable perception of the product and brand is achieved (Rundh 2005).

(8) *To target specific consumer groups*. In some cases, packaging design has to include the requirements of specific target consumer groups at which the product is aimed. Especially the design of pharmaceutical packaging has to impart ergonomic features that, for instance, facilitate easy opening by the elderly.

(9) *To enhance consumer experience and increase consumer satisfaction through engagement and entertainment*. An improved consumer experience can be achieved in several ways by several strategies at several contact points. For instance, aesthetically attractive packaging improves the consumer experience at the store, whereas ergonomic packaging with easy-fit storability increases consumer satisfaction at home. Advances in smart interactive packaging have enabled brands to engage and interact with consumers in novel and revolutionary ways.

(10) *To communicate sustainability messages in relation to low environmental impact and other related matters*. According to Mason (2010), consumers are becoming more educated on sustainability and increasingly interested in their impact on the environment; that is, they would rather buy more sustainable products than regular (non-

sustainable) ones. Due to this, companies have started to apply graphical elements to packaging designs to reflect their efforts toward sustainable development.

Discussion

The connection between smart packaging, main packaging functions, and packaging features

Every investigated packaging strategy possesses features and sub-functions that maintain and enhance the main packaging functions. Consequently, enhanced packaging functions regarding marketing-, environment-, and consumer-oriented strategies have led to more sophisticated packaging applications, that is, smart packaging. Therefore, this section will connect data from the theoretical background and analysis regarding active, intelligent, ergonomic, and interactive packaging.

The environmental strategy improves convenience and protection with active, ergonomic, and intelligent packaging

The environmental strategy addresses the improvement of packaging regarding (i) the sustainable nature of packaging materials, (ii) facilitation of recycling, (iii) reduced waste of materials, (iv) minimisation of the environmental impact, and (v) overall sustainable development. As a result, active packaging is designed to employ biodegradable, renewable, and biocompatible active nanomaterials and compounds that can interact with the food and, thereby, maintain its quality for longer. In other words, active packaging reduces waste of packaged products by prolonging their shelf-lives. For instance, active packaging with a broad antimicrobial spectrum due to incorporated chitosan carvacrol and grape seed extract improves the physical, barrier, and mechanical properties of the biofilm, which, in turn, extends the food's shelf-life, reduces waste and pollution, and benefits from the employment of degradable materials (Rubilar et al. 2013). Meanwhile, intelligent packaging also plays a significant role in reducing waste due to visual informational elements on the packaging. This kind of smart packaging incorporates sensors, indicators, or communication systems to detect, sense, record, and inform consumers about the changes and current status of packaged products. For example, a freshness indicator with a nanolayer of silver reacts with poisonous chemical compounds like hydrogen sulfide that are spread by putrescent food and forms a visually detectable change in label colour on the specific area on the package. Therefore, in this case, intelligent packaging makes retailers aware of the approaching expiration date of a product that could be placed on sale. The reduced price of a product might stimulate the intent to purchase and at the same time reduce the food waste. Finally, ergonomic packaging facilitates recycling as well as reducing the wastage of packaging materials. WikiCells packaging, developed at Harvard University, is consumed together with the food it contains due to the specific technology, which fabricates a thin tasteful membrane with significant water diffusional resistance and adjoined shells that ensures the stability of the package over long periods of time (Raheem 2013). As a result, such packaging enhances convenient consumption and reduces waste. Furthermore, packaging might engage with consumers in a completely unexpected way and become repurposed. At first, Hangerpack developed by graphic designer Steve Haslip looks like a conventional

cardboard packaging used for shipping. However, it can be transformed into an actual coat-hanger to hang the T-shirts it contains. In this case, ergonomic packaging fulfils the environmental strategy by not only employing recycled materials but also presenting a sustainable, reusable way to design packaging. All of the examples provided, in general, reduce the environmental impact and contribute to the sustainable development of the packaging.

Concerning the main packaging functions, the environmental strategy greatly improves convenience and protection. The former is ensured by ergonomic packaging and the latter by active and intelligent packaging.

The marketing strategy enhances communication with interactive packaging

The investigated marketing strategy addresses the improvement of packaging features based on (i) attracted attention, (ii) sustained competitive advantage, (iii) marketing-oriented communication, (iv) promotion and advertising, (v) marketing and merchandising, (vi) enhanced product perception, and (vii) improved brand experience. Consequently, interactive packaging with integrated smart communication technologies can become one of the most effective marketing assets by attracting attention, communicating various brand and product cues, and enhancing consumer experiences. As consumers typically have a preconceived idea of what brands they will purchase before entering the store, it is essential to capture their attention and encourage deviation from their routine (Landi 2015). A captivating aesthetic appeal can be created not only by design-based attributes such as colour, shape, or typography but also by technology-based improvements that might attract consumers' attention even more. For instance, Saralon GmbH developed interactive packaging solutions that catch consumers' eyes directly at the shelf by incorporating various printed electronic elements such as LED lights, illuminated and EC displays, capacitive touchpads, and others. Moreover, exclusive effects and distinctive characters created by the improved interactivity of the packaging are other essential triggers to start the conversation with potential buyers. For example, Philips Hue Lamp packaging, with an integrated spin wheel on the side to change the colour of the light bulb image illustrated on the package, interacts creatively with consumers not only to entertain but also to advertise the product it contains at the point of purchase. Thus, interactive elements have a greater influence on consumers' attention than traditional ones. As a result, interactive packaging has a greater effect on the differentiation of a brand or product from others and thereby contributes to the competitive advantage of the company. Furthermore, an interactive packaging campaign might have a significant impact on branding and marketing of the product. The Ribbon Magic Bow campaign by Coca-Cola® embraced consumers' interaction with the packaging by allowing them to transform the bottle label into a ribbon. Also, the company launched a unique video related to this campaign that went viral and contributed to the overall marketing strategy.

All of the described examples mostly engage and interact with consumers in the retail environment. However, the investigated marketing strategy also profoundly enhances consumers' experiences at home and affects the perception of a product and its overall performance. Interactive packaging can improve the functionality or experience of a product it contains to serve its primary initial purpose more efficiently. In most cases, the packaging is thrown out immediately after purchase unless it serves as a container

until product is consumed. Therefore, marketing strategy features can extend the 'life' of the packaging and give it an additional purpose or function with regard to consumer entertainment. For instance, due to the millennial party culture and social gatherings, the alcoholic beverage industry has found new ways to interact with its consumers through the packaging. Corona has designed its beer packaging so that it can be transformed into a board game in which the bottle caps can be utilised as game tokens. The primary purpose of this product has been improved to entertain consumers during the consumption process. Moreover, added interactivity has also enhanced the functionality of the packaging from the initial goal of holding bottles to the entertainment of consumers in unforeseen ways. Furthermore, interactions achieved by integrating enabling technologies such as smart sensors, printed electronics, IoT, augmented reality, and NFC tags into the packaging design promotes an even higher number of improvements of both product and packaging functionalities (Carmigniani et al. 2011). For example, ThinFilm provides highly scalable printed electronics solutions by deploying printed NFC tags that contain unique identifiers for possible authentication operations and can also instantly identify the product: through a simple tap with a phone on the marked spot of the packaging, the consumer is redirected to the appropriate URL. Another example is the electrochromic (EC) displays developed by Ynvisible, which can be integrated in the packaging design together with motion, temperature, or capacitive touch sensors, greatly enhancing the consumer experience in the retail environment. Finally, in terms of the main packaging functions, the marketing strategy greatly improves communication.

Consumer-oriented packaging improves communication and convenience with interactive and ergonomic packaging

The investigated consumer-oriented strategy addresses the improvement of packaging features in relation to (i) increased intent to purchase, (ii) the influence on decision-making at the store, (iii) consumer preferences, (iv) consumer perception, (v) consumer–packaging interaction, (vi) consumer–brand interaction, (vii) increased consumer loyalty, (viii) targeted consumer segments, and (ix) enhanced consumer experience. Consequently, both ergonomic packaging and interactive packaging aim to address and improve these sub-functions. The previously described Philips Hue Lamp interactive packaging with its unique, entertaining design can have an impact on decision-making and, in turn, might increase the desirability and probability of purchase of the product. A consumer-centred packaging design improved by interactive and intelligent communication technologies can monitor and track consumers' behaviour and their preferences. For instance, Smart Cap technology with integrated smart sensors, developed by Water.IO, can automatically measure the product usage and make the analysis of its consumption trends, including typical consumer habits and behaviour. Moreover, this solution also prolongs consumer–packaging interaction when the product is consumed at home. Smart Cap communicates with the user in various ways, such as through reminders on the app to stay hydrated, to re-order washing-up liquid, or to take medicines, and builds personal profiles for each consumer based on data collected from sensors. On the other hand, this technology also creates preeminent value for businesses to improve their business models and provide more customised, personalised, and efficient services that further enhance brand–consumer relationships. Based on the retrieved data on consumer consumption and behaviour, the Water.IO smart system builds dashboards with real-time

and historical data that are then analysed and allows CPG companies to know their consumers at almost the same level as Google does. For instance, based on historical usage data created by analytics, the technology is able to calculate how much of the product is left in the bottle. Then when the product is about to run out, the Water.IO app will send the consumer a message with a fixed-term discount code and directions to the nearest shop where the consumer can purchase this product. As a result, this interactive and intelligent solution for everyday packaging benefits both consumers and businesses. However, in some cases, the capabilities of different smart packaging types are combined to create unique consumer experiences. A good example of the mix of ergonomic, interactive, and intelligent packaging is the Right Moment campaign introduced by Coca-Cola®. It was found in a study that Coca-Cola drink tastes best when served cold at a temperature of around 3–5 °C. Therefore a technological solution was developed to visually inform the consumer whether the bottle is at the right temperature or not. The shapes of ice cubes and bottles were printed on the can with thermochromic ink, which can display different colours depending on the temperature of the can. As a result, the colour of such shapes informs the user whether the drink is cold enough to have an ultimate taste experience. In this case, the improvement was created based on the preferences of specific target consumers.

Based on the smart interactive packaging examples described, the combination of consumer-oriented and marketing strategies aims to enhance consumers' experiences through engagement and entertainment in both the retail and the usage environment. The latter employs more effective physical interaction between a consumer and a product and brings memorable feelings that lead to higher enhancement of engagement. Interactive consumer-oriented packaging strengthens the emotional and physical connection between consumers, products, and brands. Also, the consumer strategy mainly improves the communication and convenience functions of packaging.

Proposed new model of packaging functions

The capabilities of smart packaging solutions based on the investigated packaging strategies profoundly affect and enhance the traditional role of the primary packaging and, in turn, the model of the main packaging functions. Based on the studied and analysed data, through the use of enabling technologies, the protection, convenience, and communication functions have been significantly improved with regard to environmental-, marketing-, and consumer-oriented matters. As a result, this work proposes a new model of the primary packaging functions concerning smart packaging.

First of all, the protection function is upgraded by smart active and intelligent packaging. Enhanced packaging improves the quality of the product by integrating into the package design nanomaterials with higher strength and barrier properties that ensure higher resistance to the surrounding environment (Mlalila et al. 2016). Various nanomaterials, such as silver nanowires, carbon nanotubes, and graphene, have been investigated for wireless wearable communication systems to inform and engage with the user (Huang et al. 2015). For instance, self-healing and self-cleaning systems can repair themselves after tamper-related accidents. Self-healing can be achieved by dynamic swelling and electrostatic repair of the polyelectrolyte multilayers in the vicinity of the fracture, stresses, corrosion, tears, and even molecular weight fractures.

Self-cleaning systems, on the other hand, are superhydrophobic and thus create a contaminant-free surface. Both intelligent systems ensure the protection of the packed products in the packaging. Furthermore, active packaging goes beyond the traditional preservation function and has the ability to change the condition of the product and the packaging by (i) releasing active compounds, for example, antimicrobial films and antioxidant packaging, or (ii) absorbing substances like O_2 scavengers, ethylene scavengers, and moisture regulators from the packaged food or surrounding environment (Nandanwade Priyanka and Nathe Parag 2013). In this case, active packaging protects the product from microbial contamination and deterioration of food and controls its spoilage. On the other hand, intelligent packaging integrated communication-enabling technologies, such as NFC tags, ensure a high level of security in terms of anti-counterfeiting, pilferage, theft, track and trace, and assures verification of the origin and authenticity of the packed product.

Secondly, the convenience function is relatively well-established within traditional packaging design. However, recent environmental concerns regarding packaging disposal have induced the development of more profoundly ergonomic packaging that facilitates the reuse and repurposing of packaging. Both edible and repurposed ergonomic packaging types considerably reduce waste of packaging materials; the latter also creates additional consumer experiences. Furthermore, the enhanced packaging is closely related to innovations in the design of packaging regarding the consumer-oriented strategy. Such packaging form, structure, or design ensures a higher level of convenience to consume or apply products without any other accessory. For example, self-heating packaging can heat packaged food without any external heat source. Also, microwavable active packaging is self-venting during the cooking process. Thus the temperature is gradually regulated to maintain food quality (Biji et al. 2015). Consumers experience a better quality of their cooked meals and feel more satisfied. Furthermore, the consumer-oriented strategy concerns challenges regarding easy opening and dispensing of the product, especially in the pharmaceutical industry. Therefore ergonomic packaging solutions like one-handed opening, non-slip packaging materials, air-bubble-sealed materials, and others are being implemented.

Thirdly, the communication function of packaging is also very well-defined and well-established in terms of marketing, branding, environmental, and consumer-oriented perspectives. This function is integrated into every investigated strategy and is an efficient tool to influence consumers from the very first contact point at the store. The communication of traditional passive packaging is only carried out by visual graphical and structural elements of the packaging design, whereas smart intelligent packaging integrates digital-network-enabled elements that impart preeminent communication between producers, distributors, suppliers, retailers, and end consumers (Mlalila et al. 2016). Furthermore, such communication information is stored, accumulated, and transmitted in a digital format. For instance, smart packaging with integrated NFC carries data about the product's origin. Smart packaging greatly enhances the sub-functions and features of this role with the help of technology-based improvements. From a marketing strategy perspective, the identification, differentiation, and additional information about the product are easily obtained in a digital form by a simple tap on the packaging with a phone. Consumer awareness and attention are gained by additional interactive design elements that at the same time advertise, promote, and persuade the

consumer to purchase. Moreover, intelligent packaging with incorporated indicators or active compounds informs consumers how fresh the product is or when is the best time to consume the product.

Traditionally, the containment function is considered as the fourth main function of packaging. However, based on the findings of this work, none of the investigated packaging strategies addressed this role of packaging (see Tables 2–4). Moreover, this is the only packaging function that has no other features or sub-functions as seen in Figure 2, and none of the investigated smart packaging types embrace it. As a consequence, the containment function cannot be improved or enhanced by any means. From a literature point of view, the packaging is commonly referenced as a source of containment (Underwood 2003) that encloses and holds goods together (Ampuero and Vila 2006; Ryynänen and Rusko 2015; Olsmats 2017). Although the history of packaging began with the need for containment (Clarke 2017), the perception of this function is considered as already being included in the concept of packaging. This concept is in line with the definition of packaging, where the ability to keep goods together or hold them is considered a prerequisite for packaging (Lindh et al. 2016). This is obvious because, in practice, a package that cannot contain or hold anything can hardly be referred to as a package. Moreover, as pointed out by Lindh et al. (2016) the verb 'to contain' stems from the same root as the noun 'container', which happens to be a synonym for the noun 'package'. As a result, the proposed model of the main packaging functions based on capabilities and features of smart packaging eliminates the role of containment.

However, based on the analysis, another potential function of packaging regarding the two-way interaction created by enabling communication technologies between the consumer and the packaging has to be taken into consideration. As determined from the analysis, consumer–brand relationships are strongly influenced by experiences that the packaged product brings to the consumer. Since packaging is an inseparable part of the product, it has the possibility of enhancing such experiences and playing a key role in building relationships. As a result, more interactive activities are considered greater ways to create strong emotional and memorable states or reactions. Tafesse (2016) states that sensory, emotional, and social sensations are the main building blocks to stimulate consumer's engagement and entertainment. Bangcuyo et al. (2015, 2) contribute and claim that: 'engagement is a complex construct that depends on the aesthetic appeal, novelty and usability of a system such that attention and interaction are maximized'. According to the investigated and analysed data, consumers' engagement and entertainment is in many cases narrowly related to the environment where the packaging is exploited. In the retail environment, visual awareness is critical to attract consumers' attention. Therefore the purchase situation is triggered by the momentary and instantaneous desire to buy the product. On the contrary, visual awareness is less significant in the use environment after the purchase, where usage situations stimulate more memorable feelings than purchase situations and create physical impacts and emotional connections. In other words, during physical interaction with the product and packaging at home, consumers are more bound to remember the continuous actions and become emotionally connected to the product. Consequently, the product brings to a higher level of interaction, engagement, and entertainment. Finally, the effective interactivity improvements based on consumers' involvement in the use environment influence consumer–brand relationships, and, for example, the consumer becomes loyal and purchases the

same product or other products by the same brand again. As a result, this work proposes to attach a new main function of packaging regarding the two-way interaction created by enabling communication technologies between the consumer and the packaging/product/brand. The main aim of the proposed interaction function is to improve and enhance consumer experience in terms of engagement and entertainment at the point of purchase and the point of usage. A new proposed model of the main packaging functions prompted by smart packaging is given in Figure 2.

Conclusion, limitations, and future research

To conclude, this work makes three main contributions to packaging theory. Firstly, the development and emergence of smart packaging have induced changes in the traditional model of packaging functions. Therefore, as the main implication for packaging theory, this work proposes a refined model of the main packaging functions including protection, convenience, communication, and interaction. The first three are extracted from the traditional model of packaging functions, whereas the fourth function has been attached to the proposed model based on the findings of this work. In general, all four functions continuously improve and encompass a cumulative number of features and sub-functions that each one of them possesses and employs. Concerning smart packaging applications, the protection function aims to maintain, improve, and ensure the safety, security, and quality of packed items. Meanwhile, convenience aims to strengthen every consumer-oriented process in the packaging life-cycle with a higher emphasis on usage and disposal. The communication function aims to transmit data about a product and brand in various physical and digital ways to identify, differentiate, authenticate, attract attention, facilitate decision-making, and establish consumer–product/brand/packaging relationships. Finally, the proposed interaction function strives to improve and enhance consumer experience in terms of engagement and entertainment at the point of purchase and the point of usage. In addition, it is vital to acknowledge the difference between communication and interaction within this proposal. Generally, communication points to the act of sharing or imparting information, whereas interaction refers to a reciprocal action or influence; that is, there is an apparent response to the action, where one act affects the other (Oxforddictionaries.com). The main difference between communication and interaction is that communication is usually one-way while interaction is always two-way, and communication is only a part of an interaction. With regard to the packaging concept, intelligent packaging with integrated sensors and indicators provides information without any action being performed by the user. Meanwhile, smart interactive packaging involves the participation of the user, more precisely his or her actions that get a response from smart systems integrated into the packaging.

Secondly, the investigation of packaging strategies demonstrated that development in packaging is highly linked with the increasing environment-, marketing-, and consumer-related concerns. Packaging is not only expected to act as an effective communication medium or silent salesperson but also has to be continuously elevated in regards to changing consumer behaviours, needs, and perceptions in order to create unique experiences and stronger consumer–brand relationships through the implementation of enabling and sustainable technologies and technological processes.

Thirdly, this work carried out an explicit classification of the main smart packaging types, providing a more accurate definition of each type, as well as their core purposes.

Active packaging is only related to food packaging and aims to improve and maintain food quality and extend shelf-life. In contrast, intelligent packaging does not directly affect the product but instead monitors the condition of the packaged goods and informs the user about the changes. Meanwhile, ergonomic packaging facilitates convenience in the logistics, utilisation of the product, and disposal of the package. Finally, smart interactive packaging creates two-way communication between the user and the package by allowing the user to initiate the interaction to obtain some sort of a reward.

Every investigated packaging strategy progressively improves the main packaging functions by creating new features and sub-functions regarding environmental, marketing, and consumer-oriented matters. The two principal purposes of smart interactive packaging were determined from this study in relation to the combination of marketing- and consumer-oriented strategies: (i) to enhance the functionality or experience of the product in order to serve its primary initial purpose better, and (ii) to enhance consumers' experiences through engagement and entertainment in both the retail and the usage environment.

This study did not address the influence of the economical packaging strategy on smart packaging. Therefore, future research might be conducted in relation to the economic development of smart packaging. Furthermore, there is a need for a more thorough investigation of how improved packaging functionality could enhance the primary purpose of a packed product when it is utilised or consumed. Also, since this work only investigates marketing-, environmental-, and consumer-oriented strategies as smart packaging drivers, there are a high number of other drivers, such as enabling technologies, which are worth exploring.

To sum up, the sheer importance of packaging for primary consumer goods is continuously growing and, therefore, businesses have to come up with more innovative and creative packaging solutions with great regard to marketing-, environmental-, and consumer-oriented strategies. Advances in interactive packaging enable brands to engage and interact with consumers in novel and revolutionary ways both at the point of purchase and at the point of utilisation. If used creatively and with a hint of technology, packaging can be the company's most effective marketing and branding asset. Smart packaging can bring a strategic value for businesses and, thereby, a competitive advantage can be attained by employing suitable technology-based smart packaging solutions.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Full name of the PhD student: Justina Lydekaityte

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No ☒ Yes ☐ If yes, give details:

The PhD student has contributed to the elements of this article/manuscript as follows:

A. Has essentially done all the work
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C. Equal contribution
D. Minor contribution
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PAPER II

Smart interactive packaging as a cyber-physical agent in the interaction design theory: a novel user interface

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Smart Interactive Packaging as a Cyber-Physical Agent in the Interaction Design Theory: A Novel User Interface

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Abstract. The emerging infrastructure of cyber-physical systems consisting of everyday items, as product's packaging, and advanced digital communication devices opens a new digital dimension for interaction and user experience. Consequently, the concept of human-packaging interaction goes beyond the pragmatic aspects of physical packaging attributes, and, in turn, embraces the potentials of ICT systems. Due to the new forms of human-packaging interactive systems, designers have to address the relevancy of the interaction design and the complexity in the relationship between consumer behavior and interactive system design, i.e. digitally-enhanced packaging. Therefore this research aims to describe the digitally-enhanced packaging as a digital interactive system in regards to the theories of human-computer interaction, interaction design, and user-centered design. In this paper, the critical elements of the interactive packaging design are described. This study concludes that for the interactive systems to be effective and used, designers have to build not only a reward-based, intuitive and simple interaction design that would persuade users to take actions, but also they have to think of other mediate interactions, internal and external resources that are significant to reach the final aim.

Keywords: Human-packaging interaction · Smart interactive packaging · Interaction design · Cyber-technical systems

1 Introduction

Within the exponential growth in the application of computer systems, a wide range of all sorts of artifacts and interfaces have arisen ranging from mobile devices and domestic appliances to vehicles and whole houses [1]. The given access to these gadgets by information and communication technology (ICT) made communication more advanced and diverse. Today the consumer market brings into play many miscellaneous digital interfaces to create the interaction between consumers, products and brands to deliver unexpected and unique experiences [1]. Product packaging also became one of such digital interfaces.

Out of the many roles packaging has to perform, the user interaction is likely to have a profound effect on packaging innovation [2]. Packaging, also referred as 'communication surface', 'an extended user interface', 'communication medium', 'contact point', or 'silent salesman' encounters consumers daily through various visual and tactile

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interplays [3]. The communication between the user and packaging occurs in every step of the supply chain, including producer, distributor, retailer and end consumer [4]. The current research on human-packaging interaction (HPI) [5, 6], also called as user-packaging interaction [4] or consumer-packaging interaction [3], investigates either the ergonomic- or marketing-concerning factors. The former is related to the handling and usability of packaging and the utilization of the packed product [6], whereas the latter is associated with the visual appearance of the packaging [4] in terms of physical attributes as color, shape, material or typography. However, the emerging infrastructure of cyber-physical systems, induced by advanced wireless communication devices and IoT, opens a new digital dimension for interaction and user experience [7] and goes beyond the pragmatic aspects of HPI. Consequently, traditional passive packaging is able to embrace the digital transformation and become network-connected [8] due to applied a wide range of mobile, digital and wireless communication technologies. As these technologies improve, the new forms of human-packaging interactive systems appear, and thereby designers have to address the relevancy of the interaction design in relation to the complex relationship between the consumer behavior and interactive system design, i.e. digitally-enhanced packaging [9]. Therefore this research aims to (i) describe the digitally-enhanced packaging as a digital interactive system in relation to the theories of human-computer interaction, interaction design, and user-centered design, and, in turn, (ii) investigate what are the key elements of designing an effective interactive packaging design.

This research presents the work in progress and it is based on literature review focused on articles related to human-packaging interaction, HCI, interaction design, and user-centered design. This study creates a link between the everyday item, as product's packaging, and interaction design of HCI systems.

2 Theory

2.1 Smart Interactive Packaging

Generally, product packaging can be perceived as: "a socio-scientific discipline which operates in society to ensure the delivery of goods to the ultimate consumer" [5]. It is also defined as a combination of product, package, and distribution which is intended to provide the functions of protection, convenience, containment, and communication [4, 10]. However, the importance of the packaging role and the improvement of its functionalities have increased over the years due to changes in market globalization, demographics, lifestyles and consumer preferences [11]. Having in mind that packaging already served as an effective means of communication medium [10], recent advances in printed electronics, conductive printed materials, and wireless communication devices improved the communication function even more. This transformation allowed packaging to enter digital innovation and become network-connected [8]. As a result, smart interactive packaging goes beyond the traditional one-way informational flow and triggers the unique interaction capability between the package and consumer. Reference [12] contributes and states that integrated printable circuits onto consumer packaging would add to products such features as brand protection, customer feedback and visual product

enhancement. Connected packaging ability to collect and analyze data empowers brands to understand the effectiveness of the packaging/product and consumers' engagement better, and dynamically adapt to emerging needs by improving their services and products. Therefore, the design of smart interactive packaging, as an interactive system, has to take into account both the insights of the interactive design and user experience.

2.2 Interaction Design of Digitally Enhanced Packaging

With the increasing use of the Internet, home and leisure computing, and digital interactive consumer products, the two disciplines of engineering and design merged due to a common goal to amplify discretionary use and user experience [13]. The perspective of the user and the context of use went beyond the traditional computer and mechanical systems and started to penetrate into products and environments people interact with in daily life [5]. Consequently, the user-centered design has broadened to other cultures that gave new opportunities for consumer industry and brand owners.

The popularization of consumer-oriented ICT systems lets designers create special moments and environments giving brands the opportunity to have in-depth communication with their consumers filled with emotional and sensorial facets. As a result, it forms an exceptional link between customers and manufacturers [1]. However, the success of creating this bond depends on whether the designed artefacts and environments can offer a pleasing interface with the user [1]. Therefore, the main aim of interaction design is to: "create interactive products and systems which are usable – easy to learn, effective and pleasant to use" [1]. Reference [14] concurs and states that interaction design has been aroused by increasing industry's demand for intuitive, effortless and enjoyable computing systems. User-centered design is intended to transfer user needs into products specifications to ensure the satisfaction aspect [5]. Generally, the interaction design combines elements of HCI and user experience design to build overall essence and structure of interactive systems that support and facilitate user's goals for helpful and engaging product interfaces [1, 14]. In other words, interaction design concentrates on constructing the ways users interact with products and systems.

The design of digitally-enhanced packaging, as a digital interactive system, has to follow the principles of interaction design, if the functional and pleasing user experience is the main goal to accomplish [5]. There are four critical elements for enhanced packaging design that is based on principles of user-centered design, consumer experience, HCI, and usability theory presented by [15]: consumer, task, package and context.

Understanding the Consumer

Since consumer experience plays a central role in the interactive packaging design, the investigation of (i) the characteristics of the person including physical and cognitive capabilities, beliefs, habits and previous experience, as well as (ii) the way people respond to a stimulus is needed [5, 15]. Also, it is relevant to understand the user's needs and desires in a thorough manner to design interactive solutions that address these needs precisely [16]. Furthermore, the user's perception is built during the interaction with packaging [4]. Once an interactive system is able to find the best way

to engage with its user, stronger emotional and memorable reactions are provoked that might result in higher efficiency and recurrent use of the interactive system [17].

