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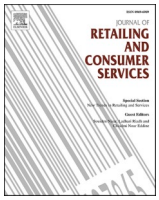

Consumer preferences for the visual presentation of non-fungible tokens (NFTs) of luxury products: The role of perceived authenticity

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ABSTRACT

Non-fungible tokens (NFTs) are increasingly used to safeguard luxury products from counterfeits. Despite their increasing adoption, limited research has investigated how brands should communicate the use of NFTs—a novel and complex concept for consumers to comprehend—to maximize their benefits. This research aims to examine this gap by highlighting that the ease of visualization is critical for effective communication. Study 1A demonstrated that consumers prefer a visualized NFT to a non-visualized one for authenticating a luxury product. Study 1B further demonstrated that consumers place greater trust in a visualized NFT and are willing to pay higher prices for luxury products that utilize it. Study 2 demonstrated that consumers have more favorable attitudes toward a luxury product that features an easy-to-visualize NFT than those with a difficult-to-visualize NFT and that perceived authenticity mediates this effect. Finally, Study 3 demonstrated that the positive impacts of easy-to-visualize NFT cues were more significant for luxury than non-luxury products. Subsequently, this study suggests an effective communication strategy for NFT use and provides managerial implications for luxury brands aiming to maximize the benefits of using NFTs.

1. Introduction

The market for counterfeits is growing as rapidly as the demand for luxury goods (Hietanen et al., 2020). According to Fontana et al. (2019), the global trade of counterfeits is estimated to be worth approximately $4.5 trillion, with counterfeit luxury goods accounting for 60%–70%. More importantly, research has demonstrated that counterfeits dilute the perceived quality of luxury brands and decrease consumers' purchase intentions (Song et al., 2021).

Non-fungible tokens (NFTs) are unique digital assets stored in a blockchain, each identified by specific codes and metadata that distinguish them from one another (Peres et al., 2023). NFTs have the potential to significantly transform marketing functions, including transactions (Chohan and Paschen, 2021). For example, when a pair of sandals that Steve Jobs had worn during Apple's early days was sold for $218,750 at an auction, unlike traditional auctions, a 360-degree NFT was part of the transaction. As in the case of Steve Jobs's sandals, NFTs can be utilized for both physical and digital items as long as they are distinguished by a unique identifier (such as a serial number) or digitized through filming or scanning. Importantly, NFTs can provide an unforgeable digital certificate of authenticity for physical products (Hofstetter et al., 2022), making them increasingly valuable for safeguarding luxury items against counterfeits.

Despite the increasing use of NFTs, limited research has been conducted on their applications in the marketing domain. This research gap is significant because NFTs are novel and complex concepts that can be difficult for consumers to understand fully. Thus, it is essential to understand how consumers perceive and assess products that incorporate

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this technology to leverage its advantages effectively. To address this gap, this study investigates how ease of visualization, a crucial attribute of NFTs, affects consumer perceptions and preferences. Because of their ability to verify authenticity, for products or brands where consumers' perception of authenticity is paramount, NFTs can play a crucial role (Hofstetter et al., 2022). By acting as digital certificates of authenticity, NFTs assure consumers that their luxury items are genuine, thereby alleviating counterfeiting concerns.

Specifically, we propose that consumers will prefer and be willing to pay a higher price for a luxury product that uses an NFT that is easy (versus difficult) to visualize. We further predicted that the advantage of easy-to-visualize NFTs is mediated by perceived authenticity. In addition, as authenticity is particularly relevant for luxury goods, we expected the focal effect to be more pronounced for luxury (versus non-luxury) products. Four experiments provided evidence supporting these hypotheses, highlighting the importance of using correct visual cues to maximize the benefits of NFTs in safeguarding luxury products from counterfeiting.

Despite the popularity of NFTs (Ali and Bagui, 2021; Beck et al., 2018; Wang et al., 2021), very few studies have attempted to understand their impact on consumer behavior (Fu et al., 2023; Hajian et al., 2024; Liu et al., 2023a). This study demonstrates the importance of visualizing NFTs in selling luxury products by focusing on the role of perceived authenticity and, subsequently, fills a substantial gap in the literature on the role of NFTs in retail and consumer services (Alexander and Bellandi, 2022; Eggenschwiler et al., 2024; Luong et al., 2024). Specifically, easy-to-visualize NFT cues significantly affected consumers' perceived authenticity and attitudes, especially toward luxury products. However, this effect does not appear in non-luxury products. These findings add to the literature on authenticity (Montecchi et al., 2019; Nunes et al., 2021; Tanaka et al., 2024), visual cues (Ding and Keh, 2017; Huddleston et al., 2023; Saxena and Sarkar, 2023), and luxury consumption (Duma et al., 2016; Hietanen et al., 2020; Ngo et al., 2020). This study offers important insights for practitioners, highlighting the need for marketers to integrate visually appealing and intuitive NFTs into their product strategies to enhance consumers' perceptions of authenticity and build trust. Policymakers should consider developing clear regulatory frameworks to ensure that NFTs communicate authenticity effectively and empower consumers to make informed purchasing decisions.

