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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.

References

[1] Ben-Daya, M., Hassini, E., and Bahroun, Z. (2019) "Internet of things and supply chain management: a literature review." International Journal of Production Research 57 (15-16): 4719-4742.

[2] Rajagopal (2019) "Brand Positioning and Value Creation. In: Competitive Branding Strategies." Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-030-24933-5_3

[3] Dutot, V. (2015) "Factors influencing near field communication (NFC) adoption: An extended TAM approach." The Journal of High Technology Management Research 26 (1): 45-57.

[4] Lydekaityte, J. (2020) "Extended User Interface: NFC-Enabled Product Packaging for Enhanced User Experience." in the proceedings of the International Conference on Human-Computer Interaction, 285-304. Springer, Cham.

[5] Fernandez, C. M., Alves, J., Gaspar, P. D., Lima, T. M., and Silva, P. D. (2022) "Innovative Processes in Smart Packaging. A Systematic Review." Journal of the Science of Food and Agriculture, 1-18.

[6] Hakola, L., Jansson, E., Futsch, R., Happonen, T., Thenot, V., Depres, G., ... and Smolander, M. (2021) "Sustainable roll-to-roll manufactured multi-layer smart label." *The International Journal of Advanced Manufacturing Technology* **117 (9)**: 2921-2934.

[7] Vannucci, V., and Pantano, E. (2019) "Digital or human touchpoints? Insights from consumer-facing in-store services." *Information Technology & People* **33 (1)**: 296-310.

[8] Frydrychowski, M. (2020) "5 Product Label Trends to Differentiate Your Brand in 2021." *Flexible Packaging* **23(11)**: 24–28.

[9] Đurđević, S., Novaković, D., Kašiković, N., Zeljković, Ž., Milić, N., and Vasić, J. (2018) "NFC technology and augmented reality in smart packaging." *International Circular of Graphic Education and Research* **11**: 52-65.

[10] Escobedo, P., Bhattacharjee, M., Nikbakhtnasrabadi, F., and Dahiya, R. (2021) "Flexible Strain and Temperature Sensing NFC Tag for Smart Food Packaging Applications." *IEEE Sensors Journal* **21(23)**: 26406-26414.

[11] Singh, N. K. (2020) "Near-field Communication (NFC)." *Information technology and libraries* **39 (2)**: 1-14.

[12] Wang, Q., Mohammed, S., & Fiaidhi, J. (2017) "Near Field Communication Tag-based System in Retail Marketing." *International Journal of Future Generation Communication and Networking* **10 (7)**: 67-76.

[13] Pereira, A., Bergeret, E., Benzaim, O., Routin, J., Haon, O., Tournon, L., ... and Depres, G. (2018) "Near-field communication tag development on a paper substrate—application to cold chain monitoring." *Flexible and Printed Electronics* **3 (1)**: 1-8.

[14] Nguyen, T. B., Nguyen, T. H., and Chung, W. Y. (2020) "Battery-free and noninvasive estimation of food ph and co2 concentration for food monitoring based on pressure measurement." *Sensors* **20 (20)**: 1-12.

[15] Barge, P., Biglia, A., Comba, L., Ricauda Aimonino, D., Tortia, C., and Gay, P. (2020) "Radio Frequency IDentification for Meat Supply-Chain Digitalisation." *Sensors* **20 (17)**: 1-17.

[16] Violino, S., Pallottino, F., Sperandio, G., Figorilli, S., Antonucci, F., Ioannoni, V., ... and Costa, C. (2019) "Are the Innovative Electronic Labels for Extra Virgin Olive Oil Sustain-able, Traceable, and Accepted by Consumers?." *Foods* **8 (11)**: 1-14.

[17] Tambo, T. (2017) "Enterprise Architecture beyond the Enterprise-Extended Enterprise Architecture Revisited." in *International Conference on Enterprise Information Systems* **2**: 381-390.

[18] Shin, S., and Lee, W. (2014) "The Effects Of Technology Readiness And Technology Acceptance On Nfc Mobile Payment Services In Korea." *Journal of Applied Business Research* **30 (6)**: 1615-1626.

[19] Museli, A., and Navimipour, N. J. (2018) "A model for examining the factors impacting the near field communication technology adoption in the organizations." *Kybernetes* **47 (7)**: 1378-1400.

[20] Tiekstra, S., Dopico-Parada, A., Koivula, H., Lahti, J., and Buntinx, M. (2021) "Holistic approach to a successful market implementation of active and intelligent food packaging." *Foods* **10 (2)**: 22.

[21] Ratten, V. (2015) "International consumer attitudes toward cloud computing: A social cognitive theory and technology acceptance model perspective." *Thunderbird International Business Review* **57(3)**: 217-228.

[22] Talantis, S., Shin, Y. H., and Severt, K. (2020) "Conference mobile application: Participant acceptance and the correlation with overall event satisfaction utilizing the technology acceptance model (TAM)." *in Journal of Convention & Event Tourism* **21 (2)**: 100-122.

[23] Ng, P. C., She, J., and Ran, R. (2020) "A reliable smart interaction with physical thing attached with ble beacon." *IEEE Internet of Things Journal* **7 (4)**: 3650-3662.

[24] Martínez-Mesa, J., González-Chica, D. A., Duquia, R. P., Bonamigo, R. R., and Bastos, J. L. (2016) "Sampling: how to select participants in my research study?" *Anais Brasileiros de Dermatologia* **91 (3)**: 326–330.

[25] Meyer, O. A., Omdahl, M. K., and Makransky, G. (2019) "Investigating the effect of pre-training when learning through immersive virtual reality and video: A media and methods experiment." *Computers & Education* **140**: 1-17.

[26] Tokel, S. T., and İsler, V. (2015) "Acceptance of virtual worlds as learning space." *Innovations in Education and Teaching International* **52 (3)**: 254-264.

[27] Likert, R. (1932) "A technique for the measurement of attitudes." *Archives of Psychology* **22 (140)**: 55.

[28] Pham, T. T. T., and Ho, J. C. (2015)."The effects of product-related, personal-related factors and attractiveness of alternatives on consumer adoption of NFC-based mobile payments." *Technology in society* **43**: 159-172.

[29] Davis, F. D. (1989) "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology". *MIS Quarterly* **13 (3)**: 319–340.

[30] Venkatesh, V., Thong, J. Y., & Xu, X. (2016). Unified theory of acceptance and use of technology: A synthesis and the road ahead. Journal of the Association for Information Systems, 17(5), 328-376.

[31] Escobedo, P., Erenas, M. M., Lopez-Ruiz, N., Carvajal, M. A., Gonzalez-Chocano, S., de Orbe-Paya, I., ... and Martinez-Olmos, A. (2017) "Flexible passive near field communication tag for multigas sensing." *Analytical chemistry* **89 (3)**: 1697-1703.

[32] Aldughayfiq, B., and Sampalli, S. (2021) "A framework to lower the risk of medication prescribing and dispensing errors: a usability study of an NFC-based mobile application." *International journal of medical informatics* **153**: 1-10.