The Task

Interactive packaging design has to consider the series of actions and goals to be performed and accomplished by the user that interacts with the package [15]. In regards to HCI, these tasks go further from conventional actions carried out with packaging as opening, handling, reading instructions, disposing [4], and involve a new set of interactive activities related to ICT systems, where users, for example, have to bring their mobile devices to scan the package, download an app, enabling specific communication settings to enable the consumer-packaging interaction [18].

The Package

Digitally enhanced packaging can be embodied with various digital communication electronics, thus the design and integration of these objects of interaction should also be taken into account. Reference [7] refers to such packaging as a hybrid digital physical object consisting of Cyber-Physical Systems, Cloud Computing and IoT. Cyber-Physical Systems, like microprocessors, sensors and actuators can be embedded into objects, like product's packaging, and the interaction will happen not directly with the digital device, but with ordinary everyday objects with concealed digital technology [7].

The Context

Another critical element of HPI is the identification of specific stages, context or touch-points, where users interact with packaging in order to support designers and manufacturers and help them understand the elements necessary at each stage of interaction to evaluate, modify or develop packages that would achieve targeted goals [4]. The first stage of the interaction occurs in the distribution system, including warehousing, transportation, and stacking. Due to ICT, packaging with integrated RFID tags can improve real-time location tracking and, in turn, ease logistics operations, whereas packaging with smart temperature, pressure, or shock sensors can register accidents during distribution and handling allowing users to re-evaluate the most efficient means of transportation and the best conditions for it [8]. The second stage takes place at the point of purchase, where packaging reaches the retailer and thereby it has to fulfill a set of new communication activities to draw attention, convince or persuade consumers to purchase the product [2]. At this stage, for instance, light emitting devices or capacitive touch sensors added to the package's exterior design provide distinctive characters as flashy and multisensory effects that may add value to the product and trigger momentary and instantaneous desire to purchase it due to peculiar visual appearance [17, 18]. Finally, once the packaging is bought, it lives at consumer's home and becomes a part of their life, therefore more tactile-based in-depth interaction happens during consumption and utilization of the packed product [3]. Contrary to visual awareness, usage after purchase might give an impulse to the emotional and physical connections to the product and the brand [17]. Sensory, emotional and social sensations induced by IoT-enhanced packaging providing insights of user consumption behavior to improve his/her health condition can be the building blocks for better engagement and entertainment. As a result, this research put emphasis on the last two stages of consumer-packaging interaction, in-store and at-home, due to their particular importance for user-centered design, user experience and interactive activities.

3 Cases of Smart Interactive Packaging

In this section three conceptual cases of digitally enhanced packaging will be described including emphasizing the perspective of user-centered design, instead of technological capabilities of the interactive system. The described cases will be used for more in-depth assessment in regards to the HCI and interaction design in the discussion. Furthermore, each case is summarized in Table 1 according to the four-elements-based framework of user-centered and HCI-supporting packaging design presented in the theory section.

3.1 Olive Oil Package with Attached NFC Tag

The credibility of the source the product was obtained from could have a higher impact on persuading the consumers to purchase a product [18]. Therefore the interactive visual demonstration of the origin of the food product, as olive oil, as well as the conditions and the environment of the plants and harvest might trigger instant decision to buy the product. Cyber-Physical Systems can bring the consumers during their grocery shopping closer to the olive tree plants in sunny southern Italy. The olive oil packaging with incorporated NFC tag can redirect the shopper to a website of the olive oil producer filled with photos and videos of the farming site by a single scan on the package with a mobile device.

3.2 Cereal Package with Integrated NFC Tag

Although marketing is considered as a secondary function of packaging, in the retail environment it plays a significant role in convincing shoppers to take the item out of the shelf and place it in their shopping bag [4]. One of the highly persuading marketing techniques is the coupon, voucher or discount system. A cereal package with an advert "tap me with your phone and get 10% to milk", for instance, in exchange of the email address, would give higher changes that the products will be bought since cereals and milk are usually consumed together. Likewise, by tapping on a NFC tag attached to cereal packaging, users can download a discount code or voucher valid for a particular period.

3.3 Mouthwash Bottle with Smart Sensors

As mentioned earlier, at the stage of product usage it is more likely to make strong emotional, sensory and social connections to the product and brand. However, more pretentious aims require higher consumer interaction resulting in continuous and long-lasting activities/tasks. Likewise, the more time the activities take, the more sophisticated ICT systems are enrolled in the overall interactive system design. In this case, Cyber-Physical Systems, as smart capacity sensors, Cloud Computing and IoT cooperate for better engagement [7]. A smart capacity sensor incorporated in the mouthwash lid can estimate how much of the product is left, then collect, transmit and analyze the data to build a personal profile for a user to track his/her usage history and dental

hygiene habits. The interactive system can contribute to the user's well-being and encourage healthier behavior in a form of reminders.

Table 1. The summary of each packaging case

Package	Users	Tasks (few examples)	Context
Olive oil package with attached NFC tag	Grocery shoppers Olive oil users	Enable NFC settings Download the app (iOS) Find symbol and scan/tap	In-store
Cereal package with attached NFC tag	Grocery shoppers Cereals users		In-store
Mouthwash bottle with smart sensors in the lid	Dental hygiene supporters	Download the app Consume the product Track personal profile React to reminders	At-home

4 Discussion and Conclusion

The aim of this section is twofold. The first part will describe and illustrate how digitally enhanced packaging as a digital interactive system fits the overall HCI and interaction design theory. The second part will present the five steps approach that should be considered when designing a successful interaction packaging design.

4.1 The Design of Digitally Enhanced Packaging

In relation to the interaction design theory presented by [19], the design of smart interactive packaging usually encompasses (i) the human agent, i.e. the consumer of the product, (ii) the computational agent, i.e. the mobile device, and (iii) the cyber-physical agent consisting of a physical product packaging and digital communication devices (Fig. 1). In this model of interaction, the computational agent is an intermediate part between the human agent and cyber-physical agent. In other words, the interaction between the human agent and the cyber-physical agent can only be granted by the computational agent. For instance, in the presented case of olive oil packaging, the shopper first has to interact with the mobile device (to download the app, enable settings, unlock the screen, and other), and only then tap with the device of the package.

On the other hand, this sequence of interactions and the involvement of different agents highly depends on the ICT system incorporated into packaging design and could be done the other way around, i.e. human agent-package-mobile device. For example, packaging with printed capacitive touch buttons will induce direct human agent-packaging interaction, and a mobile device could be used to display the digital content aroused by this interaction.

Fig. 1. The interacting agents in the interaction design of digitally-enhanced packaging

4.2 The Five Step Approach for Interactive Packaging Design

There are five critical concerns that should be addressed when designing a successful interaction packaging design:

1. *Why the user should take action or perform a task?*

First designers should think carefully how to encourage consumers to use technologies [18]. Because it is a consumer that chooses to download or open a mobile application or not in order to obtain digital packaging experience [18]. In this stage, according to [18]: "marketers must first convince the consumer to use their application before convincing them to buy their product". Therefore, in order to take action, consumers should get a stimulus from the environment [1], an implied benefit upon completion [19] in the form of a particular reward. Consequently, if the user is satisfied with the reward, it can contribute to continued and enhanced usage of the interactive system [9].

2. *Is the overall design intuitive and simple to use?*

For successful implementation and acceptance of a system, users have to be consciously aware what actions to take [19, 20]. For instance, the graphic design of the interactive system must clearly state where to scan or tap with the phone, which mobile application to download and etc. Also, actions have to be simple and intuitive, because the design of any interaction has to consider the human agent's inherent capacity to accomplish this task [19]. As a result, the designers have to build simple, fast and intuitive actions that could be carried out without mastering any extra skills [20].

3. *What other interaction might appear in the process of accomplishing the main interaction?*

The modelling of the interaction space that surrounds the new interaction designers wish to create is significant and consists of the two main steps [19]. First, other agents that will be local to the new interaction have to be indicated, and then their likely effects on the new interaction have to be examined [19]. The comprehensive analysis of other mediated interactions enhances the chance for the main interaction to succeed [19]. In the context of the interactive packaging system, the main interaction is between the consumer and product packaging. However, other forms of mediate interactions, such as user-phone or phone-packaging, have to be taken into account in order not to

subvert the main interaction. As a result, it is crucial to keep the user motivated during all steps of interaction to reach the final aim [19].

4. *What other internal and external resources are needed for accomplishing the interaction?*

Designers have to take into account and build all internal and external ICT systems that support and are directly related to the core interaction. In terms of smart interactive packaging, the internal resource could be a mobile phone that enables the user to perform a task, i.e. tap on the package and read the NFC tag. Whereas, the external resource could be a QR code printed on the package to download the app for NFC tag reading. Also, one should consider that such internal or external agents have their own tasks, cost, benefit, and limitations [19]. Therefore, the implied benefit upon the completion has to be greater than the cost of resources in order to induce the human agent that all actions are worth doing [19].

5. *What other attitudes, intentions and motivations of user have to be incorporated into overall design?*

The design of information and communication system has to consider the people who will use them [19]. User-centered design demonstrates a great importance in the design process, thus designers have to investigate their potential users attitudes, intentions, motivations, and inspirations [19]. According to the author, the user research with the aim to ascertain their goals has to be carried out before creating interactions.

Based on the findings, it is apparent that for the interactive systems to be effective and used, designers have to build not only a reward-based, intuitive and simple interaction design that would persuade users to take actions, but also they have to think of other mediate interactions, internal and external resources that are significant to reach the final aim. New insights of consumer packaging as a digital interactive system are expected to have significant practical implications for brand owners and retailers that aim to improve their consumer engagement and make memorable, long-lasting connections. Especially, in these days, when people are always connected to the Internet, new forms of interaction with purchased goods via ICT technologies might turn into unique business models to improve consumer satisfaction, perception, and loyalty.

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PAPER III

Extended User Interface: NFC-Enabled Product Packaging for Enhanced User Experience

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Extended User Interface: NFC-Enabled Product Packaging for Enhanced User Experience

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Abstract. User-centered physical-digital systems let designers create interactive interfaces filled with special moments and experiences, giving brand owners the chance to have profound communication with their consumers. In fact, product's packaging has recently begun to investigate as one of such interfaces to form a strong link between manufacturers and their end-users. Microprocessors, sensors, actuators and wireless data-exchange supporting chips can be embedded, into packaging design creating an extended user interface – a touchpoint for a visual, tactile and digital encounter with consumers. Near Field Communication (NFC) is one of the rapidly increasing technologies that researchers begin to investigate as a potential tool for enhanced consumer-brand communication. However, although NFC is available in the market since late 2010, the technology is still not widely applied to the packaging industry. As a result, the main purpose of this research is to investigate the current state-of-the-art and potentials of NFC system. The results of this study provide a systematic review of NFC characteristics, including technological capabilities, consumer- and brand-oriented benefits, and technology- and user-centered potential barriers for NFC to become widely accepted. The findings of this study are expected to contribute to a better understanding of the effectiveness of NFC-enabled packaging, allowing brands to dynamically adapt to emerging consumer needs by improving their products and services.

Keywords: Near field communication · Smart packaging · Technological capabilities

1 Introduction

In the recent years, the accelerating adoption of enabling technologies, such as Internet of Things (IoT), cloud computing, augmented reality, smart sensors, touch-sensitive surfaces and gestural interfaces, has induced the emergence of interconnected systems, where smart, sensory and interactive objects communicate among themselves, as well as with their users [1, 2]. At the same time, the cost of the tools needed to connect products to the internet has dropped down to enable the continued growth of the Internet of Everything [1]. As a result, the increasing use of the internet and the development of interconnected digital-physical systems have merged engineering and design due to a common objective to enhance user experience [3]. Consequently, according to [4], the

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concept of Human-Computer Interaction (HCI) has gone beyond the traditional mechanical computer systems and begun to penetrate into everyday objects and environments people are in touch with in their daily life.

User-centered physical-digital systems let designers create interactive interfaces filled with special moments and experiences, giving brand owners the chance to have profound communication with their consumers [5]. In fact, product's packaging has recently begun to investigate as one of such interfaces to form a strong link between manufacturers and their end-users [6–8]. Microprocessors, sensors, actuators and wireless data-exchange supporting chips can be embedded, laminated or directly printed onto packaging design creating an extended user interface – a touchpoint for a visual, tactile and digital encounter with consumers.

Although the traditional passive packaging already served as an effective communication medium [8], advances in conductive ink and nanomaterials, printed electronics techniques and ICT allowed packaging to enter digital innovation and become connected. In this work, such packaging is referred to as Smart Interactive Packaging. The latter provides an interactive dimension between the consumer and the brand with the help of informing and measuring sensors, light-emitting displays, standardized communication protocols and other electronic elements that increase the design freedom for new packaging applications.

Near Field Communication is one of the rapidly increasing technologies that researchers begin to investigate as a potential tool for enhanced consumer-brand communication. In general, NFC is a standard for a wireless data transmission that provides secure, short-range, and paired communication capability between devices triggered by a simple touch [9]. However, despite the fact that NFC is available in the market since late 2010, the technology has not yet reached its way to enhanced consumer engagement through the product's packaging. Even though the technology has been already commercialized, it is still not widely applied to the packaging industry. As a result, the main purpose of this research is to investigate the current state-of-the-art and potentials of NFC system, including the overview of the main characteristics, technological capabilities, benefits, and potential barriers for NFC to become widely accepted.

2 Methodology

This research methodology employs multi-method research approach to combine the current theoretical knowledge about NFC technology from the scientific literature with real-world empirical cases to expand the understanding of both theory and observed phenomena [10]. As a result, the study is based on a systematic literature review focused on scientific publications related to the topic of Near Field Communication and its application, particularly for smart packaging. Moreover, this research employed a set of empirical examples from the industrial cases of diverse NFC technology providers collected by desk research (including product datasheets, technical reports, press releases, whitepapers), direct observations and semi-structured interviews with companies' representatives during the attended industrial events. Practical industrial data was needed to verify current NFC specifications, to broaden the scope of collected knowledge, and increase data triangulation.

Literature review used the keyword-based search approach in the largest databases of peer-reviewed literature, namely Scopus and Web of Science. A wide range of keyword variations was used to come up with the best combination yielding publication results concerning and related to the selected research scope.

During the keyword search, a few insights were gained that allowed to limit the search process. For instance, the abbreviation of NFC also refers to fluorescent nanofibrillated cellulose/carbon dot (NFC/CD) that is also present in the packaging research, and therefore in order to prevent confusion and irrelevant research outcomes, the abbreviation was changed to the specific phrase of "near field communication".

Another observed insight was that packaging could also be referred to electronic packaging, where research is carried out in regards to sophisticated electronics systems. Therefore it was decided to limit the search specifically to product packaging.

Also, some publications related to materials science and fabrication of the NFC, as [11–14], were included only to support the theoretical background of the research in terms of NFC components.

Moreover, a handful list of research [7, 13, 15–17] investigates NFC as a way to communicate sensor information in regards to food spoilage, track and trace, monitoring of the package surrounding environment.

However, this study aims to take a more novel approach and investigate NFC potentials substantially related to enhanced consumer, retailer and brand experiences, such as engagement and entertainment, confirmation of authenticity, prevention of counterfeiting and grey market division. It has been an increasing interest from the industry for anti-counterfeiting and entertaining capabilities provided by NFC technology [18–24], therefore the search was narrowed down to these specific experiences. Also, several studies [25–27] have been selected to include that identified factors facilitating or impeding the adoption of NFC technology and consumer acceptance of NFC system.

The final determined limitation was not to take into consideration the mobile payment possibilities with NFC since a significant number of researches towards NFC and user experience is done in terms of contactless payment.

The outcomes from systematic literature review based on keyword search and empirical data collection yielded results presented in this paper as (1) an overview of the main components of NFC system, (2) a list of technologies capabilities provided by NFC attached to product packaging, (3) a list of contributed/created consumer and brand experiences, (4) an overview of potential barriers for NFC to become widely accepted.

3 Theory

3.1 From Passive to Connected: Smart Interactive Packaging

Nowadays, the consumer market brings into play many different digital interfaces to create the link between consumers, products and brands in order to deliver unexpected and unique user experiences [5]. Recently, product packaging also became one of such digital interfaces. The emerging infrastructure of digital-physical systems consisting of everyday items and advanced wireless communication devices, such as wireless networks, light-emitting devices, smart sensors and tags, opens a new digital dimension for human-packaging interaction (Fig. 1).

In general, the packaging is defined as a combination of product, package, and distribution, which is intended to provide protection, convenience, containment, and communication throughout the entire supply chain until goods reach the end-user [8, 28]. However, recent advances in enabling technologies improved the communication function profoundly and allowed the packaging to become connected. As a result, such packaging improves the traditional one-way information flow and triggers continuous interaction between the consumer and the brand [29]. Therefore we define smart interactive packaging as packaging that provides an interactive dimension between the consumer and the brand with the help of various enhanced communication devices, where the user initiates the interaction willingly to get some response.

In fact, there are several different environments/touchpoints, where users-packaging interaction takes place: manufacture, distribution system, retail or in-store, and at-home. This study investigates human-packaging interaction enabled by NFC technology in retail and at-home settings – the environments that are likely to benefit the most from of NFC systems. The following section will provide more detailed information about the main characteristics of NFC technology.

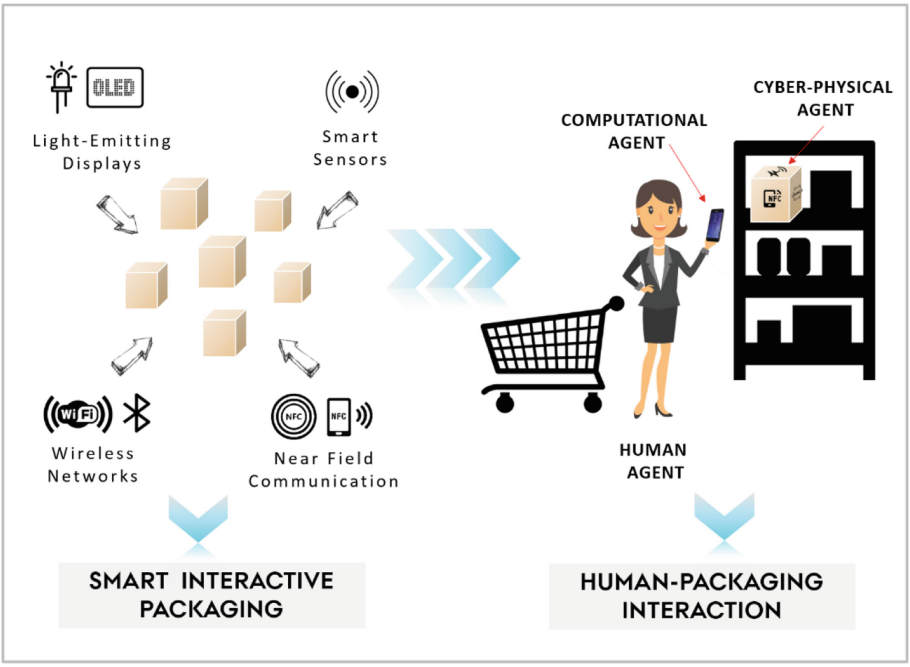

Fig. 1. Smart Interactive Packaging as interactive system that includes actions from the human agent, computational agent (mobile device), and cyber-physical agent (packaging).

3.2 Near Field Communication

In recent years, different types of short-range communication technologies have been integrated into smartphones, including Bluetooth, infrared transceivers, RFID, and NFC [25]. The former is currently perceived as one of the most promising technologies for mobile devices in the coming years [25]. Although NFC has existed for more than a decade, it has just recently come into the surface with the remarkable growth of the Internet of Things [16].

In general, NFC is a standard for a wireless data transmission that provides secure, short-range, and paired communication capability between devices triggered by a simple touch [9]. NFC technology is based on the ISO/IEC14443 protocol. It operates at 13.56 MHz frequency with a maximum transmission speed of 424 kbit/s within an operation radius of 4 cm (up to a maximum of 10 cm) to create a peer-to-peer network for sending and receiving information between the initiator and target [11, 30]. In the NFC system, the initiator or the reader is always an element that actively functions, e.g. mobile device, whereas the target or receiver is usually a passive element, such as NFC tag [31]. In order to initiate the data exchange, the target (NFC tag) is placed in the magnetic field created by the reader (mobile phone), the tag antenna harvest energy received from the mobile device to wake the tag up, and data is then sent to the reader using a standardized format created by NFC Forum called NFC Data Exchange Forman (NDEF) [16]. NDEF permits to storage and transport various types of information, like Uniform Resource Locators (URLs), Record Type Definition (RTD), or Multipurpose Internet Mail Extensions (MIME) messages [31].

Currently, NFC applications are widespread in transport cards, door access, contactless payment, and other mediums where simple data as an identification number or text is exchanged securely and promptly between devices without pairing [16]. NFC technology is becoming more commonly used for various purposes for product packaging as well. First of all, food and beverage packaging industries utilize NFC tags to read, store and transmit data from oxygen, relative humidity, temperature and other sensors to monitor the conditions of the packaged products to ensure their quality [7]. Also, packaging can be equipped with an NFC chip to provide brands with an additional level of protection by enabling traceability and authenticity of the product, especially to fight against counterfeiting [6]. Finally, digitalizing products via NFC technology allows personalized and customized mobile promotions and reward-based interactions to increase product perception and brand loyalty [6].

Below, in Table 1, there is a list of NFC technology providers that manufacturer, create and build various elements or services related to NFC technology. Some of the given providers present fully-integral NFC systems, where all physical and digital components are developed in-house. On the other hand, other providers specialize in specific NFC system elements. For instance, NXP's expertise lies in NFC chips, whereas Avery Dennison specializes in printed NFC antennas and inlays. Providers are also establishing collaborations to create joint technological solutions.

Table 1. The summary of NFC providers (retrieved from products' datasheets [32–39])

Provider	Key NFC technologies	Main capabilities
Thinfilm	OpenSense™ and SpeedTap™ NFC tags, opening sensors	Refill fraud, anti-counterfeiting, identification, track and trace, authentication, tampering, real-time monitoring
NXP	NTAG 213, NTAG® 424 DNA & DNA TagTamper, sensors (touch, magnetic, capacitive, motion, pressure)	Cryptography, secret keys, authentication, tampering, real-time monitoring, refill fraud, anti-counterfeiting, cloud-based services
Toppan	CorkTag™, Cachet-Tag™ with antenna circuit, InTact, OD Tag	Detection of removal and piercing of the cork, prevention of fraudulent re-labelling, cork protection, authentication and opening detection
Avery Dennison	AD-740/750 NFC Wet/Dry Inlays, T Sensor Plus™ NFC tag	Temperature data logging, originality signature, automatic serialization NDEF messages, password protection, fraud prevention, unique 7-byte serial number
PragmatIC	ConnectIC®, FlexIC®	Flexible integrated circuits, item-level monitoring, grey market, authentication, gamification, promotional offers
Identiv	NXP ICODE® SLIX, NXP ICODE® SLIX HC, ST SRI	Consumer interaction, brand protection, product integrity, status awareness, anti-counterfeiting, authentication, physical security
Stora Enso	Bobbin NTAG213	Authentication, password protection, targeted marketing, consumer engagement and experience
WISeKey	WISeCryt™ based digital authentification, NanoSeal®	Anti-counterfeiting, authentication, brand loyalty, consumer insights, access control, tamper/opening detection, traceability, maskable identifier

4 Results

Technological capabilities of NFC system have been divided into three main groups: data and information services, security services, and other services (Table 2).

4.1 Data and Information Services

Data Storage. As discussed in the theory section, the NFC tag mainly consists of a chip and antenna. The majority of technological capabilities provided by NFC technology rely on its chip. NFC tags specifically designed for smart packaging application usually comprise Read/Write memory size of between 144 and 888 bytes and they are wirelessly powered by a smartphone [11, 33]. NFC tags can store NDEF (NFC data exchange format) data in the form of URL, telephone number, geolocation, SMS, plain text, network connection and similar that makes them fully compatible with every NFC-enabled smartphone and the entire ISO/IEC 14443 infrastructure [33]. As a result, the very primary NFC functionality is to store encoded/written data in heterogeneous formats. Usually, the product-specific or customer-specific data is already encoded in the chip before the tags are shipped to the manufacturer [32].

The most common type of stored data is the URL that redirects the user to particular content, in most cases, hosted by the brand owner's CMS [32]. Consequently, NFC provides novel opportunities for brands and retailers to communicate engaging and dynamic content, such as more explicit product information, proof of legitimate distribution, region and year of production, recipes and etc [34, 40], in different means of media. For instance, NFC tag attached to a wine bottle can contain information about the product's origin, traceability, or even all processes followed up for its fermentation [18].

Data Collection. Some of the data not only can be encoded/written in advance but also it can be collected during the entire life-cycle of packaging. The combination of sensing devices and NFC connectivity allows the autonomous data collection. The collected data is uploaded securely into the cloud via NFC by a simple tap with a smartphone [33]. There are various smart sensors that can be incorporated in the overall NFC integrated circuit to monitor conditions such as relative humidity, shocks, vibrations, oxygen levels, temperature and similar, and, in turn, to collect the quantitative data of the current status of the packaged product and its surrounding environment [7, 33]. For instance, reference [15] fabricated a flexible system of NFC and sensing devices that collected data regarding ammonia (NH3) and oxygen levels in the meat packaging. Similarly, reference [17] demonstrated an NFC-enabled sensing system that was able to detect and collect the data about the level of water-soluble gases in the packaging atmosphere.

Data Logging. Another method of data collection is manual or autonomous data entry by human agents. Even though this activity might happen in every process of the supply chain, NFC technology due to its short-range reading capability is mostly related to data entry or logging that happen in the retail and at-home environments. Therefore, marketing campaigns in-store are increasingly interested in NFC capabilities for instantaneous feedback, streamlined data collection and entry that allow capturing real-time consumer interaction with products [40].

Data Transmission. Once data is stored, automatically collected or manually entered, it can be transmitted, read or exchanged between devices upon the initial request from the human agent, commonly, to receive access to the respective additional information

[7, 30]. Data from sensors not only can be collected but also be read by NFC reader to retrieve the information in a visual form on the smartphone's screen [13, 41]. According to [7] more recently, NFC has been adopted as main technologies attached to the packaging for the reading of the sensors and the transmission of data by a remote NFC reader.

Furthermore, data transmission is becoming more favorable in the retail setting, where shoppers can check and obtain diverse data about the products, for instance, the availability or stock information directly at the point of sale with their NFC-enabled smartphones [19]. When the NFC tag is positioned in the RF field, the transmission of the data is around 106 kbit/s [33]. In terms of peer-to-peer communication, NFC Simple NDEF Exchange Protocol (SNEP) permits an application on an NFC-enabled device to exchange (NDEF) messages with another NFC Forum device while operating in NFC Forum peer-to-peer mode [42]. This protocol utilizes particular connection-oriented transport modes to ensure a reliable data exchange that, for instance, is essential for voucher transmission [42].

In practice, all the sub-functions of data services capability are connected and operate in succession. For instance, Bon-Ton, a regional, departmental store company, launched an initiative to inform shoppers about the current stock status of particular sizes of [40]. First, the data about the inventory was stored and continuously updated in the NFC chip and the database. Once the consumers tap on the NFC-enabled packaging, the data transmission is initiated and the specific information, if a specific size shoe is in stock or not, is provided. NFC-enabled packaging provides shoppers with access to information through their mobile devices [43].