The remainder of this paper is organized as follows. We begin with a literature review exploring the concept of NFTs, their application to physical goods, and the critical role of authenticity in consumer perceptions. Building on the existing literature, we articulated our hypotheses regarding the effects of the visual appeal of NFTs and their underlying mechanisms. Subsequently, we present our empirical studies, followed by a comprehensive discussion that addresses the theoretical contributions, practical implications, limitations, and directions for future research.

2. Literature review

2.1. Non-fungible tokens

NFTs are digital representations of physical or digital items verified through blockchain technology. Blockchain, a decentralized and secure digital ledger system, records transactions across a network by grouping each transaction into a block, linking it to the previous one, and forming an immutable chain (Alkhudary et al., 2020). This tamper-resistant system plays a crucial role in luxury marketing, where NFTs enable brands to offer unique digital ownership of exclusive assets such as fashion, digital art, and virtual real estate (Belk et al., 2022; Sung et al., 2023). By creating scarcity and enhancing the perceived value of these goods, NFTs help luxury brands protect their intellectual property while offering verifiable, exclusive digital experiences (Alexander and Bellandi, 2022; Colicev, 2023; Kniazeva et al., 2024; Murtas et al., 2024). Due to their unique, non-fungible nature, NFTs have attracted considerable interest as digital certificates of ownership from both companies and consumers (Hofstetter et al., 2022; Joy et al., 2022; Khelladi et al., 2024).

Three NFT attributes are particularly interesting in the consumer context: transparency, immutability, and traceability. First, they offer unparalleled transparency because all relevant information, including the name, main content, and provenance, has been meticulously recorded and made publicly accessible (Wang et al., 2021). This transparency extends to all transactions involving the NFT, such as sales, purchases, and transfers, which are documented in the blockchain (Gleim and Stevens, 2021). Each new transaction adds a new block to the previously verified blocks to form a comprehensive ledger. Consequently, consumers can trace the complete history of an NFT. This level of transparency fosters positive consumer attitudes, enhances trust (Liu et al., 2023a; Rapezzi et al., 2024), and significantly influences purchasing behavior (Fu et al., 2023). Furthermore, the role of blockchains in enhancing transparency in supply chains, as demonstrated in various industries, highlights its effectiveness in addressing product inaccuracy and improving visibility (Saxena and Sarkar, 2023).

Second, NFTs are characterized by their immutable. Transactions are not recorded in a central location but distributed across the network, with each participant holding a local copy of the ledger and a linked list of blocks. To validate a new block, the participants in the blockchain network must reach a consensus. After a block is collectively accepted, it becomes extremely difficult to modify or delete it (Beck et al., 2018). This permanence enhances consumer trust in brands (Wang et al., 2021) and deepens their understanding of provenance by guaranteeing integrity, custody, and origin (Montecchi et al., 2019). Recent research has demonstrated that blockchain immutability reduces misinformation and increases consumer engagement in marketing campaigns (Alkhudary et al., 2023; Hajian et al., 2024).

Third, the traceability of NFT transactions is facilitated by timestamps and hash links to previously verified blocks (i.e., parent blocks). When a transaction occurs, the network participants can identify the block and trace all preceding transactions, including the genesis block. This traceability reduces user uncertainty (Liu et al., 2023b) and perceived risk (Montecchi et al., 2019), thereby increasing trust in the brand (Cozzio et al., 2023; Garaus and Treiblmaier, 2021) and positively influencing purchase decisions (Tran et al., 2024; Treiblmaier and Garaus, 2023). Applying blockchain-enabled traceability in various consumer services, such as mobile food delivery apps, has enhanced consumer attitudes and continued intention to use apps (Shahzad et al., 2023).

These three attributes of NFTs—transparency, immutability, and traceability—create a robust digital ownership system that enhances the value of luxury products. Given the significance of these attributes in luxury brands, this study explores how NFTs elevate the perceived authenticity of luxury goods and their impact on consumer evaluation.