4.2 Security Services

Identification. Currently, the majority of NFC applications contain simple data such as an identification number or text that are exchanged immediately and safely between two devices [16]. Similarly to barcodes that contain the International Article Number (EAN), RFID tags are designed to store the Electronic Product Code (EPC) – a standard for automated item-level product identification [19]. In the last decade, there were many attempts to develop a solution of NFC that uses HF frequencies to be compatible with EPC [19, 44]. At the moment, NFC chips store a unique identifier that provides the capability to be uniquely identified in through the Internet or managed in a supply chain [18, 20, 45]. As a result, NDEF on the NFC tag can store unique (serialized) identifiers in Unique Resource Identifier (URI) format [19], or Unique Identifier (UID) format [33]. For example, in the manufacturing line, Industrial Line Manager (ILM) consisting of a computer and NFC reader can detect any thresholds and deviations from accepted standards by reading product/packaging information written in its tag's UID [34].

Validation and Redirection. In regards to validation and redirection, UID is closely related to database and cloud services, where identities of items are protected and controlled, giving each product a persistent, addressable web-based presence [32]. For example, NXP provided NFC solutions use could services that are accessible using standard RESTful APIs to permit straightforward and prompt integration into brand owners

database/business intelligent system and software [32]. In other words, validation and redirection processes link products to manufacturers' digital platforms. As a result, NFC tags obtain a specific code that allows brands to identify and launch a unique experience for each individual package in-store [37].

Authentification. NFC-enabled intelligent packaging applications encompass a wide variety of other technological capabilities related to product's security and authenticity [31, 46]. Contrary to a prime understanding of authenticity as an action for authenticating who is accessing the information, smart packaging applications are more about the user aiming to know that the system, in this case, a product, is a product it claims to be. Consequently, some research has already been carried out to analyze the potential of NFC technology as means of the authenticity of the product [22, 45, 47, 48, 55]. According to [48], NFC tags grant a simple, small-sized and secure way to verify the genuineness of the product. NFC technology permits any object to securely authenticate itself and communicate this information online through NFC readers [39]. Currently, smart packaging contains NFC tags that are not only capable of detecting counterfeits, grey-market products, and tampering, but also implement secure marketing campaigns by assuring that only requests originated from authentic tags are forwarded to brand's web systems [32, 45]:

- Anti-counterfeiting. Counterfeit products are one of the main threats to commerce accounting up to 5–7% of all world trade goods and global economic value of over $ 865 bn [45, 48]. The development of consumer-centered NFC tags allows shoppers to determine the legitimacy of a product at the point of purchase, and, in turn, enhances direct-to-consumer digital strategies [45]. EPC standard can be used as an anti-counterfeiting measure by tracking the physical location of a tag and uploading the results in the database [45]. Consequently, product diversion can be detected by a simple scan and reported directly to the manufacturer contributing to grey market prevention [34].
- Tampering. Product tampering is another threatening factor to modern commerce. Diverse tamper-related incidents might happen in the entire supply chain that can be handled and controlled by adherence of NFC tags, including prevention of fraudulent re-labelling, opening detection/unopened product proof, refill fraud, detection of removal and piercing of the bottle cork, and other fraudulent events [33, 34]. For instance, once the wine bottle protective cork foil is removed, a brittle antenna circuit is damaged, and the tag is unreadable that might indicate a refill fraud.

Encryption. Another, more sophisticated, anti-counterfeiting approach is based on cryptography [42, 45]. In this method, each tag contains a secret encrypted value that is unreadable by anyone who does not possess a decryption key [45]. In general, this approach utilizes an encrypted challenge-response protocol and may be based on symmetric key or asymmetric key cryptography (or Public Key Cryptography (PKC)) [45]. In-store environment, where shoppers use their smartphones to read NFC tags, PKC is preferable for authentication purposes [22].

There are to main categories of counterfeiting prevention based on cryptography: off-line and on-line [45]. The former encompasses no shared secret between the NFC

reader and the tag attached to a product, i.e. if the tag's contents are verified, and the tag is authenticated, the packaged product is presumed to be genuine [45]. The latter contains secret information shared between the reader and a tag, i.e. in order to determine the authenticity of a product, the reader requires access to a server containing a database of secrets [45].

NXP developed cryptography solutions in NTAG™ 424 DNA and NTAG 424 DNA TagTamper support relevant cryptographic operations and offer trust provisioning services, including creation, provisioning and managing of (1) customer dedicated keys in hardware secure modules that have access to master secrets, (2) secure key exchange and management, (3) SUN (Secure Unique NFC) message and encrypted SUN message verification, (4) tamper message verification (5) mutual authentication [32]. Such advanced security solutions: encrypt all critical data in transit and storage, protect access to target URL or tag memory, protect the master secret against malicious attacks or breaches, permit logging of data requests and changes, detect valid/invalid authentication request, provide patent ending dynamic cryptographic digital signature [32]. To summarize, based on NXP developed products, NFC uses symmetric cryptography with secret keys for encryption and decryption to protect the information, therefore whenever a key exchange is needed, it is done with encryption applying a secure communication channel [32].

4.3 Other Capabilities

Coupons and Vouchers. NFC technology proposes several diverse opportunities for brands and retailers to interact and engage with consumers with promotional efforts, especially couponing [24, 30, 40]. Reference [42] states that "the system is responsible for diffusion, distribution, sourcing, validation, redemption and managing of vouchers, loyalty cards and all kind of mobile coupons using NFC". The potential scheme of the NFC-coupon system might be as presented by [42]: at the point of sale, the shopper uses his/her smartphone to touch the NFC-equipped product to redeem a voucher, then the information is read from the smartphone and sent to the server for the voucher validation, once the validity is confirmed, the voucher is sent to the shopper.

NFC technology also employs location-based promotional offers, when users receive coupons on their mobile phones depending on their physical location and can redeem them at the offered retail outlet [40]. Furthermore, the NFC-based promotions can also be personalized. Depending on the shopper's previous visits to the stores, time-stamped promotion coupon can be forwarded and displayed on shopper's mobile phone to facilitate purchase decisions, when a shopper enters the store [20].

Loyalty, Bonus and Memberships. With the use of NFC technology, brands and marketers can carry out better customer loyalty programs in several techniques [40]. First of all, if loyalty, bonus and membership cards are stored on the mobile phone, NFC provides a possibility to automatically accumulate points, receive discounts, coupons, priority reservations, special offers, event invitations, product samples or other incentives [30, 34, 35]. Also, NFC allows instantaneous consumer feedback and streamlined data collection and entry [40] that benefits brands with in-depth real-time insight about

their products and enables instant response to a consumer to contribute and enhance consumer loyalty.

Location-Based Services. NFC technology can be used for a wide range of context-aware services, including:

- Previously described location-based couponing, advertising, in-store marketing, and mobile marketing [21, 30, 49]. Once a registered shopper carrying an NFC-enabled smartphone with an app for personalized promotion system comes to a close range of a passive NFC tag attached to any items in the store, the is activated, and its unique ID and its location information is collected to grant a shopper with special promotions [20].
- Transparent tracking in the supply chain [32, 34, 35]. NFC enables traceability solutions relation to serialization, aggregation and data handling to provide real-time supply chain visibility in order to protect brands against grey market distribution, i.e. NFC scan allows to detect item's location at the specific time.

Social Networks. Reference [43] argues that the purchase of a product is motivated by the attempted acquisition of a certain status that is granted by a social reference group. In other words, the buying decision is highly dependent on suggestions and opinions from other consumers, such as friends, relatives, partners, etc., i.e. people tend to seek information before choosing [43]. Consequently, the opinions of others might reduce or increase the perceived credibility of the product [43]. If there is no physical presence of other consumers, the opinions and recommendations can also be derived from social networks. The NFC-enabled system is able to make links with social media to provide first-hand experience and recommendations from others [30, 34, 50].

Energy Harvesting. In general, a passive NFC tag is able to obtain energy from the radio frequency generated from the active NFC reader (smartphone) due to the electromagnetic field induced by the active device [7, 20]. Recently, NFC-based energy harvesting has been attracting more research attention in regards to its promising potential [16]. It might not only be used for data transmission, but also for powering up embedded sensor modules that measure diverse environmental parameters such as pH, soil moisture, temperature, gas concentration, humidity, and similar [16]. Reference [16] has fabricated battery-free smart sensor capable of less than 1 mW of power consumption, thus the energy from active NFC reader is enough to power up the sensor and read its data. NFC-based energy harvesting reduces the system cost by removing the need for a specialized NFC reader [16].

Network Access. The capability to provide network access is twofold. First, NFC technology redirects the user to the web through the encoded links (URLs). Second, users tapping on an NFC tag can also be logged onto a Wi-Fi or connected to a Bluetooth [30].

Device Pairing. By a simple tap, for instance, on a Bluetooth speaker, NFC technology makes the pairing process effortless, and the two devices are securely paired automatically with no need to search for a connection or type a code [30, 33].

Table 2. The summary of investigated NFC technological capabilities

Technological capabilities	Short descriptions
Data storage	To store encoded/written data in heterogeneous formats
Links to URL	To redirect the user to a particular content hosted by the brand owner's CMS
Data collection	To collect data autonomously using sensing devices that monitor different conditions
Data logging	To allow manual or autonomous data collection by human agents (e.g. feedback)
Data transmission	To transmit, read or exchange data between devices upon the initiative request from the human agent
Identification	To store a unique identifier that provides the capability to be uniquely identified in through the Internet
Validation and redirection	To protect and control product identities giving each item a persistent, addressable web-based presence
Authentication	To provide a simple and secure way to verify the genuineness of the product
Encryption	To secure data with secret keys and provide trust provisioning services/cryptography
Coupons and vouchers	To diffuse, distribute, source, validate, redeem and manage coupons and vouchers based on location or personalization
Loyalty, bonus, membership	To implement better customer loyalty programs by automatically accumulating points, providing discounts, offers and other incentives
Location-based services	To grant a user with diverse incentives based on location, and to enable traceability solutions to provide real-time supply chain visibility
Social networks	To provide a link with social media to provide first-hand experience and recommendations from others
Energy harvesting	To enable data transmission and power up embedded sensors and read their data
Network access	To log onto Wi-Fi or get connected to a Bluetooth by a tap
Device pairing	To securely and automatically pair two devices without searching for a connection or typing a code

5 Discussion

In this section, two different matters are addressed: consumer- and brand/retailer-oriented benefits from NFC, and potential user- and technology-centered barriers for NFC to become widely accepted.

5.1 Consumer-Oriented Benefits

Consumer Engagement. By attaching NFC tags to traditional customer engagement mediums, such as signage, posters and packaging, brands can create unique interactions and experiences for their customers [37, 40]. NFC-enabled packaging is able to transform products into a direct engagement channel to connect with shoppers directly at any time [34]. Reference [43] concurs and states that context-awareness technologies and ubiquitous networks provide users with access anywhere and anytime to information through their smartphone with no need of special assistance in the retail environment. As a result, the retail settings are shifting to new forms of store/space filled with increasing use of advanced technologies, such as NFC [43]. These technological innovations impart unique, interactive and entertaining tools to search, compare, and purchase products [43]. Consequently, the progressively increasing use of technologies during shopping may have an impact on consumers' shopping practices and behavior [42, 43].

Fast-moving technology-based shopping experience induced by NFC capabilities allows facilitating such elements as convenience, trust, loyalty or even intent to purchase the product. Previously presented cased of the NFC-enabled packaging for shoes not only converts the package to engaging media but also provides a straightforward and convenient way for customers to get the information about the right size availability [40]. Furthermore, NFC capability to verify authenticity, integrity, safety and quality of the packaged items builds consumer trust in both products and manufacturer/service provider [34, 49]. Finally, context-based NFC technology is also used as a mean to motivate customers to come to stores. Depending on interpreted customer interests in the displayed items, the personal promotion strategies are formulated in order to increase the intent to purchase [20].

Customization. Naturally, the employment of NFC technology allows gathering a vast amount of customer-related information about their preferences, behaviors, and responses [30, 50]. For instance, based on the purchase history from customer's previous visits to the stores, personalized promotion strategies are built and sent to customer's smartphone in forms of coupons or vouchers [20]. As a result, customization and geo-localization have beneficial effects in regards to increased market visibility for brands and products [30], as well as a deeper and more personal relationship with consumers [33].

5.2 Brand/Retailer-Oriented Benefits

There is a handful list of benefits NFC-enabled packaging brings to brand owners, including sales process optimization and increase, brand protection, enhanced brand-consumer relationship, consumer satisfaction and loyalty, and new marketing positions. Reference [19] presented the Mobile Sales Assistant (MSA) system allowing users to instantly check the availability and stock information of products might increase customer satisfaction with a fast and simple experience that, in turn, might can a positive outcome for product sales. Consequently, increased NFC-enabled engagement with consumers can

be directly related to driving sales. Likewise, the combination of digital product authentication and enhanced consumer engagement help brands improve their reputation and maintain valuable relationships with consumers.

On the other hand, NFC-based packaging also creates new forms of in-store marketing campaigns. An example of such campaign given by [20] describes a promotion scheme to increase the number of shoppers visiting the stores, where each checking with an NFC tag provide a bonus mark to the consumer. The accumulated points can be transformed into discount and purchase benefits [20].

Real-Time Analytics. Web-based or cloud-based data management and analytic platform is an integral part of the NFC system. In general, such a platform is responsible for collecting data from consumers using NFC tags and performing advanced analytic techniques to gain meaningful and actionable insights for business development [23, 34]. This platform is capable of providing:

- Real-time analysis of scan/tap activity to measure the effectiveness of the integrated NFC technology [32, 34].
- Real-time analysis of regionally-focused data (geolocation), product status awareness, notification of use-by-date and other [34].
- Real-time analysis of products' performance [32].
- Real-time detection of irregularities related to authenticity, tampering or counterfeiting that can be dealt with momentarily [32].
- Recognized changes in consumers' shopping behavior due to the impact of NFC technology [23, 43].
- Captured real-time consumers interaction with the NFC-enabled product and their experiences based on feedback [34, 35].
- Captured individual consumer engagement to provide personalized and customized promotions [35].

Overall, described capabilities contribute to product and brand data management system, customer content management system, distribution management system, marketing analysis and other with the main purpose of increasing revenue from consumers' repeated purchases due to successful analytics [23, 34]. All the findings from collected data analysis are seamlessly linked to the brand's business intelligent system in order to help gather knowledge to make better decisions and take corrective actions [32].

5.3 Technology-Centered Barriers

Despite all the advanced and beneficial capabilities and benefits of NFC, the technology is still not widely accepted by the end-users or brand owners [26]. It might be related to any technological obstacles, consumer acceptance of the technology, or the economic benefit to implementing the technology into the business model, therefore this section shortly describes the possible and potential barriers for NFC to become widely accepted.

In relation to HCI theory, the design of NFC-enabled packaging, as a digital interactive system, has to follow the main principles of the interaction design in order to create a functional and effective connection between the consumer and the brand. However,

the success of creating this bond highly depends on whether the created digital-physical object can impart a pleasing interface with the user addressing both technology- and human-related factors. Reference [27] concurs and states that the intention to adopt NFC technology is affected mostly by product-related factors, personal-related factors and attractiveness of alternatives. Likewise, reference [26] also distinguishes factors regarding NFC adoption into user-oriented and system-oriented.

Two studies [26, 27] employed the Technology Acceptance Model (TAM) to provide a profound understanding and identify factors facilitating or impeding the adoption of NFC technology. Study [26] identified four system-centric variables beneficial for such adoption, including user mobility, reachability, compatibility, and user convenience. Any issue related to these factors might have a negative impact on the user's decision to use an NFC system [26]. Likewise, study [27] identified six product-related factors: perceived usefulness, perceived ease of use, compatibility, perceived risk, perceived cost, and trialability. However, named factors by [27] are highly related user's belief and perception rather than engineering- and technology-related concerns. Overall, based on both studies, product- or system-related elements seem to have a stronger effect on the intention to adopt NFC systems [26, 27].

In addition, based on the literature review, other more practical/technological obstacles have also been identified, including:

- The stability of the regulated voltage by the NFC chip. According to the authors, there are two external parameters that have an impact on stability: the powering time and the position of the mobile device when it is brought close to the NFC antenna. The chip requires a particular level of the induced electromagnetic field to provide the regulated power supply, therefore not every position of the smartphone can activate the tag. Only a small displacement is permitted to avoid the deactivation [7].
- Transmission speed. Due to low transmission speed (up to 424 Kbps), NFC technology is not capable of large files transfer, therefore it intercommunicates with other wireless networks as Wi-Fi and Bluetooth that permits greater in size transfers [31].
- Battery saving mode. Consumers are used to switching off various settings of mobile apps connecting the mobile device with a service provider to save battery power [40]. It might cause inconvenience during data transmission, as several intermediate steps will be necessary to enable the process, i.e. set up the right settings permitting internet connection.
- Privacy settings. Very commonly due to privacy concerns customers also switch of the permission to always track their geographical location on mobile devices [40]. In this case, personalized promotion strategies might not function as accurate as expected.
- A limited number of devices that support NFC technology [51].
- Awareness of NFC technology. Finally, NFC is still not widely known by consumers, therefore public prominence has to take place before the exponential growth in usage of this communication protocol [30].

5.4 User-Centered Barriers

Since interaction design is about creating the overall essence and structure of products and systems to ensure that they support user's needs, desires, goals, perspectives and

address their problems to provide enhanced user experience in their everyday lives, it is essential that interaction would be intuitive, enjoyable and effortless [52–54]. However, NFC technology has not yet reached its way to enhanced consumer engagement through the product's packaging. Even though the technology has been already commercialized (Seritag, Toppan, Identiv), it is still not widely applied to the packaging industry. The investigated literature addresses several user-related factors regarding the efficient adoption of NFC technology.

Three different studies related to Technology Acceptance Model and NFC that include consumer-related factors very investigated [25–27]. A study by [26] indicated the main two user-oriented factors, i.e. personal innovativeness and NFC knowledge, and two additional belief factors, i.e. perceived ease of use and perceived usefulness. Similarly, reference [25] included a few more concerns: personal innovativeness, convenience, perceived ease of use, perceived usefulness, perceived security, and perceived compatibility. Research by [27] tested two individual constructs, namely innovativeness in new technologies and absorptive capacity, and two additional constructs, namely trust and attractiveness of alternatives. User-oriented factors that are common amongst three studies:

Personal innovativeness. It refers to user's willingness to try out or embrace new information technology [25–27]. Therefore the difference in consumers' personal innovativeness should be taken into account in order to facilitate the usage of NFC technology. Also, one should consider that there are two different groups of people: early adopters and late adopters, i.e. users with a higher degree of personal innovation find NFC system more approachable [26].

- Perceived ease of use. It relates to the degree to which a user believes that the NFC system would require no substantial effort, i.e. NFC system has to be easy to use and easy to learn [25, 26].
- Perceived usefulness. The acceptance of NFC system highly relies on its provided unique advantage in comparison to existing solutions, like barcodes, QR codes, or Electronic Article Surveillance (EAS) tags [25, 26]. If users perceive alternatives as more attractive, it will have a negative effect on the intention to adopt NFC [25].
- Security and trust. According to the survey results by [25], users are more willing to use the NFC technology, if the perceived security is high. Users seem to be more interested in the security and trust of the NFC operations than on its ease of use [25, 27]. Moreover, it might also raise some privacy concerns, thus NFC system, for instance, has to offer valuable incentives in exchange for data [30].
- Knowledge and absorptive capacity. Users already having some knowledge about NFC would find the technology easier and more encouraging to adopt [26]. Moreover, understanding, acquisition and application of knowledge play a major role in user's absorptive capacity [27].

6 Conclusion

Equipped with NFC and other supporting computational devices capabilities physical items become uniquely identifiable, traceable, and, most importantly, interactive so they

are able to increase the value from the point of manufacture to the end-user hands. NFC ability to connect products to the network by a single tap brings the technology to light to be spotted by innovation-seeing brand owners and retailers. The engaging and interactive medium provided by the Internet can be handed over to consumers' palms through NFC and mobile devices. Technology-enriched stories about products, instant verification of product's genuineness, just-on-time received offers can significantly improve consumers' experiences and positively influence their perception of products. Likewise, since brand identity and reputation are built through consumers' interaction with their products, NFC enables brands to dynamically adapt to emerging consumer needs by improving their products and services, and deliver personalized value-added solutions.

This study brought a comprehensive understanding of prominent technological capabilities provided by NFC technology applied to the product packaging. The incorporation of NFC into overall packaging design allows the package to become an interactive digital interface with infinite possibilities depending on brands and retailers creativity. Based on the results, NFC technology can contribute and create better experiences for consumers, brands, and retailers. Furthermore, in order to build an intuitive, enjoyable and effortless system, packaging designers have to take into consideration technology- and user-centered factors that might form barriers for successful adoption of NFC technology.

To conclude, the study aimed to build a bridge and establish a close relationship between the industry and academia and merge both sources of knowledge to contribute to a better and more practical understanding of the current state-of-the-art of the NFC and overall human-packaging interaction.

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PAPER IV

Experimental Approaches to NFC-enabled Packaging for UX / CX of Physical Artefacts: A Technology Maturity Study

Karpavičė, J., Hafith, I., A., Tambo, T., Chinello, F., Venytė, L., Gegeckienė, L.

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Experimental approaches to NFC-enabled packaging for UX / CX of physical artefacts: A technology maturity study

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Abstract

Product's packaging with integrated electronic intelligence turns into a visual, tactile and digital encounter with consumers influencing their shopping experience and purchase behavior. The Near Field Communication (NFC) tag attached to the packaging can transform everyday objects into a direct communication channel. However, the NFC technology is still not widely accepted by the industry, thus it is necessary to analyze the influential factors related to consumer behavior, changing needs, and acceptance. As a result, this study carries out the user experiment, where a product's packaging with NFC capabilities is built and tested with selected participants to track user engagement with the smart interactive packaging. The main aim of this study is to examine the peculiarities of the user interaction with NFC-enabled packaging to find out consumer perception and technology acceptance of NFC to retrieve more comprehensive insights regarding barriers to the successful NFC application to a product's packaging. The participants were asked to interact with a set of three NFC-enabled cardboard packages with attached NFC stickers, and afterwards each participant evaluated their experience via survey designed based on Technology Acceptance Model (TAM). According to the results, all three proposed research hypotheses were tested and confirmed to some extent. This study provides a thorough elaboration regarding the technology- and consumer-related barriers that might prevent the successful acceptance of NFC technology applied to the packaging. This research contributes to a better understanding of how different variables have an impact on consumers' perception and technology acceptance of NFC. All business management practitioners, marketers and designers could employ the results of this research as a way to improve the adoption process of the NFC technology in the packaging industry.

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Keywords: smart interactive packaging ; near field communication ; user experiment ; technology acceptance model.

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1. Introduction

The challenges of ever-changing and complex business environments induced by increasing customer demands and products' complexity lead many industries to the rapid changes in technology and the continuous introduction of new products [1]. Companies have undergone significant evolution by utilizing technologies and enhancing brands and branding channels [2]. IoT-enabled smart objects can collect, store and transmit data that later on is analyzed and transformed into useful information – early warnings, presumptive outcomes, or advantageous course of action [1]. The ability to connect and communicate from everywhere is changing people's lifestyles, especially when doing business and creating meaningful interactions with products and companies [3]. In fact, especially in the retail settings, products and their packaging turn into such smart objects for an extended user interface [4]. Especially when the package is equipped with a sensor or any other communication device, the product becomes a 'thing' in the IoT [5]. For instance, printing technologies allows the manufacturing of sustainable electronic devices on paper-based substrates for emerging applications, such as the anti-counterfeit label [6].

According to [7], there is an increasing trend in digitizing in-store services by using digital touchpoints as the first contact point between consumers and retailers replacing the traditional human assistants. Furthermore, the continuous growth in information and communication technology allows consumers to acquire brand knowledge through mobile devices [2]. As a result, a product's packaging with integrated electronic intelligence turns into a visual, tactile and digital encounter with consumers influencing their shopping experience and purchase behavior [7]. When the consumer walks into a store, the only point-of-purchase touchpoint is the product's packaging [8]. The NFC is one of the rapidly increasing technologies that academics and professionals have started to explore as a potential tool for improved consumer-brand interaction [4]. NFC is a short-range wireless connectivity standard approved by the International Organization of Standardization (ISO) that utilizes magnetic field induction to provide communication between devices [9, 10]. NFC technology is based on bi-directional communication, i.e., data is exchanged in both directions, with a typical range of 4 to 10 cm depending on the output power and the antenna design [11]. NFC has been widely used for contactless payment systems [12], home automation, product tracking, locating and quality control, and healthcare application [13], identification, retail and transport industries [14].

Moreover, the NFC tag attached to the product's packaging can transform these everyday objects into a direct communication channel that opens up immense engagement possibilities with consumers while they are shopping. Consequently, the retail environment is shifting to new forms of space filled with novel experiences. For instance, consumers can access personalized promotions and coupons, collect loyalty points, and retrieve additional information about the product by simply tapping their phones on a product's packaging with an attached NFC tag [12; 15]. Furthermore, a short-range interaction of NFC simplifies the identification and authentication processes that refer to the safety and quality of the packaged products that, in turn, build consumer trust in the manufacturer [16]. Finally, the embedding of the NFC technology into the packaging design facilitates the communication between the enterprise's internal and external stakeholders and allows the enterprise to be connected to the entire supply chain network [17]. With the standardization of NFC technology, the industry could combat counterfeiting, increase economies of scale, reduce investment risk, and achieve better transparency in businesses [18].

Although the potential of the NFC-equipped system is significant, the technology is still not widely accepted by consumers, retailers or manufacturers [4]. Various challenges related to technological feasibility, customer acceptance, and economic benefit for the business model hinder NFC technology from being widely applied to the packaging industry [3]. According to [19], the NFC implementation depends on consumers' willingness to accept and utilize the technology. Consequently, it is necessary to analyze the influential factors related to consumers, especially when consumer behavior, changing needs, and acceptance are vital for adopting technologies and driving innovations [20]. As a result, this research aims to examine the peculiarities of the user interaction with NFC-enhanced packaging to find out consumer perception and barriers to technology adoption by conducting an experiment and employing the TAM to analyze the results.

This paper is structured as follows. Section 1 provides a short introduction into the related work covering the topics of smart interactive packaging and NFC, along with a brief definition of TAM and the proposed research hypothesis. The research design and experiment framework are described in Section 2. A detailed discussion of the experiment and survey results is presented in Section 3 followed by research limitations and future research. Finally, the main outcomes are summarized in Section 4.

1.1. TAM and proposed research hypotheses

A number of different theories have been utilized to describe and investigate the process of the adoption of technological innovations [21]. One of the most widely cited theories is the Technology Acceptance Model [21]. TAM has been applied in many research studies and became an accepted model to examine an individual's technology acceptance and behavior [22]. Due to limited context availability, TAM has been extended to explain behaviors in a broader range of environments [22].

Several main concerns were taken into consideration while constructing the research hypotheses. First, consumers' identification and recognition of available technologies are critical factors for the actual interaction to happen. Research carried out by [20] claims that most consumers do not recognize or even realize that some of the product packaging they are using on a daily basis are technologically enhanced. Second, the intuitive and easy-to-use design of the technology system is expected to facilitate the consumers' intention to adopt technologies [19]. Finally, the majority of emerging technologies require users to initiate the interaction [23]. Therefore, consumers need to be motivated and interested enough to engage with a product's packaging to gain some benefits or rewards for their efforts. As a result, the following hypotheses were proposed:

H1: There is a significant relationship between the identifying sign of the NFC and the initiation of the interaction.

H2: There is a significant relationship between the identifying sign of the NFC and the Perceived Ease of Use.

H3: There is a significant relationship between the context and the Perceived Usefulness and Behavior Intention of Use.

2. Methodology

This study carries out the user experiment, where a product's packaging with NFC capabilities is built and tested with selected participants to track user engagement with the smart interactive packaging. The experimental approach was adopted to the contemporary COVID-19 regulations, where physical attendance and communication were not permitted. Consequently, the main interaction between the participant and packaging took place in the participant's household. All the physical artefacts of the experiment were sent to the participants, and the interaction was observed through Microsoft Teams.