2.2. Use of non-fungible tokens for physical goods

NFTs have emerged as a technology that cannot be illegally copied or tampered with in digital economic activities, thereby changing the structure of existing industries and breaking boundaries in various fields, including sports, gaming, and ticketing (CB Insights, 2022). Not only service industries but also product industries dealing with physical goods are proliferating in the NFT market. From art (e.g., The Kiss by Gustav Klimt; Rozan, 2024) to luxury brands (e.g., Gucci and Bulgari; Hirschmiller, 2024), companies link their products to digital tokens known as physical NFTs (Hammi et al., 2023). Physical NFTs typically consist of physical and digital components. The owner holds physical copies, and digital copies are stored in the blockchain. Using quick response (QR) codes or NFC technology, companies can link physical products or serial numbers to NFTs. User-defined scripts can be executed when certain transactions occur on the blockchain platform. Smart contracts, often referred to as such, enable parties to establish rules that

are encoded with tamper-proof properties. Because this procedure is automated, no intermediaries are required to complete it, which reduces transaction costs, eliminates moral hazard, and builds trust between the parties involved (Hawashin et al., 2023; Yermack, 2017).

The combination of physical goods and NFTs can give brands and consumers two advantages in terms of authenticity. First, it certifies the physical products made by a particular brand. Using NFTs, companies can include information about a product, such as serial numbers, materials, and buyer details so that the buyer can access this information anytime and anywhere. In other words, NFT owners demonstrate that they own authentic physical items with digital copies and are entitled to any rights granted in the smart contract. Thus, physical goods with NFTs can enhance brand loyalty by giving consumers a greater sense of ownership and authenticity. Second, NFTs provide transaction transparency. Fraud prevention initiatives are not limited to markets for brand-new products but also apply to markets for second-hand items, such as vehicles, collectible postcards, and luxury goods (Butera et al., 2023). As NFTs can trace all product transactions, brands can protect their products from being tampered with or forged, and buyers can feel less uncertain and have a comprehensive view of the product (Alkhudary et al., 2023).

2.3. Authenticity

While consumers seek authentic products, authenticity can have various meanings depending on the context, such as originality, integrity, or manufacturing location (Nunes et al., 2021). However, the concept of authenticity ultimately encapsulates "what is genuine, real, and/or true" (Beverland and Farrelly, 2010, p. 838), and an authentic product is considered a real or original thing, not a copy or imitation (Grayson and Martinec, 2004; Tanaka et al., 2024). Two products may look the same, but only the authentic one has a clear factual link with the source with which they claim to be associated. For example, consumers judge a Prada bag as authentic if they believe it can be traced back to an authorized manufacturer or retailer.

Firms strive to signal the authenticity of their products. Counterfeit proliferation is a global market problem that threatens brands and consumers. While some consumers actively purchase counterfeits (Ngo et al., 2020; Thaichon and Quach, 2016), others may unknowingly fall victim (Kim et al., 2024). Because the judgment of authenticity is facilitated by verification, such as certification or a credible context (Grayson and Martinec, 2004), firms develop ways to verify the authenticity of their products. Such verification methods not only make the work of counterfeiters difficult but also make it easy for consumers to distinguish an authentic product from a counterfeit.

Authenticity assurance benefits both consumers and sellers. Providing authenticity assurance can reduce consumers' psychological and social risks (Montecchi et al., 2019). It can also increase the chance of purchase by eliminating consumers' post-purchase regret (Pun et al., 2021) and increasing perceived quality, brand loyalty (Hyun et al., 2024), and purchase intention (Pandey et al., 2024). Conversely, a lack of authenticity can deter consumers from making purchases. For example, Han and Kim (2017) investigated Taobao.com, a major Chinese online marketplace for which consumers have doubts about the authenticity of products traded on the platform, and found that perceived product risk (i.e., the possibility of receiving a product that is not as described) was negatively associated with purchase intention.

Firms are becoming increasingly interested in using blockchain technology to signal product authenticity. Recent research has proposed that blockchain technology can help combat counterfeiting by providing a product history and increasing traceability and transparency in the supply chain (Montecchi et al., 2019). Some research has also investigated the conditions (e.g., government subsidies) under which blockchain technology would benefit the manufacturer (Pun et al., 2021). However, few studies have examined how to effectively communicate blockchain information to consumers to signal product authenticity.

3. Hypothesis development

3.1. Visual cues and consumer acceptance of non-fungible tokens

Companies commonly develop new products by adding novel attributes to an existing product. For example, a company may develop vitamin-fortified orange juice by adding extra vitamins to orange juice or a vitamin-fortified vodka by adding extra vitamins to vodka. Despite having the same added attributes, consumer acceptance of these two products can be very different: vitamin-fortified vodka may not be as successful as its orange juice counterpart (e.g., Jhang et al., 2012). Why do some products succeed while others fail?

Prior research has demonstrated that new product success is often influenced by the degree to which a novel attribute is inconsistent with the current product category (Jhang et al., 2012; Mandler, 1981). Consumers evaluate products that are moderately rather than extremely incongruent with the existing product categories (Jhang et al., 2012). This so-called moderate incongruity effect (Mandler, 1981) occurs because it is easier to understand how newly added attributes benefit existing products when they are moderately incongruous. However, this is much harder when novel attributes are extremely incongruous, and failure to resolve extreme incongruity leads to a lower evaluation of such products.

The important premise of Mandler's (1981) framework of moderate incongruity effect is that consumer acceptance of new products depends on the likelihood of resolving the incongruity (i.e., making sense of how a new attribute adds value to an existing product). When cognitive flexibility is enhanced through various methods, consumers often perceive highly incongruent products as favorably incongruent because they can effectively overcome extreme incongruity (Jhang et al., 2012). This suggests that providing aid that facilitates the resolution of incongruity leads to a more positive evaluation of extremely incongruent products.

Consider a new product such as a luxury bag with an NFT. Those who cannot grasp how an NFT could benefit the luxury bag did not evaluate this new product more favorably than the existing luxury bag without the NFT. However, a more favorable evaluation ensues when consumers can resolve the incongruity. For example, consumers who know that authenticity is an important dimension of luxury goods (Ko et al., 2019) and that NFTs are blockchain-based tokens with unique identification codes can resolve incongruity more easily by associating these two concepts. They can make sense of how NFTs could benefit luxury brands by providing a potential solution to the luxury brands' battle against counterfeits or reassuring consumers with authentication. Resolving this incongruity leads to a positive evaluation of a luxury bag with an NFT.

As the above example shows, consumers must have proper knowledge of the novel attribute to resolve incongruity. However, the public seems far from understanding the nature of NFTs. According to a recent NFT awareness survey (Vigderman, 2023), only 4% of people in the US reported being very familiar with NFTs, 61% reported being somewhat familiar with them, and 28% were unsure of what they were. This lack of public understanding is partly because NFTs are new products. Really new products (RNPs) are formally defined as new categories that defy classification within existing categories (Urban et al., 1996). People tend to have difficulty imagining how to use an RNP, which hampers their ability to learn about its benefits (e.g., Zhao et al., 2012). NFTs are intangible assets. Prior research has found that product intangibility not only increases consumers' risk perception (Laroche et al., 2004) but also makes it more difficult for consumers to evaluate the product's benefits (Park et al., 2023).

It is well known that visual cues improve our understanding of difficult subjects (e.g., Klein et al., 2019). Prior studies have revealed that the presentation format (pictorials vs. words) of marketing communications significantly influences consumer learning about RNPs (Feiereisen et al., 2013) because pictorials convey potential benefits more efficiently without overloading consumers. Furthermore, when

some attributes or functions are intangible or invisible, consumers feel they understand the benefits better when presented visually (Majer et al., 2022; Park et al., 2023). Prior research has demonstrated that visualization helps consumers overcome the difficulty caused by intangibility and thus facilitates their evaluation of services (Ding and Keh, 2017). Huddleston et al. (2023) explored how visual cues during shoppers' journeys impact their shopping behavior, highlighting the importance of these cues in the retail environment. Marketing practitioners have embraced this idea and actively used visual aids. For example, Intel has long used its Intel-inside logo in advertising campaigns, and the food industry uses various visual cues, such as sustainability labels and non-GMO labels, to help consumers understand the intangible/invisible aspects of products.

Based on this logic, we argue that consumers will experience less difficulty comprehending the benefits of NFTs when the embedded technology is (vs. is not) visually presented because it facilitates the visualization of novel attributes. Furthermore, consumers' enhanced ease of processing and understanding of NFTs will lead to more favorable evaluations of luxury items with an NFT. These are formally hypothesized as follows:

H1. Consumers prefer visualized (vs. non-visualized) NFTs in luxury products.

H2. Consumers exhibit more favorable attitudes toward luxury goods with easy-to-visualize NFTs (vs. difficult-to-visualize NFTs or control).

3.2. The mediating role of authenticity

We argue that visualized (vs. non-visualized) NFTs can improve consumer attitudes toward a physical luxury product. Several studies show that using NFTs in marketing can influence consumer perceptions and decision-making (Alexander and Bellandi, 2022; Eggenschwiler et al., 2024; Luong et al., 2024). Given that an NFT is authenticated by blockchain technology, it increases the perception of the authenticity of a target object or asset.