2.1. Participants

The experiment was pilot tested on a group of 12 participants attending a higher education institution in Denmark. The participants were enrolled in the bachelor´s and master´s degree programmes, and 82% of the participants were aged between 23-27 years. It was chosen to select the sample that represents a developed country with immense potential for adapting emerging communication technologies and comprises young consumers and users of innovative technologies. The participants were selected using the convenience sampling method proposed by the reference [24] based on their convenient accessibility and geographic location. To test the proposed hypotheses, the participants were divided into two groups, the control group and the test group, consisting of 6 and 5 participants, respectively. Only 11 participants completed the experiment because one participant's mobile device did not support NFC technology. Each participant was appointed to the group at the beginning of the experiment based on her/his knowledge and experience with NFC technology. The control group was composed of all participants who had minimal knowledge regarding the NFC technology and had never used it before. The test group included all participants who had some experience with NFC and were able to provide a general explanation of the technology. This group was provided with additional information regarding NFC.

2.2. Research design

2.2.1. Physical and digital artifacts

A set of three NFC-enabled cardboard packages was the central part of this experiment. Each package is built with a different digital capability provided by NFC technology to test chosen hypotheses. Packages are 10×10×20 cm and are made from single-wall white corrugated cardboard. Packages are equipped with NFC tag stickers purchased from

ShopNFC. The stickers are placed on the inner side of the package. NFC paper stickers have an overall thickness of 120 μ ±15 μm, and the diameter is 29 mm. NFC tags consist of a printed antenna and NXP NTAG213 user memory chip. The chip is compliant with the ISO 14443 A standard, equipped with 144 bytes of re-writable user memory, operate at 13.56 MHz frequency, support password protection. More information is given in Table 1.

Table 1. Detailed information about NFC-enabled corrugated cardboard packages.

Information	Package No. 1	Package No. 2	Package No. 3
Description	Corrugated cardboard package without graphics or NFC sign	Corrugated cardboard packaging without graphics but with a sign of NFC	Corrugated cardboard packaging with graphics of a specific cosmetic product and with a sign of NFC
Objective	To test how Intuitive is the Use of Technology (IUoT)	To test how Intuitive is the Use of Technology (IUoT) and the Perceived Ease of Use (PEoU)	To test the Perceived Usefulness (PU) and the Intention of Use (IoU) based on the provided package design and NFC function
Hypothesis	H1	H1 and H2	H3
NFC tag data	Youtube video of NFC technology	PhD research website	Authentication mock-up for the packaged product
Picture			

2.2.2. An instruction sheet of NFC

An instruction sheet of explanation of how NFC technology operates. These instructions were given to the participants before interacting with the packages to familiarize them with NFC working principles.

2.2.3. Digital content for an NFC chip

Each NFC tag contains a digital content. All three NFC tags are encoded with particular URLs using the NXP TagWriter app and iPhone 11. The first package is equipped with an NFC tag that redirects the user to the YouTube video about NFC technology. The NFC tag attached to the second package has a link to the interactivepackaging.dk website. The third package contains a NFC tag with a fictive authentication capability. Mock-up was created to depict how simply NFC can verify the genuineness of a product.

2.3. Experiment framework

The framework of the experiment was designed to include every stage in researcher-participant communication and participant-packaging interaction, taking into consideration all pre-experiment, experiment, and post-experiment activities:

STEP 1: social media and e-mail communication. Pre-experiment activities consisted of the invitation to participate in the experiment via social media platforms and a brief overview of the experiment. Once participants had confirmed their participation, the consent forms were sent out to be signed. A specific date and time for the experiment were proposed. Participants were informed about the parcel delivery and reminded not to open the received boxes before the experiment.

STEP 2: preparation and dispatch of the parcel with a set of smart interactive packages. Each participant received one box containing all three packages. Each package was marked with a particular shape identifying symbol on the top and placed in a specific sequence in the box to make sure that the participant would interact with packages in the

correct order, i.e. the first is Package No. 1 with a rectangle drawing on the top, then is Package No. 2 with a triangle drawing, and the last is Package No. 3 with a circle drawing.

STEP 3: e-mail communication. Once the parcels were delivered to participants' households, the specific date and time for the experiment were agreed upon, and Microsoft Office invitations were sent. Participants were provided with some guidelines on how to prepare for the experiment.

STEP 4: the start of the experiment. Once the communication between the researchers and participants was established online, all the experiment guidelines were checked, and an unopened parcel was placed in a proper range of vision.

STEP 5: a short questionnaire. It took place before the interaction with packages. The aim of this questionnaire was to find out to which group, control or test the participant belongs based on their knowledge and experience with NFC technology. The questionnaire consisted of three questions.

STEP 6: a short description of the experiment. The participants were introduced to (a) the experiment aim, (b) physical experiment artifacts – a set of three different packages with attached NFC tags, (c) the experiment order, e.g. participants were asked to interact with each package in a given sequence, (d) the task they needed to achieve – using their smart device to initiate the NFC tag attached to a package that will redirect to specific digital content.

STEP 7: a description of NFC technology (only to a test group). A short introduction of the technology, including the definition, working principles and demonstration, was provided to the participants assigned to the test group.

STEP 8: an interaction with packages. It was the main part of the experiment, where participants were asked to read the instructions and try the NFC experience with each package in a particular order: package No.1, package No. 2, package No. 3. A brief brand-product story was told before the interaction with package No. 3 to create a context for the package that might facilitate the willingness and motivation to try the interaction to receive a reward.

STEP 9: a questionnaire. After the interaction with packages, regardless of whether it went successfully or not, each participant was provided with a link to a survey to evaluate their overall experience of the experiment.

2.4. Survey design

The survey design followed a similar approach performed by [25] and applied the theory of the TAM provided by [3] and [26]. All the questions were split into nine main categories: Perceived Usefulness (PU), Behavior Intention to Use (BItU), Personal Innovativeness (PI), Perceived Ease of Use (PEoU), Intuitive Use of Technology (IUoT), Basic Information (BI), Absorptive Capacity (AC), User Convenience (UC), and other optional questions. The results of the survey are presented in Table 2. Also, a five-point Likert Scale was utilized for the participants' answers, ranging from highly disagree to highly agree with the given statements [27]. Some statements were given in reverse order in order to minimize the response bias.

3. Results and discussion

Based on the experiment results, although 11 out of 12 participants had smartphones with integrated NFC technology, more than half of them were not aware of their devices' NFC availability. Consumers lack knowledge not only about technologies implemented in the product's packaging but also about the technological capabilities of their devices. Consequently, an individual's absorptive capacity becomes significantly relevant for studying the user's adoption of new technology [28]. Therefore, the prior knowledge of the technology, i.e., participants' knowledge of NFC technology embedded in their devices, together with the ability to apply that knowledge in smart packaging interaction, might facilitate better understanding and, in turn, potential acceptance of the NFC.

Another insight from the experiment related to an individual's absorptive capacity is that all the participants have already tried NFC technology before within the wireless payment realm. However, most of them did not know that the technology is called NFC. It could be interpreted as consumers are not keen or concerned about the particularities of the technologies around them and are only interested in how to make it work., i.e. tap with their credit cards on the payment machine. Consumer education and knowledge building are inherent parts of technology adoption [20].

The overall NFC system lacks integrity and consistency among various devices and operating systems. Separate manufacturers of mobile devices activate NFC technology features in different ways. Some smartphones with earlier versions of operating systems require third-party applications to read the NFC tag, whereas some devices do not

request any additional parties. Devices supporting iOS 13 can read NFC chips without an app, whereas all the devices supporting Android OS did not need any additional application. The lack of NFC system integrity and consistency might negatively affect consumers' perception and adoption of the technology. This phenomenon of inconsistency correlates with individual constructs such as PEoU, UC and PI. According to [29] and [30], the adoption of new technologies highly depends on the system complexity and efforts needed to succeed. Research participants were ranked with a moderate to a higher level of personal innovativeness. They were interested in state-of-the-art innovative technologies. However, they admit that they are not the first to buy new products. Therefore, PEoU and UC of NFC technology were evaluated positively, varying from 45.5% to 90.9% of responders highly agreeing with the given statements.

Based on the experiment results, the specific location where the NFC reader is integrated into the mobile devices is critical for interaction success. According to [31], there are two external parameters that affect the stability of the regulated voltage by the NFC chip: the powering time and the position of the smartphone when it is placed closer to the NFC antenna. Reference [15] adds that the distance between the reader antenna and the chip is a critical parameter for the good performance of the NFC system. During the experiment, if the participant had never used his/her smartphone to interact with the NFC tag, he/she would not be aware of where the NFC reader is embedded in the device. As a result, it took longer for the participants to succeed in the interaction as they needed to test different locations on their smartphones. For example, smartphones supporting iOS have NFC readers implanted on the upper part of the device, whereas Android smartphones have NFC readers fixed in the middle. Furthermore, different smartphone models exhibit significant differences in the maximum reading distances [15]. Once participants found out where the reader was located on their smartphones during the experiment, the interaction became faster and smoother. 72.7% of participants answered that reading a product´s packaging with NFC technology is rapidly learnable after the first time. Therefore, prior knowledge of technical specifications, such as NFC placement in the device, would highly affect the interaction success.

The first and second hypotheses of the package No. 1 and No. 2 were confirmed based on the experiment results. A significant relation was observed between the identifying sign of the NFC, the initiation of the interaction and the PEoU. According to the observation summary presented above, within each package, the interaction time was abbreviated from 5 minutes to less than one minute as packages No. 2 and No. 3 had the symbol of NFC. The interaction with NFC-enabled packaging gradually became more intuitive. Based on the research results, all the participants somewhat agreed or highly agreed (18.2% and 81.2%, respectively) that the identification sign of NFC allowed them to use the interaction intuitively. As a result, consumers' recognition of available technologies is a critical factor for the actual interaction to happen. Moreover, 81.8 % of participants found that learning to use NFC technology is easy, and 72.7% claimed that it is easy to use once one becomes familiar with the technology. A study conducted by [32], also found out that nearly 97% of participants found the NFC technology easy to use.

The third raised hypothesis for package No. 3 was partially confirmed. Based on the survey results, participants perceive NFC technology as a valuable tool for faster access to product information, new features, and immediate product authenticity. However, only about a half of the participants somewhat agree and highly agree (18.2% and 27.3%, respectively) that using NFC technology might influence their lifestyle and the way they do shopping. Approximately 64% of participants agree that the presence of an NFC tag for a product's authenticity will increase the possibility of purchasing the product. A bit more than one-third of participants strongly agreed that they intend to interact with NFC technology once they notice it on the package and intend to use the technology to authenticate the products they purchased. Participants find the interaction with NFC-enabling packaging motivating to some extent for the efforts needed.

Consumer education and knowledge are inherent parts of technology adoption [20]. The survey results from this experiment validate the interrelation: all the participants somewhat agree 36.4% and strongly agree 63.6% that the provided instructions helped them to understand better how to use NFC and succeed in their interaction with the packages. The test group participants also confirmed the connection, somewhat agreeing (27.3%) and highly agreeing (72.7%) that the shown demonstration helped them understand how NFC technology works and succeed in their interaction.

Table 2. Summarized survey answers of the participants' experience with the NFC-enabled packaging interaction.

Category	Questions	Highly disagree	Somewhat disagree	Neutral	Somewhat agree	Highly agree
BI	Do you own a smartphone? What brand?	NA	NA	**NA**	NA	NA
BI	What age group do you belong to?	NA	NA	**NA**	NA	NA
PEoU	The identification sign of NFC placed on the package allows me to easily use the technology	0	0	0	9.1%	**90.9%**
PU	Using NFC technology allows me to have a faster access to some sort of information (e.g. cosmetic products)	0	0	0	9.1%	**90.9%**
PU	I believe that NFC technology will allow new features for product's packaging	0	0	0	9.1%	**90.9%**
UC	NFC is convenient because the mobile phone is usually with	0	0	0	9.1%	**90.9%**
UC	NFC is convenient because I can use it at anytime	0	0	0	9.1%	**90.9%**
IUoT	The identification sign of NFC allows me to use the interaction intuitively	0	0	0	18.2%	**81.8%**
AC	I use internet banking, credit cards, PayPal or other online payment options when purchasing goods/services online	0	0	0	18.2%	**81.8%**
PEoU	Learning to use NFC technology is easy	0	9.1%	0	9.1%	**81.8%**
PEoU	I consider that NFC technology is too technical to be used everyday	**81.8%**	9.1%	9.1%	0	0
IUoT	The identification sign of NFC allows me to use the interaction intuitively (PEoU)	0	0	0	18.2%	**81.8%**
PI	I feel uncertain/discouraged about new technologies.	**72.7%**	18.2%	9.1%	0	0
PEoU	It was clear and understandable how to interact with NFC (PEoU)	0	9.1%	0	18.2%	**72.7%**
PEoU	I find NFC easy to use (PEoU)	0	0	0	27.3%	**72.7%**
PEoU	Reading product's packaging through NFC technology is rapidly learnable after the first time (PEoU)	0	0	18.2%	9.1%	**72.7%**
PU	Using NFC technology can make things easier, e.g. to get additional information about the item.	0	0	9.1%	18.2%	**72.7%**
OQ	The shown demonstration helped me to understand how NFC technology works, and succeed my interactions with the packages.	0	0	0	27.3%	**72.7%**
PI	State-of-the-art and innovative technologies/products excites me.	0	0	9.1%	27.3%	**63.6%**
AC	I feel able and I have the skills to use NFC technology.	0	9.1%	9.1%	18.2%	**63.6%**
OQ	The provided instructions helped me to better understand how to use NFC, and succeed my interactions with the packages.	0	0	0	36.4%	**63.6%**
AC	I enjoy using mobile apps for my daily routine tasks.	9.1%	0	9.1%	27.3%	**54.5%**
PU	Using NFC can be useful for some of my everyday products.	0	0	18.2%	27.3%	**54.5%**
UC	NFC is convenient because it is not complex.	0	0	27.3%	18.2%	**54.5%**
BItU	Using NFC technology might influence my lifestyle and the way I like to do shopping.	0	0	**54.5%**	18.2%	27.3%
IUoT	NFC technology is intuitive to use.	0	0	9.1%	36.4%	**54.5%**
IUoT	It was difficult for me to interact with the technology without the identification sign of NFC.	18.2%	18.2%	0	9.1%	**54.5%**
PI	I know more about new products before other people do.	0	18.2%	18.2%	**45.5%**	18.2%
BItU	The presence of an NFC tag for product's authenticity will increase the possibility to purchase the product.	9.1%	9.1%	18.2%	**45.5%**	18.2%
PI	I am usually among the first to try new products.	18.2%	**45.5%**	27.3%	9.1%	0
PEoU	Reading product's packaging through NFC technology is easy and intuitive (PEoU)	0	9.1%	0	**45.5%**	**45.5%**

Category	Questions	Highly disagree	Somewhat disagree	Neutral	Somewhat agree	Highly agree
PU	Using NFC technology enables the consumer to have immediately the guarantee of the authenticity of the product.	0	0	9.1%	**45.5%**	**45.5%**
BItU	I intend to use NFC technology because I see the benefits of it.	0	18.2%	0	36.4%	**45.5%**
BItU	The presence of an NFC tag for product's authenticity will increase the possibility to purchase the product.	9.1%	9.1%	18.2%	**45.5%**	18.2%
PI	I tend to be the first in buying new products.	27.3%	**36.4%**	**36.4%**	0	0
PU	Using NFC technology for the product's packaging will improve the efficiency of my shopping experience.	0	0	**36.4%**	**36.4%**	27.3%
BItU	Once I notice the NFC tag on a package, I intend to interact with it.	0	18.2%	18.2%	27.3%	**36.4%**
BItU	I intend to use NFC technology to check the authenticity of the products I purchase.	18.2%	9.1%	9.1%	27.3%	**36.4%**
BItU	I would prefer to purchase products from retailers that use NFC tags for authentication.	9.1%	9.1%	**36.4%**	27.3%	18.2%

3.1. Limitations and future research

As mentioned before, the experiment was a pilot test on a group of 12 participants attending a higher education institution in Denmark. Based on this experiment's results, a broader study will comprise participants from several developed countries. Several modifications are planned to be performed, including the design of package No. 3, which will be changed to a more realistic cosmetic product's packaging with authentication and storytelling capabilities; the classification of categories in TAM and several questions will be reformulated; the differences of the experiment groups will be extended by reducing the provided information about the experiment to a minimum. Furthermore, future research is expected to apply the Statistical Package of Social Sciences (SPSS) for statistical examination of the questionnaire. A similar approach provided by [19] will be used by performing partial least squares (PLS) software for testing the hypotheses.

4. Conclusion

This study conducted the experiment to examine the peculiarities of user interaction with NFC-enhanced product packaging to determine driving factors and barriers to consumer perception and technology acceptance of NFC. Based on the study results, there is a significant relationship between the identifying sign of the NFC and the user initiation of the interaction. Participants initiated the interaction with packages with a printed NFC symbol much faster than the blank one. Moreover, a significant relation was observed between the identifying sign of NFC and the PEoU. The interaction with NFC-enabled packaging gradually became easier and more intuitive. However, there is still some struggle regarding participants' perception of the NFC benefits to the product packaging and overall interest in initiating the interaction. According to the experiment results, diverse technology- and consumer-related barriers that might prevent the successful acceptance of NFC technology applied to the product's packaging. This research contributes to a better understanding of how different variables have an impact on consumers' perception and technology acceptance of NFC. Practitioners could employ the results of this research to improve the adoption process of the NFC technology in the packaging industry.

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Declaration of co-authorship*

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This declaration concerns the following article/manuscript:

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Authors:	Justina Karpavičė, Iusef Abdel Hafith, Torben Tambo, Francesco Chinello, Ingrida Venytė, Laura Gegeckienė

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Has the article/manuscript previously been used in other PhD or doctoral dissertations?

No ☒ Yes ☐ If yes, give details:

The PhD student has contributed to the elements of this article/manuscript as follows:

A. Has essentially done all the work
B. Major contribution
C. Equal contribution
D. Minor contribution
E. Not relevant

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PAPER V

Digitalisation of product packaging using near-field communication: towards an extended Technology Acceptance Model

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Digitalisation of product packaging using near-field communication: towards an extended Technology Acceptance Model

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Abstract

The purpose of this research is to approach an integrated understanding of introduction and acceptance of digital elements in consumer packaging. The research design follows three lines of studies: (1) to investigate the important variables impacting the adoption of Near-field Communication (NFC) in product packaging, (2) to propose an applicable technology acceptance model for it, and (3) to identify the most impactful variables for the NFC technology acceptance for packaging applications. This research presents a mixed-method study investigating 25 articles concerning the adoption of interactive technologies for user engagement in retail and other consumer-oriented environments. The study uses the multi-criteria decision analysis (MCDA) approach together with an interval scale to assess the identified variables to select the most impactful ones for NFC technology acceptance for product packaging. The findings include 182 variables that were collected from the 25 studies investigating on the adoption of diverse smart in-store technologies. The proposed model consists of 42 variables grouped into 13 categories. Based on the MCDA, the top 5 most impactful factors for NFC technology acceptance are Perceived Enjoyment, Perceived Privacy and Security, Perceived Quality, Perceived Value and Social Influence. This article sheds light on the factors sought in using NFC technology in product packaging and contributes to the literature of technology acceptance of consumer-oriented interactive technologies by highlighting the most impactful determinants of adoption. The study also makes managerial implications for brand owners, retailers and developers concerning the impact of a wide range of factors when designing NFC – or similar digital - systems to achieve successful consumer interactions.

Keywords: technology acceptance model; near field communication; smart interactive packaging; UTAUT; digital packaging

1. INTRODUCTION

The business environment has experienced a rapid shift due to the emergence of new technologies and innovations, and increased demand from consumers (Gbongli *et al*., 2019). The advancement of ICT and wireless services enabled mobile technology to become an inseparable part of everyday life (Gbongli *et al*., 2019). The adoption of smartphones and their role in providing personal and professional services promote the widespread and growing use of mobile devices (Liébana-Cabanillas *et al*., 2015). The push on digitalization facilitated by technological advancement, the development of e-commerce, and the use of smartphones, support the discussion on the digitalization of physical stores (Boudkouss and Djelassi, 2021). Consequently, technological advances have provoked phenomenal shifts and disruptions in the retail environment (Shankar *et al*., 2021). Emerging technologies significantly impact the consumer experience and retailer business models (Shankar *et al*., 2021). Consumers have increased interest and demand for entertaining, consistent, and positive shopping experiences (Savastano *et al*., 2019). Retailers adapt to these changes by implementing interactive technologies in the store and shifting toward the "phygital" experiences (Boudkouss and Djelassi, 2021). The concept of phygital refers to the application of technology in an interactive and agile manner by integrating physical and digital platforms to create a seamless customer experience (Singh *et al*., 2019). As a result, recent studies revealed the growing trend in digitizing in-store services by introducing the phygital touchpoints as the first points of interaction between brands or retailers and consumers (Vannucci and Pantano, 2020). In particular, retailers deploy such advanced in-store systems to enhance the consumer experience by providing innovative means for obtaining auxiliary product information, saving time and becoming more independent while shopping (Savastano *et al*., 2019). The most common examples of phygital touchpoints are smartphones and mobile apps. Castillo and Bigne (2021) reported that "57% use, or are willing to use, mobile apps for in-store navigation to assess products and find deals" (p. 875). Researchers emphasized that smartphones and mobile apps, in combination with other engaging contactless technologies, such as Near Field Communication (NFC), have transformed the consumer experience and influenced behavioral intentions (Castillo and Bigne, 2021). The NFC technology presented at the point of purchase enables a new level of functionalities, including mobile payments, personalized promotions, and location-based services (Savastano *et al*., 2019). Moreover, the NFC tag embedded into the product's packaging can turn these objects into a direct communication channel with consumers filling up their shopping experiences with authentic

and secured product information, product differentiation, and brand promotion (Karpavičė *et al*., 2022). In fact, the power of packaging as a tool for influencing consumer purchase behavior is worthy of retailers' attention in relation to the fact that 7 out of 10 consumers agree that packaging design has an impact on their purchase decision (Rotsios *et al*., 2022). NFC-enhanced packaging is expected to increase consumer interest further leading to more engaging and memorable experiences directly impacting the consumer perception of the brand or retailer.

Even though the potential of the NFC-enabled system is significant, the technology is still not widely accepted by consumers (Karpavičė *et al*., 2022). According to the authors, numerous challenges regarding the economic benefit of the business model, consumer acceptance, and technology capabilities prevent NFC adoption in the packaging industry. Museli and Navimipour (2018) claim that consumers' willingness to accept and utilize the technology highly impacts NFC implementation. As a consequence, it is necessary to investigate the determining factors related to the acceptance of NFC technology in product packaging applications.

Various research has been conducted in information systems to explain and predict the determinants that can influence individuals' adoption of technologies and innovations (Dutot, 2015). The assessment of individuals' acceptance of technology enables researchers and developers to predict the feasibility of new technology among users (Rostam *et al*., 2015). Overall, user acceptance is defined as "the demonstrable willingness within a user group to employ new technology for their daily activities" (Rostam *et al*., 2015, p. 53). This led to the development of existing user acceptance models that test how a system's design features influence user acceptance aiming to minimize the risk of resistance or rejection from users. The technology acceptance model (TAM) developed by Davis (1989) aims to explain technology adoption by proposing that the acceptance and use of technologies are driven by individuals' perceptions of their usefulness and ease of use (Shankar *et al*., 2021). However, the TAM is limited to its inability to satisfactorily capture the hedonic aspect of technology acceptance (Choong *et al*., 2021). As a result, the original TAM model has been subject to various incremental expansions that aimed to enhance its predictive power by appending new variables (Brooksbank *et al*., 2022; Dutot, 2015). Therefore this study expands the TAM model by aggregating the factors proposed by other studies as potential determinants of NFC technology acceptance.

An extensive literature search revealed a scarcity of published research on TAM and NFC-enabled product packaging. Although the TAM has been applied to a consumer engagement context in various studies, to the best of our knowledge, it has not been applied to the specific case of NFC-enabled product packaging. Instead, extant TAM research in consumer-oriented environments for their engagement has focused on various interactive technologies, such as QR codes (Rotsios *et al*., 2022; Acuti *et al*., 2022), mobile apps (Talantis *et al*., 2020; Schrage *et al*., 2022), Augmented Reality (Romano *et al*., 2022; Castillo and Bigne, 2021), and smart in-store technologies (Kim *et al*., 2017; Boudkouss and Djelassi, 2021). Furthermore, the adoption of NFC has mostly focused on wireless payments (Flavian *et al*., 2020; Zhao *et al*., 2020; Khalilzadeh *et al*., 2017; Ooi *et al*., 2016; Ramos-de-Luna *et al*., 2016), with several studies on medication prescription, dosage and intake (Aldughayfiq and Sampalli, 2021), tourism for smart posters and mobile apps (Boes *et al*., 2015; Liébana-Cabanillas *et al*., 2020), conferences and expositions (Han *et al*., 2016), automation in railway services (Museli and Navimipour, 2018), education in ULE (Osman *et al*., 2018), and home appliances (Teh *et al*., 2014). Consequently, this paper concentrates on the technology acceptance of a new application of the NFC system for product packaging that has not yet been researched to this date. Therefore, this study aims to investigate the important variables impacting the adoption of NFC in product packaging, propose an applicable technology acceptance model for it, and identify the most impactful variables for NFC technology acceptance for packaging applications.

This paper is structured as follows. Section 1 provides a short introduction to the related work covering the topics of technological advances in retail landscape, consumer experiences, and technology acceptance, along with proposed research purposes. Section 2 presents a literature review of NFC technology and the commonly used technology acceptance models and theories related to the scope of this study. The research design is described in Section 3, followed by the research findings provided in Section 4. A detailed discussion of the proposed model, together with research limitations and future research, is presented in Section 5. Finally, conclusions and implications are provided in Section 6.

2. THEORETICAL BACKGROUND

2.1. Near Field Communication Technology

Near Field Communication (NFC) is a relatively new technology that is expected to change multiple aspects of consumers' everyday lives (Museli and Navimipour, 2018). Initially, the commercial interest in NFC-enabled smartphones used to be limited

except for new mobile phones, such as Nokia 3200 (Teh *et al*., 2013). However, the launch of NFC-compatible smartphones has facilitated the acceptance of the technology in the marketplace. This rapid proliferation of NFC is triggered by the growing number of NFC readers and increasing consumer awareness (Boes *et al*., 2015). Analysts expect 1.6 billion NFC-enabled devices by 2024. The influence of NFC technology on businesses and society has been investigated in academia (Dutot, 2015). In general, NFC refers to a standardized technology that "enables bi-directional wireless proximity communication between electronic devices" (Museli and Navimipour, 2018, p. 1379) through an intuitive, simple and secure wireless connection (Liébana-Cabanillas *et al*., 2020). It is a short-range wireless technology for data exchange without physical touch (Han *et al*., 2016). Since NFC was integrated and developed by Radio Frequency Identification (RFID), the technology is based on RFID standards and is standardized in ISO/IEC 18902 (Chen and Chang, 2013). In relation to the technical aspect of NFC, it uses a magnetic field to enable communication between devices once they are brought within a few centimetres of each other (Dutot, 2015). There are three different modes to operate the NFC service: card emulation mode (a passive tag), read and write (an active tag for reading and writing), and peer-to-peer mode (two devices actively communicate with each other) (Boes *et al*., 2015).