As authenticity certificates via blockchain, the use of NFTs helps verify ownership and trace its reliable aspects for various types of digital items, including songs, videos, games, and virtual fashion (Ali and Bagui, 2021). NFTs can also ensure the originality and uniqueness of physical goods such as artwork or sneakers, tracing the original manufacturing process, representing genuine aspects, and verifying ownership (Chakrabarti and Chaudhuri, 2017; Whitaker, 2019). For example, a new hoodie brand, Overpriced Hoodie, launched a physical hoodie digitally linked to the NFT. Krigler also launched a subscription program linked to an NFT, including a digital video of their famous perfume, and established a license to lease it for 12 months. If an NFT can be identified with a unique identification number or credentials in a digital manner, the digital records of the NFT linked to a physical object can also be traced and transferred, proving the object's authenticity.

Given the positive link between perceived authenticity and product evaluations or brand loyalty via improved confidence (Morhart and Malär, 2020; Tanaka et al., 2024), we propose that visualized NFT increases consumers' perceived authenticity of a luxury product, which in turn increases their attitudes toward the product. In other words, using an NFT signals the product's authenticity linked to the NFT and, in turn, enhances consumer evaluation. Formally,

H3. Perceived authenticity will mediate the positive effect of visualized (vs. non-visualized) NFTs on attitudes to luxury products.

3.3. The product type as a boundary condition

We proposed the product type as an important boundary condition for our proposed effect. Specifically, we suggest that the positive effect of NFTs on product attitudes is salient for luxury products but not for non-luxury products. We theorize that this effect occurs because of the consumers' increased sense of authenticity, as there is a key assumption that consumers' perceived authenticity plays a critical role in their product attitudes. In general, luxury products provide customers with authentic, exclusive, and prestigious experiences (Duma et al., 2016). Like artwork, many luxury brands often provide exclusive clothing or accessories created by designers (McKinsey & Company, 2023). The perceived authenticity of luxury goods with craftsmanship and heritage is an important factor in assessing the value of items (Tanaka et al., 2024). Additionally, because NFTs cannot be copied or replaced, their use helps improve the credibility and transparency of transaction records, making it difficult to copy them in the counterfeit luxury market (Owens, 2017).

The strong features of authentication and traceability of NFTs based on blockchain systems help authorize the original source and sponsorship of a luxury product as a complementary digital twin for a physical item (Caldarelli et al., 2021). As NFTs cannot be replaced or exchanged based on blockchain technology, they are also useful for confirming the originality and ownership process (Treiblmaier, 2023). Some luxury fashion companies have begun using NFTs to prove and trace the ownership records of their accessories or clothing (Bao et al., 2024; Hirschmiller, 2024; SanMiguel et al., 2024). By contrast, this effect is not salient for non-luxury products, as authenticity is relatively unimportant when evaluating such products. Therefore, we propose the following hypothesis:

H4. The effect of visualized (vs. non-visualized) NFTs on product attitudes will hold for luxury items and disappear for non-luxury items.

3.4. Overview of empirical studies

To test this causal relationship, we primarily used experimental studies that manipulated the visualization of NFTs. We also measured various key dependent variables across studies to provide empirical evidence.

Four studies were conducted to test the hypotheses. Study 1A investigated whether consumers preferred a visualized NFT over a non-visualized NFT to authenticate a luxury product. Study 1B further examined whether consumers place more trust in a visualized authentication system than in a non-visualized one and whether they are willing to pay more for a luxury product that utilizes visualization (H1). Study 2 tested whether consumers show more favorable attitudes toward a luxury product featuring an easy-to-visualize NFT than a difficult-to-visualize one (H2) and whether perceived authenticity mediates this effect (H3). Finally, Study 3 examined whether the focal effect was stronger for luxury products than non-luxury products (H4). Fig. 1 illustrates the theoretical framework and empirical studies. We also reported multiple pretests, demonstrating the successful manipulation of NFT visualization.

The target sample of this study was strategically chosen to include people who live in the US and are part of Amazon MTurk's online panel, as they are familiar with new NFT technology based on previous literature suggestions (e.g., Hajian et al., 2024; Sestino, 2024). The participants were paid nominal compensation through an online platform. We accessed the online panel using Cloud Research to ensure its overall quality. This approach helped prevent participants from participating in multiple studies and provided a highly representative sample of the US population, in line with recommendations from the existing literature (Kim, 2024). Consequently, we did not implement attention checks or exclude the participants.

4. Study 1A: providing initial evidence of H1

Study 1A aimed to provide evidence for the first hypothesis, which predicted that consumers would prefer a visualized NFT to a non-visualized one when authenticating a luxury bag. To enhance realism, we incorporated real brand names in this study.

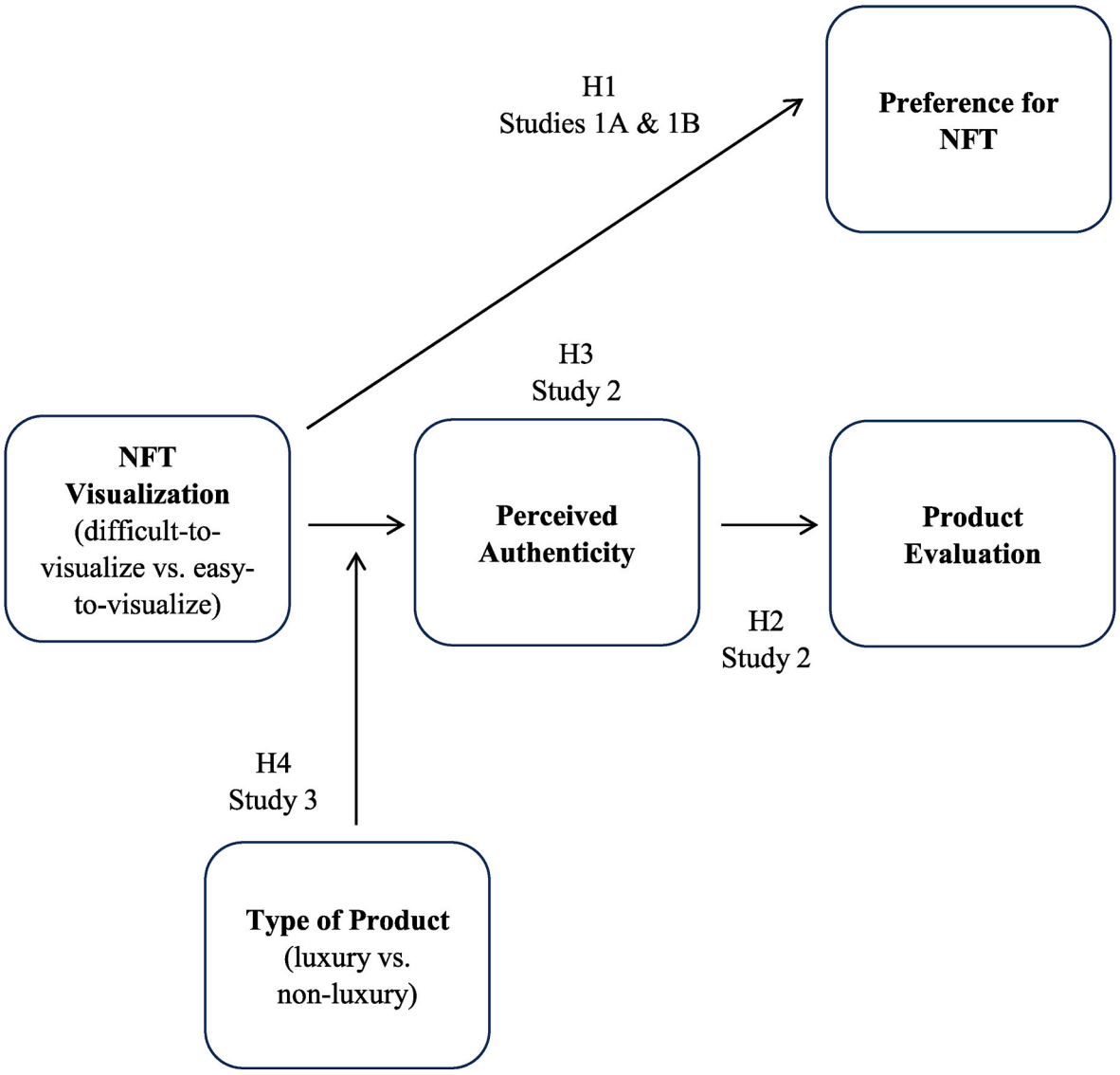

Fig. 1. Theoretical framework and empirical studies.

4.1. Method: participants, design, and procedure

In total, 203 US adults (46.3% female, $M_{\_age}$ = 39.71, SD = 11.33) participated in this study, recruited from Amazon's MTurk. The participants were first asked to imagine a situation where they considered purchasing a luxury handbag in a shopping mall. They were also asked to imagine that they had found a luxury handbag at a Prada store and contemplate purchasing it. They were then given the following statement: "*The Prada store uses a new technology: a Blockchain Authentication system. This Blockchain system makes it possible for consumers to access the product history and proof of authenticity of luxury goods – from sourcing to sales, all the way to second-hand markets. This system includes the creation of a unique digital identity (ID) for each product to record every transaction and to deliver an authenticity certificate to customers.*" Next, the participants were asked to choose one of the two methods to generate a unique digital ID: visible QR code or invisible radio-frequency identification (RFID; Fig. 2).