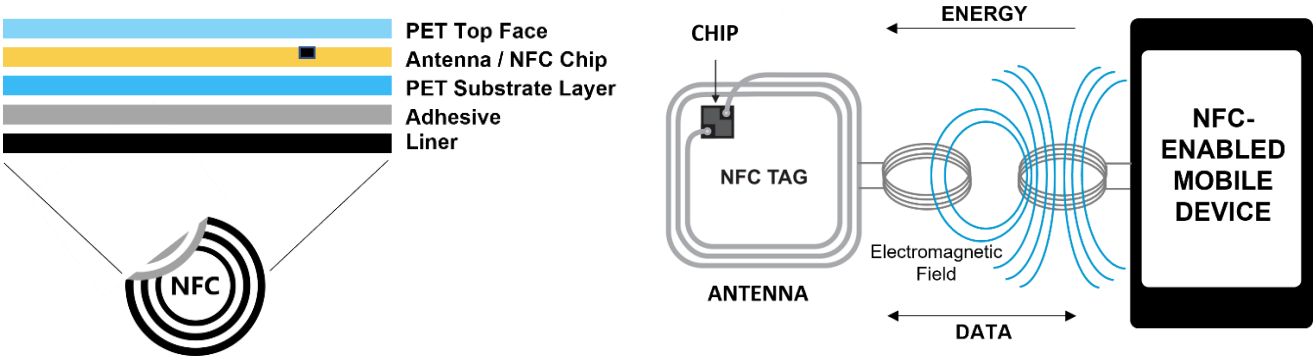
In essence, NFC is considered a mobiquitous technology that builds the bridge between the physical world objects and the virtual world of the internet (Teh *et al*., 2013). At present, NFC enables a broad range of mobiles services, including contactless data transfer, payments, e-ticketing, device pairing, Bluetooth or Wi-Fi pairing, electronic shelf labels, product authentication, location identification, peer gaming, targeted advertising, and other infotainment activities (Lydekaityte, 2020). There is a wide range of applications where the potential of NFC has been studied and used, such as pharmacies for medication prescription, dosage and intake (Aldughayfiq and Sampalli, 2021), tourism for smart posters and mobile apps (Boes *et al*., 2015; Liébana-Cabanillas *et al*., 2020), conferences and expositions (Han *et al*., 2016), automation in railway services (Museli and Navimipour, 2018), education in ULE (Osman *et al*., 2018), and home appliances (Teh *et al*., 2014).

According to Teh *et al*. (2014), "the potential for NFC-enabled smartphones is tremendous." (p. 485). From a usability point of view, NFC provides a convenient way of transferring data between two devices within close proximity, a simple communication setup, and exceptionally low power consumption (Dutot, 2015). Furthermore, NFC has the advantage of a fast read capability that allows the user to scan the NDEF message with only one command (Boes *et al*., 2015). Another compelling reason is the ability to utilize the mobile device as a functioning reader with no need for an external gadget (Boes *et al*., 2015). Smartphone users are given a more dynamic environment with more freedom in using and interacting with objects (Teh *et al*., 2014). From the socio-economic perspective, the standardization of NFC can increase competition (decrease in cost) and financial transparency, offer greater value propositions to consumers and price differentiation, and contribute to carbon footprint reduction (Dutot, 2015). From the market dimension, NFC is able to combat counterfeiting, increase economies of scale, reduce investment risk, and contribute to more transparent and successful business models (Museli and Navimipour, 2018; Dutot, 2015). Especially for retailers and brands, NFC can provoke income development, greater client encounters, and more durable, long-lasting relationships with the consumers who purchased and utilized the products (Chandrasekar and Dutta, 2021).

NFC and Smart packaging

The flexibility of the NFC sticker and the improved RF performance imparted a wide range of choices for objects to which the NFC tag could be attached, despite their shape, dimensions, and materials (NXP datasheet, 2015). On top of that, the decrease in thickness of the integrated circuit allowed the manufacturing of ultrathin NFC tags that not only alleviates the integration process but also broadens the range of application areas. Consequently, these developments in NFC tags transformed the conventional NFC system and made it a better fit for product packaging applications. Particularly for smart interactive packaging, NTAG213, NTAG215, and NTAG216 (further referred to as NTAG21x) developed by NXP Semiconductors are one of the most commonly used NFC tags in consumer applications, including retail, gaming and consumer electronics (NXP datasheet). NFC tags utilized for smart product packaging mainly consist of a memory chip and a printed antenna enclosed with several layers of protection, as seen in Figure 1(a). When NFC tag is placed in the RF field, the high-speed RF communication interface enables data transfer with a baud rate of 106 kbit/s (see Figure 1(b), (NXP datasheet (2019)). NTAG21x chips comply with the NFC Forum Type 2 and ISO/IEC14443 Type A standard specifications, are equipped with 144, 504, or 888 bytes of Read/Write memory, operate at 13.56 MHz frequency, and support password protection (Karpavičė *et al*., 2022). NTAG424 is the upgraded version of the NTAG21x that is designed for product authentication and counterfeit protection with up to 848 kbit/s data rate, compliance to ISO/IEC 14443A-2/ -3/ -4 and NFC Forum Type 4, increased security standard with AES-128 encryption and Secure Unique NFC message generation (NXP datasheet). The utilization of NFC in product packaging goes beyond the inventor control provided by RFID technology and opens new possibilities for advanced anti-counterfeiting, document authentication,

electronic shelf labels, and protected monetary offers such as coupons and vouchers at diverse user touchpoints, mainly benefiting retail and at-home environments (Singh, 2018; Lydekaityte, 2020).



a) b)

Figure 1. (a) Layers of the NFC sticker that could be utilized for product packaging; (b) NFC systems elements and working principle (adopted from NXP datasheet (2015), Seritag datasheet (2019))

2.2. Theories of Technology Acceptance

Extensive research has been carried out in ICT systems to understand, develop and anticipate factors that could have an impact on the adoption of technologies or innovations by individuals. Researchers and developers have established numerous models to address these concerns. This section contains the descriptions of theories and models, including TAM, UTAUT, UGT and MOA, that were used to make the classification of investigated variables. The below-listed theories also are related to the examined variables, however, they are not thoroughly described in this study: Innovation Diffusion Theory (IDT), Technology Readiness (TR), Human-Computer Interaction (HCI), User-Platform Interaction (UPI), Consumer Behavior Theory (CBT), Computer Supported Collaborative Work (CSCW), Engagement Theory (ET), Gestalt Models (GM), Hedonic Motivations (HM), Privacy Calculus theory (PC), Protection Motivation Theory (PMT), Privacy Trust Behavioral intention model (PTB), Technological Innovativeness (TI), Theory of Planed Behavior (TPB), Theory of Reasoned Action (TRA), TRAM - combination of TAM and TR, User Engagement Scale (UES), COM-B – Capacity Opportunity Motivation and Behavior, Expectation confirmation theory (ECT), Self-Determination theory (SDT).

Technology Acceptance Model (TAM)

The importance of investigating technology acceptance was acknowledged a long time ago (Boes *et al*., 2015). The technology acceptance model, known as TAM, presented by Davis (1989), was one of the first models that offered a theoretical mechanism to explain technology adoption in IT by proposing that perceived ease of use and perceived usefulness are the two most significant elements in determining the success of an information system (Boes *et al*., 2015). TAM attempts to identify the influence of external factors on internal beliefs regarding technology acceptance (Museli and Navimipour, 2018). TAM is widely accepted and validated in literature and has been used to investigate an individual's propensity to adopt a new information system (Shankar *et al*., 2021). The technology acceptance model is based on the previous social psychology theories, such as the theory of reasoned action (TRA), and, thereby, includes motivation-intention features with intrinsic motivations to explain and estimate consumers' technology acceptance (De Canio *et al*., 2021). TRA implies that "TAM advances a belief–attitude–intention–behavior paradigm for explaining and predicting technology adoption among potential users" (Kim *et al*., 2017, p. 26). In other words, TAM postulates that attitude impacts behavioral intention, and intention influences actual behavior (Talantis *et al*., 2020).

Prior studies suggest that the successful technology adoption depends on utilitarian and hedonic beliefs (Kim *et al*., 2017). However, the perceived usefulness and perceived ease of use are regarded as reflecting the more utilitarian aspects of ICT systems (Kim *et al*., 2017), therefore TAM is limited to its inability to satisfactorily capture the hedonic features of technology acceptance (Choong *et al*., 2021). As a result, the original TAM model has been subject to various incremental expansions that aimed to enhance its predictive power by appending new variables (Brooksbank *et al*., 2022; Dutot, 2015). Davis *et al*. (1992) developed TAM2, where the added variable of perceived enjoyment embodied the hedonic aspects of using a new

technology or system related to pure enjoyment and fun (Kim *et al*., 2017). Particularly interactive technologies are expected to enhance the user experience and impact utilitarian and hedonic values of interaction (Boudkouss and Djelassi, 2021). Later, Venkatesh *et al*. (2003) proposed a unified view of user acceptance of information technology, introducing factors, such as social influence, age or gender. Venkatesh and Bala (2008) presented a TAM 3 in the context of e-commerce with the addition of trust and perceived risk on system use. These extensions of the original model demonstrate that the TAM is easily adjustable in relation to the technology development (Dutot, 2015).

Another shortcoming of the original TAM was its suitability to only explaining the individual's behavior at work (Talantis *et al*., 2020). Consequently, over the past 20 years, multiple studies have applied and extended the TAM model to explain and predict behaviors across various research disciplines and contexts, such as mobile phones (Ervasti and Helaakoski, 2010), AR self-service technologies in retail (Castillo and Bigne, 2021), IoT in healthcare (Karahoca *et al*., 2018), Virtual Reality (Sagnier *et al*., 2020), social media sites (Bashir *et al*., 2022), mobile wallets (Shin and Lee, 2021), virtual learning (Osman *et al*., 2018), and other. As a result, the TAM approach to ascertaining the determinants of technology acceptance can also be applied to the case of NFC technology in product packaging utilized in a retail environment.

Unified Theory of Acceptance and Use of Technology (UTAUT)

To build a framework that consolidates a number of elements from the different technology acceptance models previously used in the context of information systems, Venkatesh (2003) introduced the Unified Theory of Acceptance and Use of Technology (UTAUT) (Boes *et al*., 2015). UTAUT compares the similarities and differences of existing theoretical propositions and, in turn, delivers a prominent unified method to investigate technology acceptance (Taherdoost, 2018). UTAUT is the combination of the Technology Acceptance Model (TAM), the Theory of Reasoned Action (TRA), the Diffusion of Innovation Theory (DoI), the Theory of Planned Behavior (TPB), a combined model of TAM and TPB, the model of PC Utilization, the Motivational Model, and the Social Cognitive Theory (Rostam *et al*., 2016). The theory consists of four significant determinants of the intention to use the technology and usage behaviour: performance expectancy, effort expectancy, social influence and facilitating conditions (Taherdoost, 2018). The model also includes fluctuating variables accounting for four moderating characteristics: gender, age, experience and voluntariness of use (Rostam *et al*., 2016). Boes *et al*. (2015) refer to UTAUT as a powerful tool for predicting the new technology's future success due to model's complexity and its ability to explain 70% of the variance in user intention.

Uses and Gratifications Theory (UGT)

The exploration of user motivation to engage with interactive technologies used to predominantly rely on the motivational model, such as TAM (Boudkouss and Djelassi, 2021). However, the interest in exploring hedonic motivations as determinants of technology adoption has recently increased due to the need for a comprehensive explanation of consumer behavior induced by utilitarian motives (Acuti *et al*., 2022). Consequently, the Uses and Gratification Theory (UGT) has been commonly adopted in communication research to investigate both hedonic and utilitarian needs and motivations of consumers in connection with the use of ICT systems (Acuti *et al*., 2022). UGT is widely used to examine the consumers' use of new media and technologies, particularly explaining the exploitation of technology in their daily life, as well as their adoption of the Internet- and mobile-enabled services (Ryu and Murdock, 2013).

3. METHODOLOGY

3.1. Literature Review

The purpose of this research is to investigate the important variables impacting the adoption of NFC in product packaging and propose an applicable technology acceptance model for it. Furthermore, this research aims to identify the most impactful variables for NFC technology acceptance for packaging applications. The study is based on a narrative literature review focused on scientific publications related to the technology acceptance of Near Field Communication for product packaging. Initially, a literature search was performed in Scopus and Web of Science research databases by employing keyword combinations including "technology acceptance", "NFC", and "packaging". Since the number of studies on NFC adoption for smart packaging applications is limited, the search was expanded to the technology adoption studies for NFC for diverse applications, except payments, since the latter is already quite well researched (Flavian *et al*., 2020; Zhao *et al*., 2020; Khalilzadeh *et al*., 2017; Ooi *et al*., 2016; Ramos-de-Luna *et al*., 2016). Furthermore, the search scope was also broadened to similar interactive consumer technologies to NFC employed in retail and consumer-oriented environments for their engagement, including "wireless technologies", "augmented reality", "mobile app", and "QR codes". The search criterion

ensured that the scope of the search did not deviate from the context on acceptance of mobile technologies for improved consumer interaction, found studies were not more than 10 years old and published in the English language in academic journals. The initial research strategy continued until a point where no new relevant literature was found. Based on the information provided in the abstract, the literature search was narrowed to the final 25 research papers that are summarized in Table 1. In addition, this research employed a set of empirical examples from the industrial cases of NFC technology providers in the form of product datasheets. Industrial data was needed to verify the current NFC system's specifications utilized for product packaging to broaden the scope of collected knowledge from the literature and increase data triangulation.

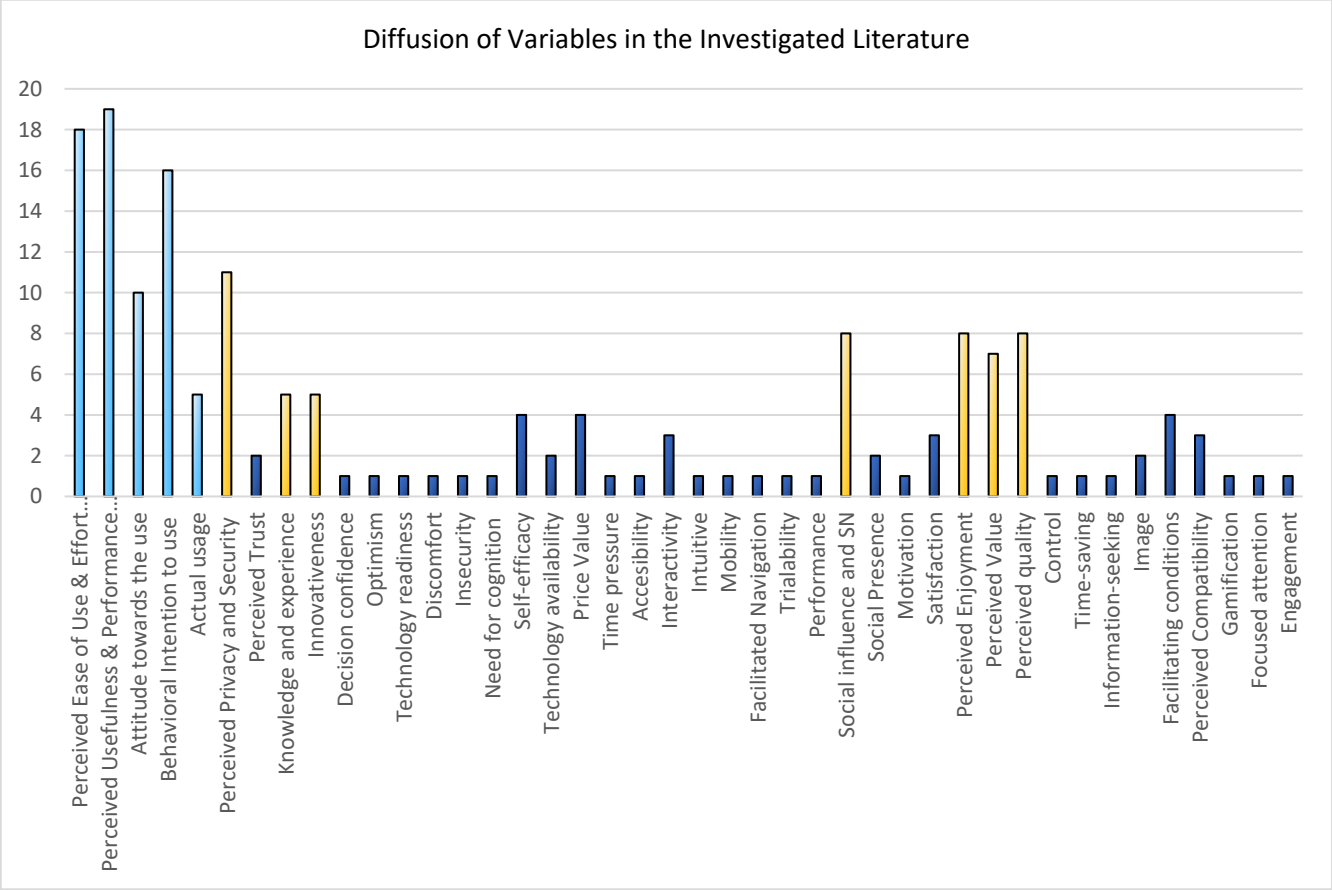


Figure 2. Diffusion of found 182 variables in the investigated 25 studies

3.2. Identification and Classification of Variables

Overall, 182 variables from the investigated 25 studies were gathered. Those variables were taken from the technology acceptance models proposed in the studies. 13 variables out of 182 were excluded from the study due to the lack of an explanation of the variable in the corresponding study and the irrelevance of the variable regarding this study scope. The remaining 169 variables were classified into 13 categories based on their descriptions and theories they are based on:

- The following five categories were adapted from the TAM model (Davis, 1989): Perceived Ease of Use, Perceived Usefulness, Attitude towards the Use, Behavioral Intention to use, and Actual Use.
- The following three categories were adapted from the Multi-level Framework of Technology Acceptance and Use proposed by Venkatesh *et al*. (2016): Individual Beliefs, Individual Attributes, and Technology Attributes.
- The following two categories were adapted from UTAUT proposed by Venkatesh *et al*. (2003): Social Context and Facilitating Conditions.
- Perceived Credibility was adapted from Protection Motivation Theory (Rogers, 1975).
- Motivation was adapted from Motivation-opportunity-ability Theory (MacInnis *et al*., 1991) and Uses and Gratifications Theory (Katz *et al*., 1974).

- Individual Experience was adapted from Engagement Theory (Kearsley and Shneiderman, 1998).

The visual demonstration of the diffusion of variables is shown in Figure 2. The comprehensive classification of variables is demonstrated in Appendix 1. Also, the classification is more comprehensively explained in Table 2.

3.3. Assessment of Variables

The assessment of the most impactful variables of the NFC acceptance has been carried out in four steps by quantifying the results and applying Multi-Criteria Decision Analysis (MCDA) with the interval ranking scale. The interval scale was selected due to its property to use numbers to rate objects with equal distances between numbers, therefore, the differences between numbers on the scale can be compared meaningfully (Hair *et al*., 2019). MCDA was performed accommodating the phases presented in Ortiz-Barrios *et al*. (2020): in phase 1, the four criteria were established through consideration of expert opinion; in phase 2, the relative importance of criteria was estimated, resulting in equal weights of each criterion (25%); in phase 3 – interval scale was implemented to rank the found values of variables from 1 to 10; in phase 4, the most impactful variables for NFC technology acceptance for product packaging were identified.

The four steps of MCDA analysis are thoroughly described in section *4.13.*, including the description of criteria and corresponding formulas. The final fourth criterion was based on the strength of the path coefficients of structural relationships. Usually, the statistical analysis for the TAM model is a two-stage procedure adapted from Gerbing and Anderson (1992). Firstly, the instrument's reliability and validity are verified by analyzing the measurement model, followed by the analysis of the structural model. The latter is commonly examined by using AMOS-LISREK type, regression equations, Partial Least Square (PLS), or Structural Equation Model (SEM) to test the hypotheses via SmartPLS or SPSS (Dutot, 2015). This linear regression test with all independent variables included demonstrates the correlations between the variables, detecting the strength of the significance of the effect one variable possesses over another that leads to either acceptance or rejection of the proposed hypotheses of the structural relationships (Boes *et al*., 2015). In other words, the research hypotheses of structural relationships between variables are tested by assessing the strength, direction and significance of the path coefficients (known as betas) estimated by PLS (Dutot, 2015). Consequently, this study considers the value of path coefficients along with the p-values estimated by investigated 25 studies to assess the strength of each variable in order to identify the most impactful variables for NFC adoption in product packaging. The results of MCDA disclosed the top 10 impactful variables aside from the original variables from the TAM model presented by Davis (1989).

4. RESULTS

Overall, 25 studies were investigated in regard to their aim to explore various factors influencing consumer acceptance of interactive mobile systems by applying diverse technology acceptance models and theories. The summary of investigated studies is provided in Table 1.

Table 1. Summary of investigated studies

No.	Reference	Final sample size	Test subject	Study Aim and Research Activities	Model
NFC-based subjects					
1	Aldughayfiq and Sampalli (2021)	21 participants that picked medication from pharmacy in the past six months	NFC-based mobile application	To assess the proposed NFC-based mobile app compared with the traditional method of managing patient's prescriptions (usability testing; questionnaire; semi-structured interview)	TAM
2	Boes *et al*. (2015)	26 international students at FH Salzburg	NFC smart posters	To explore the various factors influencing consumer acceptance of NFC smart posters by applying the UTAUT (survey; experiment with smart posters)	Extended UTAUT
3	Chen and Chang (2013)	189 participants who used NFC mobile phone	Mobile phones with built-in NFC capability	To explore the factors that affect consumer acceptance of mobile phones with built-in NFC capability.(survey questionnaire)	UTAUT TAM
4	Dutot (2015)	320 smartphone users	Near Field Communication technology	To look at the main adoption factors of NFC in France and uses a TAM-extended approach (survey)	Extended TAM
5	Han *et al*. (2016)	309 visitors at the Osong Cosmetic and Beauty Expo	Expo experience through NFC	Study focused on the MOA framework and satisfaction transfer of visitors who process information using NFC to understand NFC reuse intention and Expo loyalty	MOA

				(questionnaire survey)	
6	Liébana-Cabanillas *et al.* (2020)	218 Spanish tourists that used apps in previous 6 months	NFC mobile application for Spanish tourism	To explore and analyze the antecedents of the adoption of NFC mobile app regarding the search for information in a tourist destination (video of NFC tourism apps; questionnaire)	Not specified
7	Museli and Navimipour (2018)	262 employees of the Azerbaijan Railway in Iran	NFC adoption in automation of workflows and railway services	To investigate the important variables impacting the adoption of NFC in organizations and propose an applicable model for it (questionnaire)	TAM
8	Osman *et al.* (2018)	125 respondents – teachers and students in education institutions	NFC-based Ubiquitous Learning Environment (ULE) in education	To investigate the user's acceptance, the factors that most impact the adoption, and the applications of U-Learning using NFC technology (website about NFC-based U-Learning; video about U-Learning with NFC; questionnaire; ranking survey results)	TAM TR TRAM
9	Rostam *et al.* (2015)	133 respondents from social media	Near Field Communication technology	To identify the theory that is best suited as an assessment tool of the user acceptance to the NFC technology (online questionnaire)	TRA TPB UTAUT
10	Teh *et al.* (2014)	41 exhibition visitors from ITEX that knew about NFC	Mobiquitous home application NFC smartphone entertainment systems (NFC SES)	To develop a novel concept of NFC SES and examine age-group differences in relation to the influence of intuitive, convenience and perceived usefulness on users' behavioral intention to use NFC SES (interaction with NFC SES; survey questionnaire)	Modified TAM
Mobile applications					
11	As'adi *et al.* (2021)	-	"Desa Digital" mobile application for tourism sector	To understand the intention to use and actual system usage for "Desa Digital" mobile application users in Indonesia (literature review)	TAM
12	Talantis *et al.* (2020)	220 attendees of 4 conferences in USA who used the mobile event app	Conference mobile application	To examine the determinants that influence conference attendees' attitude toward using a conference mobile event app (instructions on how to download the conference; opt-in survey)	Extended TAM
13	Schrage *et al.* (2022)	501 participants from Germany	Location-based retail apps (LBR apps)	To identify factors influencing the customers' adoption intention of LBR apps for stationary retailing (hypothetical shopping scenario; a web-based survey)	TAM
14	De Canio *et al.* (2021)	893 Chinese consumers; snowball sampling	Mobile app for shopping	To examine the influence of several intrinsic motivations driving consumers' intention to buy using a mobile app (quasi-experimental empirical analysis based on game app; online survey)	TAM UES HM
Smart Packaging					
15	Faisal *et al.* (2022)	10 participants with chronic diseases	Smart multidose blister package	To examine the integration of a smart multidose blister package and understand medication intake behavior (ethnographic-informed study with older adults using the smart multidose blister package; interviews)	TAM, TPB, COM-B
16	Daoud and Trigui (2019)	15 Tunisian consumers responsible for food purchases	Perception of Smart Packaging for traceability purposes	To discuss the factors influencing consumer's perception and how they evaluate the information provided by traceability, emphasizing the role of smart packaging (individual interviews)	Not specified
Quick Response (QR) codes					
17	Rotsios *et al.* (2022)	537 (308) consumers, 308	QR-enabled milk package	To evaluate the use of a QR Code on bottled milk (interviews with consumers and professionals)	Extended TAM
18	Acuti *et al.* (2022)	255 Italian respondents who used QR before	QR-enabled wine label from fictional brand	To conduct exploratory analysis of the use of QR codes in the wine industry (an inter-subject online experiment)	UGT
19	Liébana-Cabanillas *et al.* (2015)	168 mobile phone consumers from Facebook	QR-based payment system	To analyze the determinants and users' acceptance of QR code mobile payment systems (video of the QR-based PS; online questionnaire)	TAM Other studies
Augmented Reality (AR)					
20	Romano *et al.* (2022)	503 recruited US retail consumers who had purchased an item in the last 3 months	Attitudes towards AR as a shopping tool	To explore how consumers differ in terms of the value they receive from using AR, as well as the trade-offs they experience when using the technology for shopping (questionnaires; the scenario of furniture shopping; video assessment)	TAM, Communi-cation theory

21	Castillo and Bigne (2021)	284 make-up using women from Nicaragua and USA	AR self-service technologies (AR SSTs) in retail (AR mobile app used to shop in store)	To determine the factors that influence customers' acceptance of AR-based SSTs; propose a model (ARiR) of extended TAM by identifying factors that influence customer acceptance of AR SSTs in retail (demonstration video; online questionnaire)	Extended TAM TRI TRAM
Interactive Technologies in Store					
22	Boudkouss and Djelassi (2021)	32 participants: 20 French consumers (Facebook), 8 sales persons and 4 phygital experts	Self-checkouts and interactive kiosks	To identify and understand consumer motivations to use interactive technologies in stores through UGT and to understand how these gratifications differ between interactive technologies in-depth interviews with consumers and professionals)	UGT
23	Kim *et al*. (2017)	625 members of marketing research company's user panel in USA	Smart in-store technology (SIST): virtual mirror, social interactive dressing room, RFID tag	To examine the applicability of the TAM for explaining consumer adoption of SIST (3 hypothetical scenarios of using three different SIST; 3 online surveys in regard to SITS)	TAM
Omni-channels					
24	Park and Kim (2021)	227 general shoppers in Korea; convenient sampling	Consumers' Omni-channel adoption	To examine the antecedents of consumers' omnichannel (OC) adoption intention and explore how consumers' personality trait affects their OC adoption behavior (consumers OC adoption model; survey)	The adoption theory TRA
Internet of Things					
25	Karahoca *et al*. (2018)	426 respondents in Turkey who owned any smart device and were over 18	IoT healthcare product	To investigate critical factors affecting individuals' intention to adopt internet of things (IoT) products in healthcare (summarized introduction of the IoT healthcare product; the online survey)	TAM IDT TI, PMT

4.1. Identified variables for the extended TAM model

Overall, 182 variables have been identified from 25 studies. 169 of them were classified into 13 categories, and 13 variables were not taken into consideration due to irrelevance to this study. The classification of variables is given in Table 2.