The participants were then asked to rate their technology anxiety using nine items (e.g., "I have difficulty understanding most technological matters.") with 7-point scales (1 = strongly disagree, 7 = strongly agree, Raub, 1981; Cronbach's α = .919). Finally, all participants were asked to provide demographic data, including family income (1 = $0 - $10,000, 2 = $10,001 - $20,000, …, 15 = $14,001), age, and sex.

4.2. Results and discussion

To test the main hypothesis, we analyzed participants' preferences for the NFT format. The results indicated that the participants preferred the visible QR code (66.5% = [135/203]) to the invisible RFID code (33.5% = [68/203]). The preference for the visible QR code option was statistically higher than a random selection of 50% ($\chi^2(1) = 11.37$, p = .001, φ = .167). We conducted a binary logistic regression analysis to investigate the impact of demographics and technology anxiety. The results indicated that no variable significantly influenced the preference for the visible (vs. invisible) option (i.e., income, p = .985; gender, p = .161; age, p = .209; and technology anxiety, p = .561).

In summary, we found that people prefer the visible NFT option in luxury consumption situations. However, the results of Study 1 could be explained by a preference for the specific technological method of a QR code rather than an RFID method but not by a preference for a visible versus an invisible NFT. To rule out this alternative explanation, we conducted Study 1B.

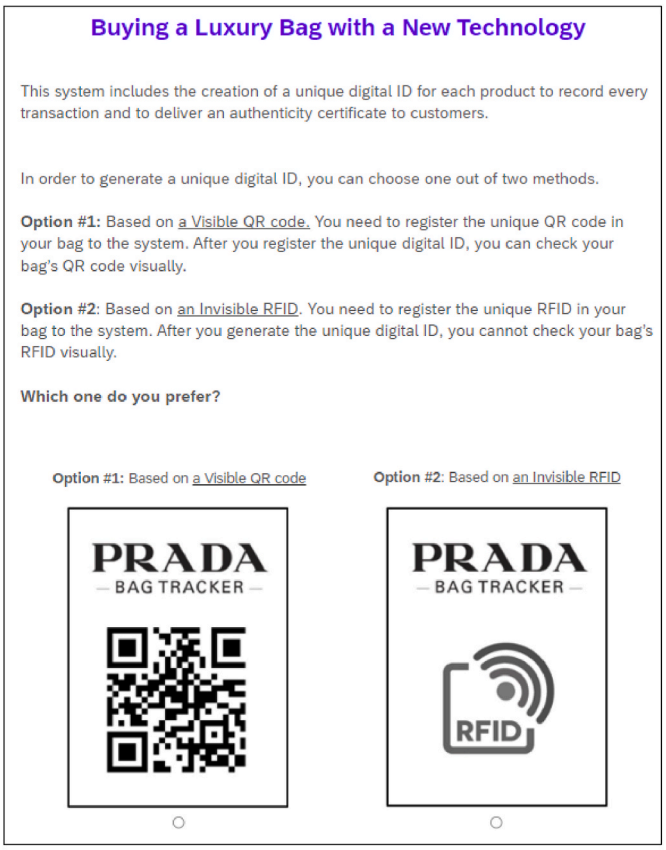

Fig. 2. Stimuli for study 1A and 1B.

5. Study 1B: testing alternative explanation

Study 1B aimed to replicate a previous study with some modifications. First, to rule out the possibility that the results of Study 1 were influenced by consumers' preferences for specific technological methods (e.g., QR codes vs. RFID), this study kept the technology constant across both options. Instead, options were framed as either visible or invisible. Second, to eliminate any potential influence of real brand names, this study avoided using specific brand names. Third, to deepen our understanding of these effects, we measured additional variables beyond the simple choice between visible and invisible NFTs. Specifically, we evaluated the perceived trustworthiness of each authentication system and the willingness to pay a premium for a luxury product utilizing an NFT based on the assumption that a higher attitude toward the luxury product is conceptually related to these two additional measurements (Zeithaml, 1988). In other words, we anticipate that customers exposed to easily visualizable NFTs will exhibit a more favorable attitude by demonstrating a higher willingness to pay for products associated with those NFTs. With these adjustments, Study 2 provided more substantial evidence supporting H1.