Table 2. Classification of variables

Categories	Code	Variables	Theories	Reference*
Perceived Ease of Use	PEoU	Perceived Ease of Use Perceived Effort Expectancy**	TAM UTAUT	1, 4, 7, 8, 10-13, 15, 17, 19-21, 23, 25 2, 3, 9
Perceived Usefulness	PU	Perceived Usefulness Perceived Performance Expectancy**	TAM UTAUT	1, 4, 5-8, 10-13, 15, 17, 19-21, 23, 25 2, 3, 9
Attitude Towards Use of Technology	ATT	Attitude towards Technology	TAM	3, 11, 12, 13, 15, 19, 20, 21, 23, 25
Behavioral Intention to Use	BI	Behavioral Intention to Use	TAM, UTAUT	2-6, 8, 10, 11, 13-15, 17, 19, 23-25
Actual Usage	AU	Actual Usage	TAM, UTAUT, IDT	4, 5, 7, 17, 24
Perceived Credibility	PSC PT	Perceived Privacy and Security Perceived Trust	TR, PCT, PMT PTB	1, 3, 4, 7, 13, 16, 17, 19, 24, 25 2, 4
Individual Attributes	KE INN DC OPT TR NfC DIS IN	Knowledge and Experience (Personal) Innovativeness Decision confidence Optimism Technology readiness Need for cognition Discomfort Insecurity	CBT TRI, IDT - TR TR GM TR TR	14, 16, 17 6, 8, 19, 20, 25 20 8 21 24 8 8
Individual Beliefs	SE TA PRV TP	Self-efficacy (capability) Technology Availability Price Value Time Pressure	TAM, TRA, COM-B - UTAUT, PC, PMT -	5, 15, 21 4, 15 7, 15, 20, 25 20
Technology Attributes	ACC	Accessibility	-	8

	INTR	Interactivity	HCI, UGT, IxD?	6, 8, 17
	MOB	Mobility	CSCW, HCI	19
	INTT	Intuitive	TAM, IxD	10
	NAV	Facilitated Navigation	-	21
	TRI	Trialability	IDT	25
	PER	Performance	-	6
Social Context	SI	Social Influence and SN	TAM, UTAUT, UGT,	2, 3, 4, 9, 13, 15, 19, 22
	SP	Social presence	TRA, TPB	11, 14
Motivation	MOT	Motivation	MOA	15
	SAT	Satisfaction	ECT	5, 12
	PEJ	Perceived enjoyment	TAM, UTAUT, UGT	6, 11, 12, 13, 14, 20, 22, 23
	PV	Perceived value	MOA	5, 6, 18, 20, 25
	PQ	Perceived quality	MOA, UGT	1, 2, 5, 16, 21, 24
	CTRL	Control	UGT	22
	TS	Time-saving	UGT	22
	IS	Information-seeking	UGT	22
	IM	Image	TAM, IDT	6, 25
Facilitating conditions *(opportunity COM-B)*	FC	Facilitating conditions	UTAUT, MPCU,	3, 5, 9, 15
	PCOM	Perceived compatibility	MOA	11, 19, 25
			IDT, TAM	
Individual Experience	GAM	Gamification	SDT	14
	FA	Focused attention	ET	14
	ENG	Engagement	ET - UPI	14

*The number of each investigated study can be found in Table 1.
**Sub-variables are not included in the final list.

4.2. The original variables from TAM

This study has identified five variables from the TAM model as impactful determinants of technology acceptance: Perceived Ease of Use, Perceived Usefulness, Attitude towards Use, Behavioral Intention to Use, and Actual Use. This study uses the traditional definitions from Davis (1989) to describe the variables. Perceived Ese of Use is "the degree to which a person believes that using a particular system would be free of effort" (p. 320). In this study, both perceived ease of use and effort expectancy (Venkatesh *et al*., 2013) are combined, and the former is appointed as the main variable for the established model (see Table 2). Perceived Usefulness is "the degree to which a person believes that using a particular system would enhance his or her job performance" (Davis, 1989, p. 320). In this study, both perceived usefulness and performance expectancy (Venkatesh *et al*., 2003) are combined, and the PU is designated as the main variable for the established model (see Table 2). Attitude towards Use is "a measure of the likelihood that a person will get the given behavior" (Karahoca *et al*., 2018, p. 747). Behavioral Intention to Use is a possible action or the tendency of an individual affected by attitude targets (As'adi *et al*., 2021). Actual Use is an individual's actual utilization of a given technology (Venkatesh *et al*., 2012)

4.3. Perceived Credibility

Perceived security and privacy have been shown to correlate highly and therefore are usually aggregated together, referring to them as perceived credibility (Dutot, 2015). In this study, the perceived credibility is an important construct that encompasses several elements, including (1) authenticity and reliability of the information displayed on the products (Daoud and Trigui), (2) privacy concerns (Dinev and Hart, 2006), (3) security concerns (Dutot, 2015), and (4) trust (Flavian *et al*., 2006). According to Daoud and Trigui (2019), providing understandable and authentic information enhances consumers' trust in the product information. Cue Utilization Theory (Olson and Jacoby, 1972) and Signaling theory (Spence, 1973) explain how consumers use product information to differentiate between better and lower quality products without previous experience. Therefore, to consumers, the credibility of product information may signal the quality of the product (Daoud and Trigui, 2019). In relation to smart packaging, the consumers' perception of traceability (e.g. authentic information about a product's origin) depends on its ability to enhance consumer confidence about the product information given by the retailer or brand (Chrysochou *et al*., 2009). Consequently, consumers tend to show a higher level of confidence towards technologies that provide traceability information and have a lower chance of being counterfeited (Daoud and Trigui, 2019).

Privacy

Another relevant element of perceived credibility is privacy. Dinev and Hart (2006) define privacy concerns as "concerns about

opportunistic behavior related to the personal information submitted over the Internet by the respondent in particular." (p. 64). In other words, privacy concerns mark the willingness to share personal information over the internet. Consumers might be concerned about what happens to their personal information that they disclose to the connected information system through smart packaging using their mobile devices. Especially since the advances in data mining allow companies to profile consumers and identify their preferences, leading to increased concerns among consumers about how their personal information is being used without their consent (Dinev and Hart, 2006). The greater the privacy concerns, the greater the uncertainty about the access and use of personal information. Chen and Chang (2013) pointed to anxiety as one of the threats to privacy and safety when using NFC-enabled mobile phones. As a result, the requirements to submit personal information or agree to use personal information might be factors that discourage consumers from using the interactive system. Furthermore, Gupta (2013) found out that people perceive tracking of their behavior using mobile phones as a threat to their privacy that negatively affects their intention to use mobile apps (Pentina *et al*., 2016) and their attitudes regarding mobile advertising (Ketelaar *et al*., 2018). Considering that location-based retail apps track personal data, users may feel a loss of control over their personal information, which might negatively affect their attitude towards the use of technology in-store (Schrage *et al*., 2022). Moreover, fear of spam is another privacy obstructor that is defined as customers' fear of receiving "various intrusive marketing messages on their mobile device", i.e. fear of spam (Dickinger and Kleijnen, 2008, p. 27). Consumers are usually threatened by unsolicited location-based advertising and tend to feel disturbed and irritated, which negatively influences their attitudes towards such technologies (Schrage *et al*., 2022).

Security

While privacy concerns evolve about how personal information is used, security concerns the level of protection against threats provided by the technology. Security concerns and risks arise from the use of the internet, that is filled with potentially untrustworthy webs, technology bugs and hackers (Nor, 2011). In general, NFC technology employs a wireless method to transfer data, therefore the security layer for transferring personal information is required, especially due to the potential risks of eavesdropping, ticket cloning, phishing, and relay attack (Aldughayfiq and Sampalli, 2021). Consequently, perceived security has been found to have an influence on a person's decision to adopt online services (Dutot, 2015). Most studies on NFC technology and security were made in the wireless payment context. According to Shin *et al*. (2014), mobile payment adoption behaviour mostly depends on three factors – security, cost and convenience when making mobile payments. Oliveira *et al*. (2016) found that perceived technology security had significant effects on the adoption of NFC mobile payment. As a result, individuals' beliefs that their interactions with interactive systems are conducted securely influence their decision to accept the technology (Dutot, 2015). Therefore, establishing of security mechanisms, standards, and rules for NFC interactions emphasize the security features of NFC technology, generates confidence and the perception of safety, and, thereby, improves attitudes towards the technology (Dutot, 2015; Zhao *et al*., 2019; Liébana-Cabanillas *et al*.,2015).

Trust

Trust is an essential determinant in high-technology-oriented environments, especially related to e-commerce and social media (Dutot, 2015). Businesses have placed a greater emphasis on creating and enhancing consumer-brand relationships (Lydekaityte and Tambo, 2020), where trust plays a central role (Dutot, 2015). Analyzing the drivers for in-store consumer services in the technology-enhanced retail environment indicated trust as a meaningful element (Vannucci and Pantano, 2020). In this study, trust is considered a behavioral component that relates to "the individual's intention to act in a certain way and reflects the security that one party has in the other one" (Dutot, 2015, p. 47). In regard to this perspective, trust can also be described as the willingness to rely on someone (Flavian *et al*., 2006). According to Museli and Navimipour (2018), users' perceived trust in the NFC technology relates to "consumers' belief that the NFC services will be handled and processed in accordance with their expectations". The increase in trust leads to positive adoption intentions (Museli and Navimipour, 2018). As a consequence, in a mobile environment, the perceived security, privacy and trust of the interaction process are significant success factors of technology adoption (Boes *et al*., 2015; Dutot, 2015). Boudkouss and Dielassi (2021) argue that trust in the seller is one of the several factors that may attract consumers to the use and adoption of information systems. De Canio *et al*. (2021) pointed to trust as one of the antecedents of customer experience that moderates the intention to use the technology. Hongxia *et al*. (2011) suggested that a higher degree of trust from consumers in regard to the use of NFC smart posters prompts a stronger and more and interest-evoking intention to use the technology.

4.4. Individual attributes

Knowledge and Experience

Attewell and Rule (1991) conceptualized the prevalence of technological innovations regarding the decrease in knowledge barriers. One of the main determinants of innovation adoption is the consumer's perception of a product's relative advantage. A previous study in consumer behavior (Bettman and Park, 1980) found that the choice process (i.e. decision-making) is highly influenced by the consumer's prior knowledge and experience with the product or technology. A survey conducted by PwC (2017) indicated that technology and relevant product knowledge became an important tool for enhancing the in-store consumer experience. In line with the findings, reported by Wyrwa and Barska (2017), which investigated consumers' perception of active and intelligent packaging and concluded that due to the lack of knowledge about smart packaging applications, the concept of enhanced packaging needs to be popularized in society. Consumers should have basic knowledge regarding the technologies embedded in the product's packaging to eliminate the anxiety of the unknown (Lloyd *et al*., 2019). Consequently, consumers' perceptions can be improved by increasing their awareness of these innovations (Daoud and Trigui, 2019). The probability of adopting the new technology will increase by overcoming the deficiency in consumers' knowledge. In relation to TAM, the model suggests that individual beliefs influence the attitudes and, in turn, the intentions and behavior to use the technology. For that matter, the theory of reasoned action (Ajzen and Fishbein, 1980) states that individual beliefs are based on a person's knowledge. Therefore, consumers' prior knowledge and experience with NFC technology highly influence their perception and adoption of enhanced product packaging. Similarly, De Canio *et al*. (2021) argue that the more expert and knowledgeable with the online shopping platform the users are, the more willing they will be to perform this interaction continuously.

Furthermore, prior experience with the same or similar technology is also considered the main factor in a person's attitude toward adoption decisions (Marangunic and Granic, 2015). Museli and Navimipour (2018) define technology experience "as the subjective personal reactions and feelings that are felt by consumers when consuming or using the defined services". If users had a favorable personal experience with the technology, their attitude toward it and intention to use would be higher (Museli and Navimipour, 2018). Therefore, it is important to investigate the effect of prior experience on technology adoption. Overall, in this study, the definition of prior knowledge and experience is about "people's perceptions of what or how much they know about a product, based on their subjective interpretation making" (Daoud and Trigui, 2019, p. 360).

Decision Confidence

Decision confidence refers to "the degree of certainty that people have about the appropriateness of their decisions" (Romano *et al*., 2022, p. 1225). Confidence in decisions lowers the cognitive effort required to make decisions and, thereby increases the decision quality and satisfaction with the decision (Oh *et al*., 2008). Previous study confirms that decision confidence is a reliable construct of consumer attitudes and actual behaviors (Guillet *et al*., 2020). In their study Romano *et al*. (2022) proved the consumers' perception of decision confidence as one of the drivers of consumer attitudes towards the interactive system.

Technology Readiness

The technology readiness model was developed by Parasuraman (2000) that refers to "people's propensity to embrace and use new technologies for accomplishing goals in home life and work" (p. 308). Osmats *et al*. (2018) define technology readiness as a person's tendency to accept and use new technologies to finish their tasks. According to Chang and Chen (2021), technology readiness is considered a formative construct to evaluate the overall personality, including four subdimensions discomfort, insecurity, optimism, and innovativeness. The first two are considered inhibitors of technology readiness, whereas others are contributors (Chang and Chen, 2021). In a study by Castillo and Bigne (2021), researchers assign personal innovativeness and optimism as subdued constructs of technology readiness, whereas Osman *et al*. (2018) employed all four subdimensions in their model.

Personal Innovativeness

Usually, innovation in IT refers to novelty in products, services and procedures that facilitate the increase in competitive advantage (Museli and Navimipour, 2018). According to Innovation Diffusion Theory, people tend to react differently when adopting innovation due to their personal differences, such as personal innovativeness (Karahoca *et al*., 2018). In innovation diffusion research, personal innovativeness has had a long-standing tradition as a construct of individual behavior toward innovations (Agarwal and Prasad, 1998). Individuals with a higher level of innovation might develop more favorable perceptions of technology innovation that would positively affect the intention to use it (Liébana-Cabanillas *et al*., 2020). Personal innovativeness is "willingness of an individual to try out any new information technology" (Agarwal and Prasad, 1998, p. 206).

It is the degree to which people seek new experiences, such as different products (Romano *et al*., 2022). Innovativeness can also be referred to the tendency to be a technology pioneer (Castillo and Bigne, 2021). Agarwal and Prasad (1998) conceptualized personal innovativeness as a personality trait that reflects the proactive and favorable personal attitude when interacting with new technology. Therefore, this study categorizes personal innovativeness as a user attribute. Since NFC-enhanced product packaging can be referred to as an innovative technology in the retail market that is likely to be a trend in a few years, personal innovativeness becomes a potential determinant that affects the intended use of the NFC system, the perceived usefulness and perceived ease of use. These assumptions are justified in relation to previous research (Liébana-Cabanillas *et al*., 2020; Osman *et al*., 2018; Romano *et al*., 2022; Karahoca *et al*., 2018), which outlines information technology effect on technology adoption, as well as determining that people with a higher level of personal innovativeness develop more positive perceptions about innovation. For example, Karahoca e al. (2018) study in IoT healthcare product context concluded that the impact of technological innovativeness toward perceived advantage was found significant. Similarly, results from Osman *et al*. (2018) confirmed that innovativeness is one of the most influencing factors in the adoption of U-learning using NFC technology. As a result, personal innovativeness in the adoption of IT is a critical determinant explaining individual user adoption behavior (Liébana-Cabanillas *et al*., 2015).

Optimism

Castillo and Bigne (2021) state that optimism captures "how consumers felt about the benefit of technologies in their daily consumption activities" (p. 891). As Chang and Chen (2021) expressed, a person's propensity to adopt an interactive system might differ based on his/her technology-related personality. Therefore, optimism is an important determinant when introducing new technologies. Castillo and Bigne (2021) argue that optimism as a mood can influence the perceived ease of use of the technology. Furthermore, in Osman *et al*. (2018) research, optimism had the highest impact factor on positive perception about using NFC technology in education, i.e. users were found optimistic about using NFC technology in education.

Discomfort and Insecurity

Parasuraman (2000) pointed out that the high values of innovativeness and optimism promote the emergence of overall technology readiness, whilst the high values of insecurity and discomfort provoke a decrease in it. Discomfort is defined as an "individual's anticipation of lacking the sense of mastery of the new technologies and being overwhelmed by them" (Chang and Chen, 2021, p. 4), whereas insecurity refers to "distrust of new technologies and septical attitude toward their abilities to work correctly" (Chang and Chen, 2021, p. 4).

Need For Cognition

Need for cognition (NfC) is a personality trait that describes the need for activity or stimulation with cognitive efforts often shaped by external influences during socialization and interaction of learning experiences (Cacioppo and Petty, 1982; Park and Kim, 2021).In general, NfC-low individuals tend to have little effort to achieve their goals, while NfC-high individuals tend to have more effort and stimulation (Yee and Braver, 2018). It is argued that "an individual's cost-benefit tradeoff is constrained by the perceived costs of exerting cognitive effort" and, therefore, the decision to engage in an effortful cognitive process is preferred (Park and Kim, 2021, p. 1394). For instance, NfC-high people might be greatly motivated to use the NFC technology compared to NfC-low people regarding benefits received from the interaction with the technology, such as making sure that the product is authentic or watching a quick video on how to cook the purchased product. According to Park and Kim (2021), the need for cognition might be a significant personality attribute that affects the relationship between extrinsic motivation and intention to use technology.

4.5. Individual Beliefs

Self-efficacy

Self-efficacy has been defined as "self-assessed expectations of performance" (Chou and Wang, 2000, p. 459). In other words, it is users' confidence in their ability and skills required to perform a task (Demoulin and Djelassi, 2016; Faisal *et al*. 2022). To possess self-efficacy in the use of NFC technology, it is imperative to be proficient in its use (Han *et al.*, 2016). According to Han *et al*. (2016) study results, the lower ability to interact with NFC technology determined the lower assessment of NFC value and satisfaction. Therefore, self-efficacy is directly related to perceived value. Zhu *et al*. (2013) in their study reported that the higher level of self-efficacy in using the technology the user possessed, the higher value of that technology is perceived by the user. Furthermore, self-efficacy as a construct was identified by Venkatesh and Bala (2008) as having a favorable impact on

perceived ease of use in TAM3 and has been confirmed in other interactive system studies (Faisal *et al*., 2022; Castillo and Bigne, 2021; Blut *et al*., 2016). When consumers are directly engaged with the technology, their confidence in technology knowledge and ability plays a significant part in assessing the ease of use of the new technology (Blut *et al*., 2016). In NFC-enabled product packaging, it is expected that consumers will feel comfortable with their phones while interacting with NFC. The ability to perform a specific task increases satisfaction and, thereby, influences the behavioral intention to use the technology or product (Han *et al*., 2016).

In addition, since the construct of perceived behavioral control belonging to facilitating conditions by definition is "the perceived ease or difficulty of performing the behavior" (Venkatesh *et al*., 2003, p. 429), it was decided to add it under the self-efficacy category.

Technology Availability

The success of the IT infrastructure depends on a robust technical infrastructure plan, a thorough implementation plan, and well-timed maintenance and upgrades (Tarafdar and Vaidya, 2006). As presented in the literature, the easier and more trusted way to access and use the technology, the easier it is for the users to adopt the technology (Museli and Navimipour, 2018). In their research, Osman *et al*. (2018) refer to the accessibility of technologies that is one of the factors influencing the utilization and usage of NFC-based U-learning. Furthermore, Faisal *et al*. (2022) confirmed that the availability of the necessary technology to use smart packaging is of considerable importance and can influence smart packaging integration into in-home medication management. Dutot (2015) considers technology availability as the degree to which "an individual believes that technical infrastructure exists to support the use of the system" (p. 48). This research adopts Dutot's (2015) proposal that technology availability is considered the extent to which consumers have access to NFC technology, including how easily they can exploit, purchase or obtain NFC technologies.

Price Value

In this research, the price value is a various construct encompassing not only the monetary value but also time and emotional efforts and price consciousness. Firstly, the perceived cost is defined "as the extent to which an individual believes that using NFC mobile payment will cost money" (Pham and Ho, 2015, p. 162). In this sense, the cost refers to the money required to acquire something (Karahoca *et al*., 2018). The lower cost of the technology, the more it will be quickly adopted and implemented (Tornatzky and Klein, 1982). Secondly, price value also includes more than just the monetary factor, such variables as time and emotional effort needed to invest in using the technology, learning cost, restrictions and limitations also highly impact the user's perception of price value (Museli and Navimipour, 2018). For instance, a study results from Faisal *et al*. (2022) disclosed that consumers are willing to pay for technologies if they receive the proper value from them, such as a reminder for their medication intake. In their research, the cost was reported as a significant determinant impacting the use of adherence technology. Finally, Romano *et al*. (2022) included price consciousness in their model as "the importance consumers place on price and price changes." (p.1225). Findings from Musel and Nivimipour (2018) indicated cost as one of the main variables impacting the adoption of NFC technology.

Time Pressure

Time pressure as a consumer psychographic factor refers to a person's predisposition to consider time as a scarce resource (Romano *et al*., 2022). According to the authors, time pressure might have an influence on attitude towards the use of technology and its perceived usefulness.

4.6. Technology Attributes

Technology Accessibility

According to Nor *et al*. (2011), the more technological infrastructure becomes readily and easily available, the more usable and accessible the internet-connected applications will appear. The previously described technology availability construct relates to an individual's belief in his/her access to technology. However, accessibility concerns how reach-able, achievable the technology is, i.e. is the technology spread worldwide, is it prevalent, is it standardized, etc. Osman *et al*. (2018)'s results support that accessibility is one of the factors that influence the adoption of U-Learning using NFC.

Interactivity

Oxford dictionary describes interactivity as "a dynamic and reciprocal communicative relationship between a user and a computerized media device where each new action is contingent on a previous action." (www.oxfordreference.com). In relation to the context of technology acceptance, user interaction with technologies has been found to impact their behavioral intention to use that technology (Liébana-Cabanillas *et al*., 2020). With regard to the study of the effects of new technologies, interactivity is determined as a construct of great relevance (Liébana-Cabanillas *et al*., 2020). According to Mollen and Wilson (2010), interactivity is "the degree to which the user perceives that the interaction or communication is two-way, controllable, and responsive to their actions" (p. 921). In terms of NFC technology, interactivity takes place when users are redirected to a specific website through a mobile device to receive additional information about the product or a voucher for the next purchase (Lydekaityte, 2020). The major advantage of interactive systems is the ability to provide information in a personalized way without any time or place restrictions (Rotsios *et al*., 2022). Interactive content helps users better comprehend the characteristics of a product (Rotsios *et al*., 2022).

Mobility

The availability of smart devices has led to rapid adaptation; one of the main reasons for this phenomenon is the mobility that these devices provide, including access to information, communication, and services independent of place and time, allowing people to be connected at any location (Mallat *et al*., 2009; Liébana-Cabanillas *et al*., 2015). Kourouthanassis *et al*. (2010) state that mobility "involves interactions within individuals and artifacts within a given space" and that the degree of mobility is application-dependent and temporal-spatial unlimited (p. 279). Mobility can also be understood as "the extent of user awareness of the mobility value of mobile services and systems" (Park *et al*., 2014, p. 6). There have been several studies in mobile communications that support causal relationships between mobility and perceived usefulness. Park *et al*. (2014) proved that mobility had significant effects on perceived usefulness. Liébana-Cabanillas *et al*. (2015) investigated the relevance of mobility to influence the perceived usefulness, attitude towards the use of technology, and intention to use the technology. Furthermore, Wu *et al*. (2007) pointed out that greater mobility makes consumers remain with mobile systems for longer periods of time, enabling a higher connectedness among people using the services. As a result, consistent with previous studies related to mobility, this study hypothesizes the following.

Intuitiveness

The industry increasingly demands intuitive, effortless and enjoyable computing systems (Lydekaityte, 2019). According to the author, the interactions with IT systems have to be simple and intuitive, taking into consideration users' inherent capacity to accomplish tasks with those systems. Therefore, tapping with a smartphone on the NFC-enabled item has to be an intuitive user-aware gesture. Teh *et al*. (2014) define intuitive as being "able to understand something by using feelings rather than by considering the facts" (p. 488). Teh *et al*. (2014) study reveals that intuitiveness is a significant determinant of adult behavioral intention to use NFC SES. Whereas Ang *et al*. (2021) found that the intuitiveness of the user interface was positively associated with the attitude towards the digital reference guide.

Facilitated Navigation

Navigation in the retail context can be described as the "process of exploring the interactive environment in alternative ways to seek out product-related information" (Childers *et al*., 2001, p. 515). The ease of navigation can be seen as a distinct, complementary feature of the NFC system that facilitates interaction with the technology through the mobile device. It has been proven that user-friendly designs of interactive systems are significant constructs for enhanced customer experience, thus, the effective navigation of the system can positively influence the perceived usefulness of the technology (Castillo and Bigne, 2021).

Trialability

Trialability represents an opportunity for experimentation (Hayes *et al*., 2015), i.e. the ease with which users can try a new product. The innovation diffusion theory defines trialability as "the degree to which an innovation may be experimented with on a limited basis" (Karahoca *et al*., 2018, p. 745). Hayes *et al*. (2015) argue that consumers' experimentation with an innovation reduces the uncertainty of the outcome, thereby leading to a more favorable adoption of the innovation.

Performance

Liébana-Cabanillas *et al*. (2020) identified two types of risk associated with the adoption of the technology that decrease the

intention to use it: social risk and performance risk. The social risk relates to the loss of social status, whereas performance risk is the possibility that the NFC system will not work as expected and will not provide the intended advantages. In relation to NFC, the distance between the reader antenna and the chip integrated into the packaging is a critical parameter for satisfactory performance (Karpavičė *et al*., 2022).

4.7. Social Context

The emergence of technological devices has embraced both physical and digital communication and social interaction represented as social networks, online communities, and mobile apps (De Canio *et al*., 2021). The assessment of the acceptance of technology should not fail to consider the social context of decision-making: the favorable social context for using the technology leads to a higher probability of adoption of the technology (Liébana-Cabanillas *et al*., 2015). Social context is included in this study through the measurement of social influence, social presence and socialness. Overall, social influence covers social factors, images and subjective norms as sub-constructs (Venkatesh *et al*., 2003).

Social Influence

Social influence is described as "the extent to which consumers perceive that important others (e.g., family and friends) believe they should use a particular technology" (Venkatesh *et al*., 2012, p.159). Similarly, Chen and Chang (2013) argue that social influence means the consumer's intention to use the new technology system based on influence from other people around them. It is linked to the degree of significance with which a person decides whether to use a particular technology (Boes *et al*., 2015). Since new technologies are considered high risk, potential consumers are inclined to seek the opinion of their social circle about such innovative products (Giovanis *et al*., 2019). People are more likely to use technology if they think that this would influence the perception of others. As suggested by Chen and Chang (2013), the intention to use NFC technology depends on the degree of influence from others who belong to a person's social circle. From Theory of Reasoned Action this is referenced as "the person's perception that most people who are important to him or her think he or she should or should not perform the behaviour in question" (Fishbein and Ajzen, 1977, p. 302). Previous research showed that subjective norms greatly influence consumers' intention to engage in mobile shopping, i.e. people demonstrate a strong tendency to rely on opinions from others when deciding to adopt mobile services (Schrage *et al*., 2022). In relation to NFC, the implementation of this technology in product packaging is still in the early stage of diffusion and development. Usually, at this stage, the potential users of any technology lack trustworthy information about the use of such technologies (Liébana-Cabanillas *et al*., 2015). The importance of the relationship between social context and intention to use the technology has been proved by several studies (Chen and Chang, 2013; Dutot, 2015; Rostam *et al*., 2015).

Social presence

Calefato and Lanubile (2010) define social presence as "the degree to which one perceives the presence of participants in the communication" (p. 287). According to the authors, Social Presence theory argues that communication medium differs in its ability to convey the perception that other people are physically present. Previous studies have used different names to define social presence. For instance, Boudkouss and Djelassi (2021) identified connectedness (social gratification) as "the use of medium or technology to interact and connect with others" (p. 1628). Whereas De Canio *et al*. (2021) used the construct of socialness that refers to "the creation of a sense of group participation and membership" (p. 926). For instance, in online games, the chance to socialize among users was found as the driver for building a sense of group participation (Holopainen, 2011). Social presence is also confirmed in retail environments, where mobile systems allow to share shopping tasks and buy and interact with relatives simultaneously (De Canio *et al*., 2021). Social Presence theory argues that social presence is a strong indicator of satisfaction: the greater sense of social presence is conveyed by a medium, the greater satisfaction is perceived by users when interacting (Calefato and Lanubile, 2010). Previous studies showed consistent results regarding the positive impact of social presence and perceived ease of use, perceived usefulness, and perceived enjoyment (Smith and Sivo, 2012; As'adi *et al*., 2021; Dutot, 2015).

4.8. Motivation

Motivation refers to the users' wants and needs to achieve specific goals with the technology (Faisal *et al*., 2022). In relation to this study, motivation is based on intrinsic and extrinsic rewards that can be obtained using NFC-enabled product packaging. Intrinsic values include playfulness and aesthetics, while extrinsic include service excellence and return on investment (Mathwick *et al*., 2001). Motivation is highly related to hedonic gratification presented in UGT (Boudkouss and Djelassi, 2021). Hedonic motivation expresses the degree to which a specific technology is fun and enjoyable and fulfils the user's needs for pleasure and

emotional release (Boudkouss and Djelassi, 2021).

Satisfaction

Expectation Confirmation Theory (ECT), proposed by Bhattacherjee (2001), explains the intention to use the information system in the future and determines that satisfaction directly impacts whether the system will be used continuously. This dependency is proven in studies related to diverse information systems (Han *et al*., 2016; Chen and Lin, 2015; Talantis *et al*., 2020).

Perceived enjoyment

The scientific literature on information systems and technology acceptance argues that intrinsic motivation, including fun, entertainment, enjoyment and playfulness, has a significant impact on the user's intention to use new systems and applications (Liébana-Cabanillas *et al*., 2020). Particularly, Perceived Enjoyment (PE) is perceived as an intrinsic factor to motivate people to engage with technology leading to interesting and exciting interactions (As'adi *et al*., 2021). Overall, perceived enjoyment was first presented in the TAM by Davis (1986). PE represents a hedonic factor (Schrage *et al*., 2022) that is defined as "the degree to which the activity of using technology is perceived to be enjoyable in its own right apart from any performance consequences that may be anticipated" (Davis *et al*., 1992, p. 1113). The NFC-enabled system, with potential connectivity and interactivity, can provide users with a degree of enjoyment, pleasure and fun (De Canio *et al*., 2021). For instance, a study by (Liébana-Cabanillas *et al*., 2020) proved that NFC-enabled mobile apps include enjoyment factors that create enjoyable experiences among consumers and provide enjoyable benefits for users, increasing their intention to use the technology. In this study, the perceived enjoyment with NFC represents consumers' positive mood experienced during the interaction with NFC-enhanced product packaging.

Perceived value

Zeithaml (1988) defines Perceived Value (PV) as "the consumer's overall assessment of the utility of a product based on perceptions of what is received and what is given" (p. 14). It contains both utilitarian factors, such as visual appearance, entertainment, enjoyment, escapism, and hedonic factors, such as economic value and service excellence (Acuti *et al*., 2022; Romano *et al*., 2022). Perceived value could also be categorized as hedonic or utilitarian from the Uses and Gratification Theory perspective. The former is pleasure-oriented and motivated by the desire for sensual fantasy, pleasure and fun, whereas the latter is related to functional attributes and focused on instrumental expectations (Acuti *et al*., 2022). According to the authors, "utilitarian outcomes refer to the effectiveness of individual activities improved by using technology, while hedonic outcomes refer to the pleasure derived from using it" (Acuti *et al*., 2022, p. 513). Both factors address the interactive system's ability to gratify consumers' needs (Acuti *et al*., 2022).

Particularly, studies in information systems proved the relationship between the perceived value and customer satisfaction of the technology (Han *et al*., 2016). The study conducted by the authors substantiated that the higher value of NFC service was perceived by the participants, the higher the satisfaction of the overall experience was ranked. Likewise, Liébana-Cabanillas *et al*. (2020) demonstrated that perceived value positively influences the user's intention to use the NFC app.

Perceived quality

The Perceived Quality (PQ) of the NFC system directly influences the perceived value of the technology (Han *et al*., 2016). PQ is "the consumers' judgment about the superiority or excellence of a product" (Zeithaml, 1988, p. 5). Perceived quality encompasses several diverse attributes in relation to both the quality of the interactive system and the quality of the information that the system provides that, in turn, influences the usage of technology (Boes *et al*., 2015).

Information quality as intrinsic motivation can also be regarded as a measure of an interactive system's success and satisfaction (Han *et al.*, 2016). A study of RFID usage in libraries by Dwivedi *et al*. (2013) proved that the higher the information quality of RFID, the higher the consumer's satisfaction with using it. Based on investigated studies, the quality of information depends on information diagnosticity (Daoud and Trigui, 2019), information's availability and reliability (Aldughayfiq and Sampalli, 2021), information integration and information consistency (Park and Kim, 2021). Adapting the definition of information diagnosticity proposed by Jiang and Bendasat (2004), in this study, information diagnosticity is defined as consumers' perception of the ability of the NFC system to convey relevant product information that can assist them in understanding and evaluating the quality and performance of products. Information availability and reliability impart a safe method to access verified information avoiding the inappropriate use of a product or service (Aldughayfiq and Sampalli, 2021). Particularly in retail settings, consistent and integrated information must be provided to consumers to facilitate their adoption and usage of interactive technologies (Park and

Kim, 2021). Information integration refers to the degree of integration of a product's information from heterogeneous sources, such as product inventory, arrival date, price, delivery information, etc. (Park and Kim, 2021). In comparison, information consistency refers to "the degree of consistency of product information" that gives a seamless experience across different interaction channels of the product (Park and Kim, 2021).

Service integration and visual appeal were named by the investigated studies as having an impact on the quality of the information system. Consumers' interaction with NFC-enabled packaging merges the physical product in-store with its digital twin online, thus, the service integration between these two channels has to be ensured and well-established. Furthermore, the visual appearance of the interactive system is just as important, including the visual elements that improve the overall presentation of the interactive system (Castillo and Bigne, 2021).

Control

Control refers to "the fact that an individual can choose the timing, content and sequence of communication" (Boudkouss and Djelassi, 2021, p. 1628). Consumers might experience a sense of control during the NFC interaction, for instance, when they initiate the interaction by willingly tapping on the NFC-marked item. Correspondingly to Bulmer *et al*. (2018) investigation on self-checkout, NFC-enabled packaging allows the consumer to control the pace of interaction and enjoy the benefits of customized features.

Time saving

Consumers consider certain technologies attractive because of their ability to facilitate convenience and help them save time (Boudkouss and Djelassi, 2021). In relation to the retail environment, shoppers with limited time aim to reduce their time and energy spent when buying products (Ray *et al*., 2019).

Information seeking

Boudkouss and Djelassi (2021) refer to information-seeking as a utilitarian goal-oriented driver. Information seeking is defined "as using social media to seek out information or to self-educate" (Whiting and Williams, 2013, p. 364). Users are choosing to use technology to gain resourceful and beneficial information (Boudkouss and Djelassi, 2021).

Image

Moore and Benbasat (1991) proposed Image as one of the extended innovation diffusion attributes. Image is defined as "the degree to which use of an innovation is perceived to enhance one's image or status in one's social system" (Moore and Benbasat, 1991, p. 195). In other words, image corresponds to the desire to gain social status by adopting an innovation (Karahoca *et al*., 2018). Liébana-Cabanillas *et al*. (2020) relate Image to the social risk that refers to the potential loss of status among family, friends and acquaintances.

4.9. Facilitating Conditions

Facilitating conditions

According to Venkatesh *et al*. (2003), facilitating conditions comprise three sub-constructs; perceived behavioral control, facilitating conditions, and compatibility. Since, by definition, perceived behavioral control is the perceived ease or difficulty of performing the behavior" (Venkatesh *et al*., 2003, p. 429), it was decided to categorize it as a sub-construct of self-efficacy. Facilitating conditions are defined "as the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system." (Venkatesh *et al*., 2003, p. 453). In their study, Han *et al*. (2016) included the construct of organizational support for using NFC as facilitating conditions. Using a new interactive system, such as NFC, needs guiding and learning about the technology. Therefore, to successfully introduce NFC technology into product packaging, brands and retailers must provide users with a guide to help them understand how to use the technology and perceive its value (Chen and Chang, 2013). The competence and accessibility to necessary resources positively impact the attitude towards information systems and the acceptance of technology (Chen and Chang, 2013).

Perceived compatibility

Perceived compatibility, as an important factor of innovation diffusion theory, is defined as "the status of an innovation that is perceived as being consistent with the existing values, past experiences and needs of potential adopters" (Karahoca *et al*., 2018, p. 745). It is implied that this construct includes the coherence of an interactive system with the behavior patterns, values, and

experiences of a user (Liébana-Cabanillas *et al.*, 2015). Moreover, the relationships between perceived compatibility and perceived ease of use, perceived usefulness and attitude towards using the technology have been confirmed by previous studies (As'adi *et al*., 2021).

4.10. Individual Experience

Gamification

In general, gamification refers to the process of using video game elements in non-gaming systems to improve user experience and engagement to encourage participation (López-Martínez *et al*., 2020). Gamification is a tool for enhancing the user's motivation and engagement generating favorable experiences for the user and, thereby, affecting their commitment towards the brand (De Canio *et al*., 2021). Authors have proved that gamification influences the intention to use the technology.

Focused attention

Focused attention, also known as a flow state, "represents the individual temporal and environmental dissociation derived by the total absorption in the performed task" (De Canio *et al*., 2021, p. 925). User awareness is narrowed only to the activity itself, resulting in a higher task involvement (Webster and Martocchio, 1995). It is one of the main elements of the hedonic perception of user engagement (De Canio *et al*., 2021).

Engagement

O'Brien (2010) defines engagement "as both the act of emotionally involving users and the state of being in gear and interacting directly with a system (p. 345). It implies the capability of technology to capture users' attention, inducing a sense of community and fun (De Canio *et al*., 2021). Furthermore, engagement with a mobile app can be outlined as "a psychological state that occurs by virtue of interactive, co-creative customer experiences with a focal agent/object (e.g., a media)" (Brodie *et al*., 2011, p. 259). In this research, NFC engagement is conceptualized as consumer experiences while interacting with NFC-enabled product packaging with their mobile devices to captivate consumers' attention and trigger a conversation with the product and brand.

4.11. Other

As mentioned before, numerous variables from other studies have been decided not to include in this study due to the irrelevance of the topic or insufficient clarification of what they represent. The following 13 constructs from investigated studies were excluded from this study: Responsiveness, Smartness, Permanency, Accessibility, Immediacy, Context-awareness (Osman *et al*., 2018); Age (moderator) (Teh *et al*., 2014); Food involvement (Daoud and Trigui, 2019); Perceived information overload, Demographic variables (Romano *et al*., 2022); Need for Personal Interaction (Castillo and Bigne, 2021); Perceived Severity and Perceived Vulnerability (Karahoca *et al*., 2018).

4.12. Extended TAM model for NFC-enhanced product packaging

Below, in Figure 3, the proposed extended TAM model for the adoption of NFC technology is provided, combining all 42 variables grouped into 13 categories. The model represents the supported structural relationships between variables based on the findings from 25 studies.

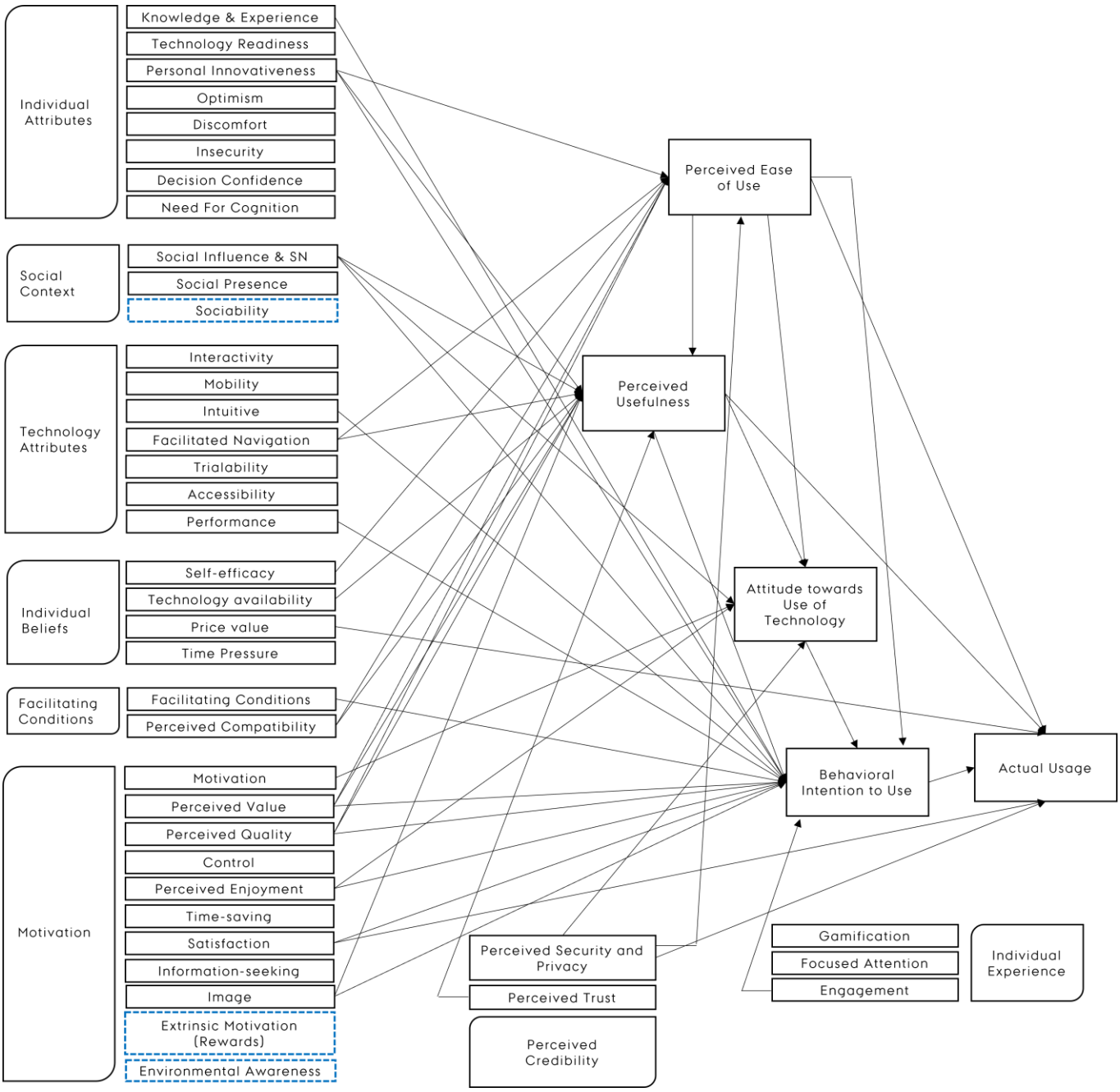


Figure 3. extended TAM model for NFC-enhanced product packaging; rectangles – indicate variables, diagonal corners rounded rectangles – indicate categories, line arrows – indicate the supported structural relationships from 25 studies, blue dashed rectangles – indicate the proposed additional variables

4.13. Selection of the most important variables impacting the adoption of NFC

The identification of the most impactful determinants of NFC acceptance has been carried out in four steps by quantifying the results and applying Multi-Criteria Decision Analysis (MCDA). Overall, 42 variables were examined by the following criteria:

a) The rate of the variable occurrence in the investigated articles, i.e., the number of investigated articles that identified the variable as a potential factor for NFC adoption.

b) The rate of variable dependencies studied in the investigated articles, i.e., the number of hypotheses of one variable's dependency on the other. The dependent variables were selected from the original TAM model (Davis, 1989), including Perceived Ease of Use, Perceived Usefulness, Attitude Towards Use, Behavioral Intention to Use, and Actual Use. The independent variables were 42 beforementioned factors accumulated from 25 investigated articles (Figure 3). All in all, 159 dependencies were calculated from the investigated studies. The following formula calculated the values of dependencies:

$$R2_{x\_dep} = \frac{n_{hyp\_x}}{n_{hyp\_all}} \times 100$$

where $R2_{x\_dep}$ – the value of the dependency of independent variable x, n_{hyp_x} – the number of all hypothesis related to the independent variable x, n_{hyp_all} – the number of all hypothesis studied in 25 investigated articles

c) The rate of supported hypotheses in relation to all propositions stated in the investigated articles, i.e., the number of how many studied hypotheses were accepted. Overall, 159 dependencies were categorized into three categories: supported (89), not supported (38), and proposed (32). The classification was based on the findings from the structural equation modelling (SEM) performed by the investigated studies to validate (or not) the research hypotheses by assessing the *path coefficients* between constructs and *p-values*. All the supported hypotheses are given in Appendix 3. The calculation of the value took into consideration the ratio of the variable's occurrence in the investigated articles to emphasize the significance of the supported hypotheses, e.g., Engagement has been assigned to only one structural relationship that was supported, leading to the R2 value of 1, whereas Perceived Usefulness has 20 structural relationships with 14 supported leading to the R2 value of 0,7; such calculation would not appropriately and comprehensively estimate the significance of the supported hypotheses. The values of supported hypotheses were calculated by the formula given below:

$$R3_{x\_hyp\_sup} = \frac{n_{x\_hyp\_sup}}{n_{x\_hyp\_all}} \times \frac{k_x}{25}$$

where $R3_{x\_hyp\_sup}$ – the value of the supported hypotheses of independent variable x, $n_{x\_hyp\_sup}$ – the number of all supported hypotheses related to the independent variable x, $n_{x\_hyp\_all}$ – the number of all hypothesis related to the independent variable x, k_x – the number of x variable occurrence in the investigated articles

d) The rate of the strength of the supported hypotheses by assessing the mean values of *path coefficients* of structural relationships. The higher value of the path coefficient, the greater impact the independent variable is expected to have on the dependent variable. The values of the supported hypotheses we calculated by the following:

$$R4_{x\_h\_str} = \frac{\sum_{i=1}^{n} k_i}{n}$$

where $R4_{x\_h\_str}$ – the strength of the supported hypotheses of independent variable x, n – the number of all supported hypotheses related to the independent variable x, k – path coefficient of supported hypothesis related to the independent variable x

The rates of criteria I-IV were calculated for 42 variables based on the declared formulas. Then each rate was assigned to the corresponding rating score on the ordinal and interval scales from 1 to 10. The intervals of the rates for assigning to the ranking scale are provided in Table 3. The rating of Criteria I employs the ordinal scale, whereas Criteria II, Criteria III and Criteria IV are based on the interval scale with equal intervals of 1.4, 0.05, and 0.07, respectively (the intervals for the rate 1 do not start from the 0, since the null values are not taken into consideration). The criteria rates and ratings for 42 variables are provided in Appendix 2.

Table 3. The intervals of the rates for assigning to the ranking scale

Rating 1-10 / *Criteria*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
C I: The number of articles that uses the variable	1-2	3-4	5-7	8-10	11-13	14-16	17-19	20-22	23-24	25
C II: The number of relations to other variables	0.01-1.4	1.5-2.9	3.0-4.4	4.5-5.9	6.0-7.4	7.5-8.9	9.0-10.4	10.5-11.9	12.0-13.4	>13.5
C III: The number of supported relations between variables	0.01-0.06	0.07-0.12	0.13-0.18	0.19-0.24	0.25-0.30	0.31-0.36	0.37-0.42	0.43-0.48	0.49-0.54	0.55-0.6
C IV: The number of the strength of supported relations	0.01-0.08	0.09-0.16	0.17-0.24	0.25-0.32	0.33-0.40	0.41-0.48	0.49-0.56	0.57-0.64	0.65-0.72	0.73-0.80

Finally, to calculate the final score of each variable, each criterion rate is multiplied by the corresponding weight of the criterion:

$$TS_x = R_{R1} \times 0.25 + R_{R2x\_dep} \times 0.25 + R_{R3x\_hyp\_sup} \times 0.25 + R_{R4x\_h\_str} \times 0.25$$

Table 4 shows the final scores of the top 14 variables that influence NFC technology adoption the most based on the aggregated findings from the 25 studies. The original constructs from Davis (1989), including PU, PEoU, BI, and ATT, were found to be the most impactful for NFC acceptance. Hereinafter, PEJ, PSC, PQ, PV, SI, SAT, INN, KE, PCOM, and SE were identified as the top 10 impactful external variables belonging to Motivation, Perceived Credibility, Social Context, Individual Attributes, Individual Beliefs and Facilitating Conditions categories.

Table 4. The list of most impactful variables of NFC technology acceptance for product packaging

Place	Total score	Variable	Category
1.	7,75	Perceived Usefulness	Perceived Usefulness
2.	7,50	Perceived Ease of Use	Perceived Ease of Use
3.	5,75	Behavioral Intention to use	Behavioral Intention to use
4.	5,50	Attitude towards the use	Attitude towards the use
5.	5,00	Perceived Enjoyment	Motivation
6.	4,25	Perceived Privacy and Security	Perceived Credibility
7.	4,00	Perceived quality	Motivation
8.	4,00	Perceived Value	Motivation
9.	3,50	Social influence and SN	Social context
10.	3,25	Satisfaction	Motivation
11.	3,00	Innovativeness	Individual attributes
12.	2,75	Knowledge and experience	Individual attributes
13.	2,50	Perceived Compatibility	Facilitating Conditions
14.	2,50	Self-efficacy	Individual Beliefs

5. DISCUSSION

5.1. Additional Variables for the proposed extended TAM model

The proposed extended TAM model consists of 42 variables classified into 13 categories based on the constructed technology acceptance models from the investigated 25 articles. However, authors of this study added the following additional variables to the proposed extended TAM model (Figure 3): Sociability, Extrinsic Motivation (Rewards), and Environment Awareness.

Sociability

The proposed extended TAM model includes the category of Social Context, which consists of two variables: Social Influence and Subjective Norms and Social Presence. However, Smith and Sivo (2012) argue that Sociability has to be separated from Social Presence. According to the authors, Social Presence differs from sociability in the sense that sociability is the degree to which the system supports the interaction of the users. Therefore, sociability itself does not build social presence, but the appearance of social presence depends on the system's capability to induce interaction and knowledge-sharing between system users (Smith and Sivo, 2012). Sociability is defined as the extent to which the medium can facilitate the emergence of social space (Kreijns *et al*., 2004). Similarly, Qiu and Li (2008) refer to sociability as "the extent to which a medium is perceived as sociable, warm, sensitive, personal, or intimate when it is used to interact with other people" (p. 268). According to As'adi *et al*. (2021), it can be measured by three indicators in relation to mobile technology: communication quality, ability to send information, and relationships between interactivity and information.

Extrinsic Motivation (Rewards)

The proposed extended TAM model mainly encompasses variables related to intrinsic motivation, such as playfulness, aesthetics, and enjoyment. As a result, more extrinsic motivational rewards were omitted from the investigated studies. However, the continuous and enhanced use of the interactive system is also driven by an implied benefit upon completion in the form of a specific reward, such as customized offers, gaming tokens, or extra loyalty points (Lydekaityte, 2019; Singh, 2018). The reward-based NFC systems have already been designed and tested for diverse applications. For instance, Garrido *et al*. (2011) investigated the NFC-enabled games for interactive teaching and learning processes that granted rewards and accelerated the students' motivation to keep using the ICT system. Alnfiai (2020) contributes and highlights that rewarding students motivates them to keep learning and continue doing the required tasks. Museli and Navimipour (2018) identified the lack of motivation and reward as one of the main determinants for resisting the technology change in organizations. Furthermore, the availability of financial incentives, such as discounts or cash back, has been found to significantly affect the intention to adopt the NFC technology (Zhao *et al*., 2020). Consequently, this study proposes to include extrinsic reward-based motivation as a variable in the motivation category (Figure 3).

Environmental Awareness

The other determinant of consumers' perception and behavior that was not included in any of the investigated studies is environmental awareness. It has not yet been determined as a significant construct by any research related to NFC technology acceptance. However, the growing interest among the general public in sustainable practices requires "reducing the negative impacts of packaging on the environment that is consistent with users' tendency to protect the environment and is therefore considered as creating a competitive advantage" (Mumani and Stone, 2018, p. 410). Furthermore, socially responsible consumption, related to the consumers' purchase behaviors, is driven by the intention to buy environmentally or socially sound products from companies that aim to help society and, in turn, boycott products that fail to implement sustainable business practices (Ma *et al*., 2017). According to the authors, it is critically important to investigate how consumers perceive product labels in terms of sustainability and how their perception of using environmentally friendly labels influences their purchase decisions. As a result, consumers' preferences are significantly influenced by the sustainable development of the overall packaging design, including all the attached technologies, such as NFC (Lydekaityte and Tambo, 2020). Park *et al*. (2022) refer to such consumers' propensity as a "green buying intention" and confirm that environmental concerns positively affect people's attitudes toward the use and behavioral intentions to use new technologies.

5.2 Implications

This research provides a range of implications for brand owners, retailers and developers. Brand owners are the key decision makers on packaging and functionality of packaging. Brand owners would need to decide whether invest in digitalization of packaging and must have confidence in a positive outcome. In areas where the digitalization is related to e.g. traceability regulated by law, anti-counterfeiting, and consumer safety, the brand owners must design the digital elements to meet the stipulated purposes. In areas where the brand-owner see opportunities for a broader consumer engagement and positive insight in application of products the proposed technology-acceptance model can be supportive in the decision making. Brand-owner will need to consider that the digitalization of packaging has broad implications for all supporting elements to the consumer perception. This can be marketing strategy, loyalty programs, customer support, smartphone applications, and digital

infrastructure. Sub-optimal understanding and implementation of implications into the operational backbone of the brand-owner can lead to degradation of the acceptance parameters.

5.3 Future research and limitations

The proposed extended TAM model contains variables obtained from the investigated 25 studies within the field of NFC technology and other most commonly used technologies in retail, including AR, QR, mobile applications, self-checkout kiosks, virtual mirrors, social interactive dressing rooms, and RFID music tags. Therefore, the proposed model can be used to investigate the adoption of other smart in-store interactive technologies besides NFC. Moreover, since the model consists of 42 variables grouped into 13 categories, depending on the future research's aim and scope, the model can be taken apart, excluding irrelevant determinants and selecting preferred ones. Therefore, multiple versions of the model are possible.

However, this study is not without limitations. First, out of 182 found variables, 13 were not included in the study due to the lack of an explanation of the variable in the corresponding study and the irrelevance of the variable regarding this study's scope. However, there still exists some potential to explore these variables in future studies of NFC technology acceptance. Second, the examination of structural relationships took into consideration only the connections that contained the original determinants from the TAM model as dependent variables. Therefore, the structural relationships between external variables were not anticipated in this study. For instance, Han *et al*. (2016) also investigated the self-efficacy influence on NFC satisfaction. However, incorporating such structural relationships between external variables might benefit future studies. Third, out of 42 investigated variables, 7 of them, including Time Pressure, Information-seeking, Time-saving, Control, Gamification, Focused Attention, and Actual Use, did not have any structural relationships as independent variables. The first six beforementioned variables only possessed proposed relations that were not tested for acceptance or rejection. Furthermore, some variables were comprehensively investigated by several studies, while others were only once. Therefore, since this study does not provide practical evidence, its findings are limited to the extracted results from 25 studies, and further research on less investigated variables might change the main outcome of this study of the most influential variables for NFC adoption. Fourth, the results from the linear regression test to detect the correlations between the variables were taken directly from the original studies together with the original authors' decision of acceptance or rejection of the hypotheses. Following Chin's (1998) recommendations, only values higher than 0.2 are allowed in exploratory studies. However, some of the originally confirmed hypotheses had values lower than 0.2. Finally, the study employed MCDA analysis based on the interval scale for rating the values of variables, whereas more comprehensive analytical tools could have been used, such as the Fuzzy Analytic Hierarchy Process exploited in the Ortiz-Barrios *et al*. (2020) study, or the synergistic Aggregation of Individual Judgements of Analytic Hierarchy Process (AIJ of AHP) utilized in De La Vega *et al*., (2018).

6. CONCLUSION

This research aimed to investigate the important variables impacting the adoption of NFC in product packaging, propose an applicable model for it, and identify the most impactful variables for NFC technology acceptance for packaging applications. The proposed extended TAM model consolidates a broad range of theories, mainly emphasizing the Technology Acceptance Model, Unified Theory of Acceptance and Use of Technology, Uses and Gratifications Theory, Innovation Diffusion Theory, Motivation Opportunity Ability Theory, and Technology Readiness theories. Overall, 182 variables were collected from the 25 studies that investigated the adoption of diverse smart in-store technologies, including NFC, QR, AR, RFID, IoT and others. The proposed model consists of 42 variables grouped into 13 categories. Based on the MCDA, the top 5 most impactful factors for NFC technology acceptance, besides the original variables from the TAM (Davis, 1989), are Perceived Enjoyment, Perceived Privacy and Security, Perceived Quality, Perceived Value and Social Influence. Furthermore, three more variables were added by the authors to the proposed model: Sociability, Extrinsic Motivation (Rewards), and Environmental Awareness. Further research needs to be carried out to assess the structural relationships between the proposed 45 variables to predict the actual most influencing factors of NFC technology acceptance in product packaging applications. In conclusion, this research sheds light on the factors sought in using NFC technology in product packaging and contributes to the literature of technology acceptance of consumer-oriented interactive technologies by highlighting the most impactful determinants of adoption. The study also makes managerial implications for brand owners, retailers and developers concerning the impact of a wide range of factors when designing NFC systems to achieve successful consumer interactions.

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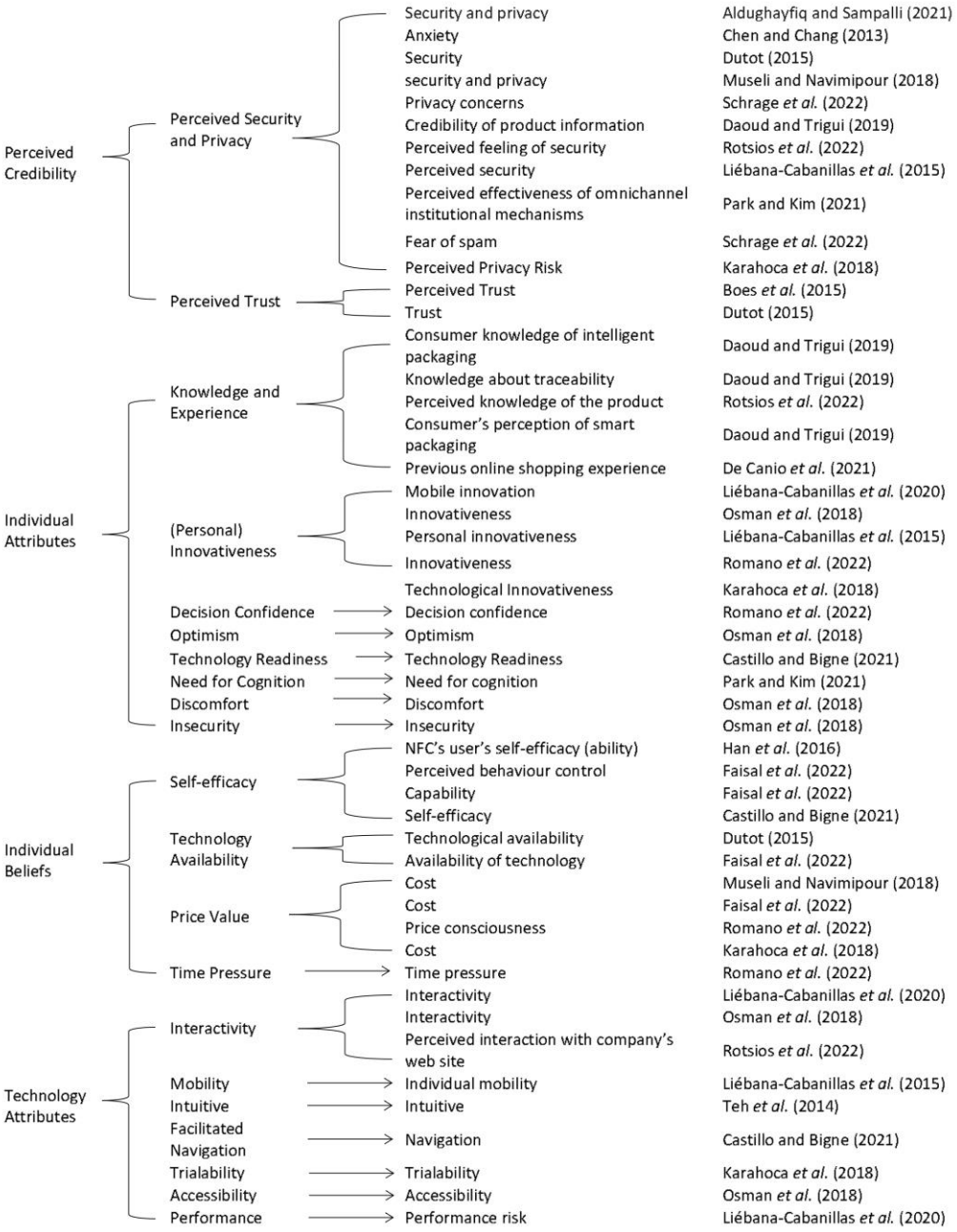
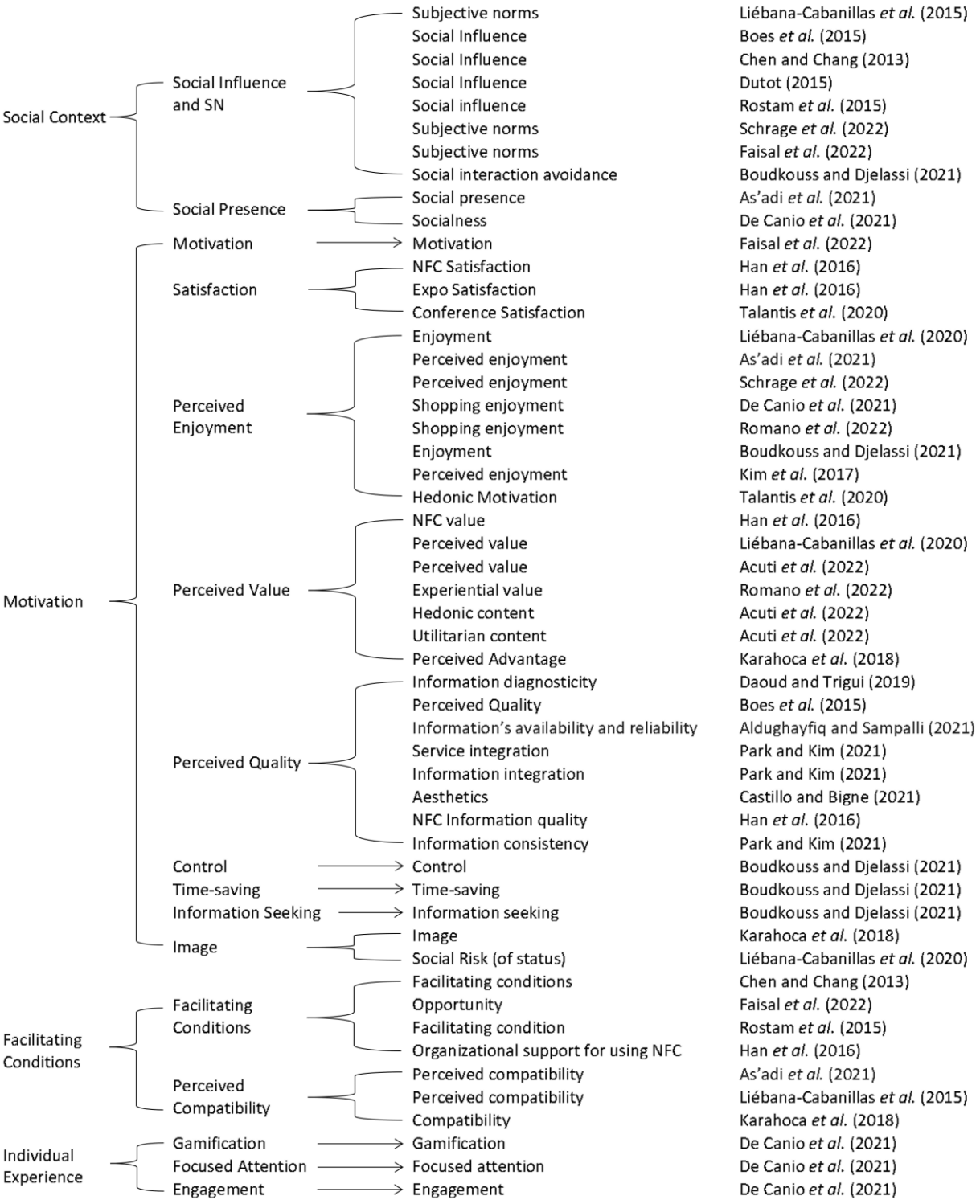
Appendix 1. The classification of 182 found variables from 25 investigated studies into 13 categories containing final 42 variables.


Perceived Credibility
Perceived Security and Privacy
Security and privacy
Aldughayfiq and Sampalli (2021)
Anxiety
Chen and Chang (2013)
Security
Dutot (2015)
security and privacy
Museli and Navimipour (2018)
Privacy concerns
Schrage et al. (2022)
Credibility of product information
Daoud and Trigui (2019)
Perceived feeling of security
Rotsios et al. (2022)
Perceived security
Liébana-Cabanillas et al. (2015)
Perceived effectiveness of omnichannel institutional mechanisms
Park and Kim (2021)
Fear of spam
Schrage et al. (2022)
Perceived Privacy Risk
Karahoca et al. (2018)
Perceived Trust
Perceived Trust
Boes et al. (2015)
Trust
Dutot (2015)
Individual Attributes
Knowledge and Experience
Consumer knowledge of intelligent packaging
Daoud and Trigui (2019)
Knowledge about traceability
Daoud and Trigui (2019)
Perceived knowledge of the product
Rotsios et al. (2022)
Consumer's perception of smart packaging
Daoud and Trigui (2019)
Previous online shopping experience
De Canio et al. (2021)
(Personal) Innovativeness
Mobile innovation
Liébana-Cabanillas et al. (2020)
Innovativeness
Osman et al. (2018)
Personal innovativeness
Liébana-Cabanillas et al. (2015)
Innovativeness
Romano et al. (2022)
Technological Innovativeness
Karahoca et al. (2018)
Decision Confidence
Decision confidence
Romano et al. (2022)
Optimism
Optimism
Osman et al. (2018)
Technology Readiness
Technology Readiness
Castillo and Bigne (2021)
Need for Cognition
Need for cognition
Park and Kim (2021)
Discomfort
Discomfort
Osman et al. (2018)
Insecurity
Insecurity
Osman et al. (2018)
Individual Beliefs
Self-efficacy
NFC's user's self-efficacy (ability)
Han et al. (2016)
Perceived behaviour control
Faisal et al. (2022)
Capability
Faisal et al. (2022)
Self-efficacy
Castillo and Bigne (2021)
Technology Availability
Technological availability
Dutot (2015)
Availability of technology
Faisal et al. (2022)
Price Value
Cost
Museli and Navimipour (2018)
Cost
Faisal et al. (2022)
Price consciousness
Romano et al. (2022)
Cost
Karahoca et al. (2018)
Time Pressure
Time pressure
Romano et al. (2022)
Technology Attributes
Interactivity
Interactivity
Liébana-Cabanillas et al. (2020)
Interactivity
Osman et al. (2018)
Perceived interaction with company's web site
Rotsios et al. (2022)
Mobility
Individual mobility
Liébana-Cabanillas et al. (2015)
Intuitive
Intuitive
Teh et al. (2014)
Facilitated Navigation
Navigation
Castillo and Bigne (2021)
Trialability
Trialability
Karahoca et al. (2018)
Accessibility
Accessibility
Osman et al. (2018)
Performance
Performance risk
Liébana-Cabanillas et al. (2020)


Social Context
Social Influence and SN
Social Presence
Motivation
Satisfaction
Perceived Enjoyment
Perceived Value
Perceived Quality
Control
Time-saving
Information Seeking
Image
Facilitating Conditions
Perceived Compatibility
Individual Experience
Gamification
Focused Attention
Engagement
Subjective norms — Liébana-Cabanillas et al. (2015)
Social Influence — Boes et al. (2015)
Social Influence — Chen and Chang (2013)
Social Influence — Dutot (2015)
Social influence — Rostam et al. (2015)
Subjective norms — Schrage et al. (2022)
Subjective norms — Faisal et al. (2022)
Social interaction avoidance — Boudkouss and Djelassi (2021)
Social presence — As'adi et al. (2021)
Socialness — De Canio et al. (2021)
Motivation — Faisal et al. (2022)
NFC Satisfaction — Han et al. (2016)
Expo Satisfaction — Han et al. (2016)
Conference Satisfaction — Talantis et al. (2020)
Enjoyment — Liébana-Cabanillas et al. (2020)
Perceived enjoyment — As'adi et al. (2021)
Perceived enjoyment — Schrage et al. (2022)
Shopping enjoyment — De Canio et al. (2021)
Shopping enjoyment — Romano et al. (2022)
Enjoyment — Boudkouss and Djelassi (2021)
Perceived enjoyment — Kim et al. (2017)
Hedonic Motivation — Talantis et al. (2020)
NFC value — Han et al. (2016)
Perceived value — Liébana-Cabanillas et al. (2020)
Perceived value — Acuti et al. (2022)
Experiential value — Romano et al. (2022)
Hedonic content — Acuti et al. (2022)
Utilitarian content — Acuti et al. (2022)
Perceived Advantage — Karahoca et al. (2018)
Information diagnosticity — Daoud and Trigui (2019)
Perceived Quality — Boes et al. (2015)
Information's availability and reliability — Aldughayfiq and Sampalli (2021)
Service integration — Park and Kim (2021)
Information integration — Park and Kim (2021)
Aesthetics — Castillo and Bigne (2021)
NFC Information quality — Han et al. (2016)
Information consistency — Park and Kim (2021)
Control — Boudkouss and Djelassi (2021)
Time-saving — Boudkouss and Djelassi (2021)
Information seeking — Boudkouss and Djelassi (2021)
Image — Karahoca et al. (2018)
Social Risk (of status) — Liébana-Cabanillas et al. (2020)
Facilitating conditions — Chen and Chang (2013)
Opportunity — Faisal et al. (2022)
Facilitating condition — Rostam et al. (2015)
Organizational support for using NFC — Han et al. (2016)
Perceived compatibility — As'adi et al. (2021)
Perceived compatibility — Liébana-Cabanillas et al. (2015)
Compatibility — Karahoca et al. (2018)
Gamification — De Canio et al. (2021)
Focused attention — De Canio et al. (2021)
Engagement — De Canio et al. (2021)

Appendix 2. MCDA rates and ratings

	Var	*C I R1*	*Rating 1-10*	*Var*	*C II* $R2_{x\_dep}$	*Rating 1-10*	*Var*	*C III* $R3_{x\_hyp\_sup}$	*Rating 1-10*	*Var*	*C IV* $R4_{x\_h\_str}$	*Rating 1-10*
1.	PU	19	7	PEoU	13,8	10	PU	0,53	9	ATT	0,72	9
2.	PEoU	18	7	PU	12,6	9	BI	0,43	8	SAT	0,66	9
3.	BI	16	6	PSC	7,5	6	PEoU	0,39	7	BI	0,53	7
4.	ATT	10	4	PCOM	5,7	4	ATT	0,32	6	PEJ	0,52	7
5.	PSC	10	4	PEJ	5,7	4	PEJ	0,25	5	PU	0,48	6
6.	PEJ	8	4	PQ	5,7	4	SI	0,23	4	KE	0,43	6
7.	SI	8	4	INN	5,0	4	PQ	0,21	4	MOT	0,42	6
8.	PQ	6	3	SI	4,4	3	PSC	0,20	4	PEoU	0,41	6
9.	AU	5	3	ATT	3,1	3	PV	0,20	4	PV	0,41	6
10.	INN	5	3	INTR	3,1	3	FC	0,16	3	PQ	0,39	5
11.	PV	5	3	PV	3,1	3	SE	0,12	2	SE	0,34	5
12.	FC	4	2	IM	2,5	2	INN	0,10	2	ENG	0,33	5
13.	PRV	4	2	KE	2,5	2	PRV	0,08	2	NAV	0,29	4
14.	INTR	3	2	NAV	2,5	2	SAT	0,08	2	INTT	0,24	3
15.	KE	3	2	BI	1,9	2	DC	0,04	1	TA	0,24	3
16.	PCOM	3	2	MOB	1,9	2	ENG	0,04	1	PRV	0,23	3
17.	SE	3	2	PT	1,9	2	IM	0,04	1	SI	0,23	3
18.	IM	2	1	TRI	1,9	2	MOT	0,04	1	FC	0,20	3
19.	PT	2	1	INTT	1,3	1	PCOM	0,04	1	INN	0,20	3
20.	SAT	2	1	PRV	1,3	1	PER	0,04	1	PSC	0,20	3
21.	SP	2	1	SAT	1,3	1	TA	0,04	1	PCOM	0,19	3
22.	TA	2	1	SE	1,3	1	KE	0,03	1	PT	0,17	3
23.	ACC	1	1	SP	1,3	1	NAV	0,03	1	DC	0,16	2
24.	CTRL	1	1	TA	1,3	1	PT	0,03	1	PER	0,16	2
25.	DC	1	1	TR	1,3	1	INTT	0,02	1	IM	0,12	2
26.	DIS	1	1	ACC	0,6	1	ACC	0,00	0	ACC	0,00	0
27.	ENG	1	1	DC	0,6	1	AU	0,00	0	AU	0,00	0
28.	FA	1	1	DIS	0,6	1	CTRL	0,00	0	CTRL	0,00	0
29.	GAM	1	1	ENG	0,6	1	DIS	0,00	0	DIS	0,00	0
30.	IS	1	1	FC	0,6	1	FA	0,00	0	FA	0,00	0
31.	IN	1	1	IN	0,6	1	GAM	0,00	0	GAM	0,00	0
32.	INTT	1	1	MOT	0,6	1	IS	0,00	0	IS	0,00	0
33.	MOB	1	1	NfC	0,6	1	IN	0,00	0	IN	0,00	0
34.	MOT	1	1	OPT	0,6	1	INTR	0,00	0	INTR	0,00	0
35.	NAV	1	1	PER	0,6	1	MOB	0,00	0	MOB	0,00	0
36.	NfC	1	1	AU	0,0	0	NfC	0,00	0	NfC	0,00	0
37.	OPT	1	1	CTRL	0,0	0	OPT	0,00	0	OPT	0,00	0
38.	PER	1	1	FA	0,0	0	SP	0,00	0	SP	0,00	0
39.	TR	1	1	GAM	0,0	0	TR	0,00	0	TR	0,00	0

40	TP	1	1	IS	0,0	0	TP	0,00	0	TP	0,00	0
41	TS	1	1	TP	0,0	0	TS	0,00	0	TS	0,00	0
42	TRI	1	1	TS	0,0	0	TRI	0,00	0	TRI	0,00	0

Appendix 3. Supported structural relationships amongst variables from the investigated articles

PEoU → PU	β=0.116	p < 0.01	Boes *et al.* (2015)
PEoU → PU	β=0.55	p < 0.05	Chen and Chang (2013)
PEoU → PU	β=0.440	p < 0.001	Dutot (2015)
PEoU → PU	β=0.297	p < 0.001	Karahoca *et al.* (2018)
PEoU → PU	β=0.471	p < 0.001	Liébana-Cabanillas *et al.* (2015)
PT → PU	β=0.169	p < 0.01	Dutot (2015)
INN → PU	β=-0.109	p < 0.0005	Karahoca *et al.* (2018)
TA → PU	β=0.237	p < 0.001	Dutot (2015)
NAV → PU, (Nicaragua)	β=0.254	p < 0.01	Castillo and Bigne (2021)
NAV → PU, (USA)	β=0.368	p < 0.01	Castillo and Bigne (2021)
SI → PU	β=0.197	p < 0.001	Dutot (2015)
PV → PU	β=0.579	p < 0.0005	Karahoca *et al.* (2018)
PQ → PU	β=0.35	p < 0.001	Boes *et al.* (2015)
PQ → PU, (Nicaragua)	β=0.536	p < 0.01	Castillo and Bigne (2021)
PQ → PU, (USA)	β=0.363	p < 0.01	Castillo and Bigne (2021)
IM → PU	β=0.123	p < 0.0005	Karahoca *et al.* (2018)
PCOM → PU	β=0.098	p=0.028	Karahoca *et al.* (2018)
PCOM → PU	β=0.349	p < 0.001	Liébana-Cabanillas *et al.* (2015)
PSC → PEoU	β=0.274	p < 0.001	Dutot (2015)
INN → PEoU	β=0.200	p=0.003	Karahoca *et al.* (2018)
INN → PEoU	β=0.235	p < 0.001	Liébana-Cabanillas *et al.* (2015)
SE → PEoU, (Nicaragua)	β=0.286	p < 0.01	Castillo and Bigne (2021)
SE → PEoU, (USA)	β=0.401	p < 0.01	Castillo and Bigne (2021)
NAV → PEoU, (USA)	β=0.252	p < 0.01	Castillo and Bigne (2021)
PV → PEoU	β=0.380	p < 0.0005	Karahoca *et al.* (2018)
PQ → PEoU, (Nicaragua)	β=0.385	p < 0.01	Castillo and Bigne (2021)
PQ → PEoU, (USA)	β=0.300	p < 0.01	Castillo and Bigne (2021)
PCOM → PEoU	β=0.135	p=0.066	Karahoca *et al.* (2018)
PU → ATT	β=0.53	p < 0.05	Chen and Chang (2013)
PU → ATT, (Nicaragua)	β=0.649	p < 0.01	Castillo and Bigne (2021)
PU → ATT, (USA)	β=0.664	p < 0.01	Castillo and Bigne (2021)
PU → ATT	β=0.428	p < 0.0005	Karahoca *et al.* (2018)
PU → ATT, (virtual mirrors)	β=0.38	p < 0.01	Kim *et al.* (2017)
PU → ATT, (RFID)	β=0.16	p < 0.05	Kim *et al.* (2017)
PU → ATT	β=0.692	p < 0.001	Liébana-Cabanillas *et al.* (2015)
PU → ATT	β=0.503	p < 0.001	Schrage *et al.* (2022)
PU → ATT	β=0.511	p < 0.05	Talantis *et al.* (2020)
PEoU → ATT, (USA)	β=0.167	p < 0.05	Castillo and Bigne (2021)
PEoU → ATT	β=0.124	p=0.029	Karahoca *et al.* (2018)
PSC → ATT	β=-0.23	p < 0.05	Chen and Chang (2013)
PSC → ATT, (privacy concerns)	β=-0.095	p < 0.001	Schrage *et al.* (2022)
PSC → ATT, (fear of spam)	β=-0.065	p < 0.05	Schrage *et al.* (2022)
SI → ATT	β=0.4	p < 0.05	Chen and Chang (2013)
MOT → ATT	β=0.420	p < 0.05	Talantis *et al.* (2020)
PEJ → ATT, (virtual mirrors)	β=0.54	p < 0.001	Kim *et al.* (2017)
PEJ → ATT, (dressing room)	β=0.57	p < 0.01	Kim *et al.* (2017)
PEJ → ATT, (RFID)	β=0.79	p < 0.001	Kim *et al.* (2017)
PEJ → ATT	β=0.361	p < 0.001	Schrage *et al.* (2022)
DC → ATT (different method)	-	-	Romano *et al.* (2022)

PV → ATT (different method)	-	-	Romano *et al.* (2022)
PU → BI	β=0.652	p < 0.001	Boes *et al.*, (2015)
PU → BI, (virtual mirrors)	β=0.31	p < 0.05	Kim *et al.* (2017)
PU → BI	β=0.231	p < 0.001	Liébana-Cabanillas *et al.* (2015)
PU → BI, (adult group)	β=0.778	p < 0.001	Teh *et al.* (2014)
PEoU → BI	β=0.348	p < 0.001	Boes *et al.*, (2015)
PEoU → BI	β=0.836	p < 0.001	Dutot (2015)
PEoU → BI	β=0.137	p=0.012	Karahoca *et al.* (2018)
PEoU → BI, (youth)	β=0.958	p < 0.001	Teh *et al.* (2014)
ATT → BI	β=0.79	p < 0.05	Chen and Chang (2013)
ATT → BI	β=0.366	p < 0.0005	Karahoca *et al.* (2018)
ATT → BI	β=0.917	p < 0.001	Liébana-Cabanillas *et al.* (2015)
ATT → BI	β=0.808	p < 0.001	Schrage *et al.* (2022)
KE → BI	β=0.433	p < 0.01	De Canio *et al.* (2021)
INN → BI	β=0.244	p=0.014	Liébana-Cabanillas *et al.* (2015)
INTT → BI, (adult)	β=0.243	p < 0.05	Teh *et al.* (2014)
SI → BI	β=0.23	p < 0.001	Boes *et al.* (2015)
SI → BI	β=0.247	p < 0.001	Liébana-Cabanillas *et al.* (2015)
SI → BI	β=0.092	p < 0.05	Schrage *et al.* (2022)
SAT → BI	β=0.610	p < 0.001	Han *et al.* (2016)
PEJ → BI, (virtual mirrors)	β=0.44	p < 0.001	Kim *et al.* (2017)
PEJ → BI, (RFID)	β=0.74	p < 0.001	Kim *et al.* (2017)
PEJ → BI	β=0.206	p < 0.001	Liébana-Cabanillas *et al.* (2020)
PV → BI	β=0.314	p < 0.0005	Karahoca *et al.* (2018)
PV → BI	β=0.383	p < 0.001	Liébana-Cabanillas *et al.* (2020)
PQ → BI	β=0.616	p < 0.001	Boes *et al.* (2015)
IM → BI	β=0.124	p=0.005	Karahoca *et al.* (2018)
FC → BI	β=0.2	p < 0.05	Chen and Chang (2013)
ENG → BI	β=0.333	p < 0.01	De Canio *et al.* (2021)
PER → BI	β=0.159	p < 0.001	Liébana-Cabanillas *et al.* (2020)
PSC → BI	β=0.185	p=0.079	Park and Kim (2021)
PQ → BI, (service integration)	β=0.234	p=0.001	Park and Kim (2021)
PQ → BI, (info consistency)	β=0.340	p=0.002	Park and Kim (2021)
PU → AU	β=0.213	p < 0.001	Museli and Navimipour (2018
PEoU → AU	β=0.443	p < 0.001	Museli and Navimipour (2018
BI → AU	β=0.556	p < 0.001	Dutot (2015)
PSC → AU	β=0.120	p < 0.001	Museli and Navimipour (2018)
PRV → AU	β=0.233	p < 0.001	Museli and Navimipour (2018)
SAT → AU	β=0.709	p < 0.001	Han *et al.* (2016)
BI → AU	β=0.5	p < 0.001	Park and Kim (2021)

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Declaration of co-authorship*

Full name of the PhD student: Justina Karpavičė

This declaration concerns the following article/manuscript:

Title:	Digitalisation of product packaging using near-field communication: towards an extended Technology Acceptance Model
Authors:	Justina Karpavičė, Torben Tambo, Ingrida Venytė, Laura Gegeckienė

The article/manuscript is: Published ☐ Accepted ☐ Submitted ☒ In preparation ☐

If published, state full reference:

If accepted or submitted, state journal: International Journal of Retail & Distribution Management

Has the article/manuscript previously been used in other PhD or doctoral dissertations?

No ☒ Yes ☐ If yes, give details:

The PhD student has contributed to the elements of this article/manuscript as follows:

A. Has essentially done all the work
B. Major contribution
C. Equal contribution
D. Minor contribution
E. Not relevant

Element	Extent (A-E)
1. Formulation/identification of the scientific problem	A
2. Planning of the experiments/methodology design and development	B
3. Involvement in the experimental work/clinical studies/data collection	A
4. Interpretation of the results	B
5. Writing of the first draft of the manuscript	A
6. Finalization of the manuscript and submission	C

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*As per policy the co-author statement will be published with the dissertation.