5.1. Method: participants, design, and procedure

In total, 102 US adults (59.8% female, M_{age} = 40.75, SD = 12.60) recruited from Amazon's MTurk participated in this study. The procedure for Study 1B was similar to that of Study 1A but with a few modifications. First, after reading a shopping scenario similar to that in Study 1A, the participants were asked to choose one of two options for the authentication system: visible or invisible individual code (Fig. 2). Second, after making their choice, all participants were asked to rate their perceived trustworthiness of each authentication code, using three items with 7-point scales (i.e., 1 = not at all credible/trustworthy/believable, 7 = very credible/trustworthy/believable, Huang and Gong, 2018; Cronbach's α = .941 and .975). They also assessed their willingness to pay for the luxury bag with each authentication code, provided that the regular price of the bag without an authentication code was $1,000, using an 8-point scale (i.e., 1 = less than $1,000, 2 = $1,000, 3 = $1001–$1,100, …7 = $1401–$1,500, 8 = more than $1500). Finally, all participants were asked to provide demographic data, including family income, age, and sex.

5.2. Results and discussion

To test the main hypothesis, we analyzed participants' preferences for the NFT format. The results indicate that the participants preferred the visible code (84.3% = [86/102]) to the invisible code (15.7% = [16/102]). The preference for the visible code was statistically higher than the random selection of 50% ($\chi^2(1) = 27.23$, $p < .001$, $\varphi = .365$). We conducted a binary logistic regression analysis to investigate the impact of demographics. The results indicated that no variable significantly influenced the preference for the visible (vs. invisible) option (i.e., income: $p = .856$, gender: $p = .149$, and age: $p = .472$).

We also found that the perceived trustworthiness of the authentication system was higher for visible code than for invisible code ($M_{visible}$ = 5.49, SD = 1.35 vs. $M_{invisible}$ = 4.01, SD = 1.79, $t(101) = 7.65$, $p < .001$). In addition, the willingness to pay for the luxury bag was also higher when it was accompanied by the visible code compared to the invisible code ($M_{visible}$ = 2.81, SD = 1.41 vs. $M_{invisible}$ = 2.46, SD = 1.39, $t(101)$ = 2.95, $p < .001$).

6. Study 2: testing the mediation hypothesis

In previous studies, we compared the impact of two different methods on the same participants. However, in this study, we used a between-subject experimental design to investigate the impact of a visualized NFT on the evaluation of a luxury bag. Specifically, we compared the evaluation of luxury bags (i) without NFT authentication, (ii) with an easy-to-visualize NFT, and (iii) with a difficult-to-visualize NFT. We predicted that consumers would prefer a luxury bag with an easy-to-visualize NFT over one with a difficult-to-visualize NFT or without an NFT. Perceived authenticity is measured as a key mediator. Additionally, to assess the influence of NFTs across different market conditions, we presented the bag as brand-new and used. Finally, we measured the participants' blockchain knowledge to determine their level of knowledge about this new technology.

6.1. Method: participants, design, and procedure

In total, 400 US adults (53.5% female, M_{age} = 43.26, SD = 12.75) recruited from Amazon's MTurk participated in this study. The participants were randomly assigned to a 2 (product type: brand new vs. used) × 3 (NFT: without NFT authentication vs. difficult-to-visualize NFT vs. easy-to-visualize NFT) between-subjects design. They were asked to read about luxury Prada bags with additional information. This information was manipulated using experimental factors (Kim, 2017). We specified whether the bag was brand new (i.e., *Brand New*) or used (i.e., *Pre-Owned*). For the NFT manipulation, we did not provide any additional information to the participants in the without NFT condition group. However, participants in the difficult-to-visualize NFT condition were given information about 'Prada Blockchain Authentication,' while those in the easy-to-visualize NFT condition were given the information as well as the visualized code, as illustrated in Fig. 3.

All participants were then asked to rate their attitude toward the luxury bag using four items with 7-point scales (i.e., 1 = very bad/

Fig. 3. Stimuli for study 2.

unfavorable/unappealing/not at all likable, 7 = very good/favorable/appealing/very likable, Kim et al., 2022, α = .946). They were also asked to state their perceived authenticity on a 7-point scale (1 = not at all authentic, 7 = very authentic, Morhart et al., 2015). They then answered a manipulation check for the type of product manipulation using a 7-point scale (1 = not at all new, 7 = brand new). Finally, to measure the participants' knowledge of blockchain, they were asked to choose one example of blockchain technology from five alternatives (i.e., self-driving car, Bitcoin, robotics, nanotechnology, or I do not know). Approximately 77% (308 out of 400) of the participants showed a high level of knowledge by choosing the correct answer, Bitcoin.

6.2. Pretest for ease of visualization of non-fungible tokens

To verify the effectiveness of our manipulation of the ease of visualization of NFTs, we conducted a pretest using the same online panel (N = 116, 53.4% female, M_{age} = 44.79, SD = 13.53). The participants were exposed to one of two different NFT authentication types: easy-to-visualize and difficult-to-visualize NFT, as in the main study. Then, they were asked to rate the perceived ease of visualization of the NFT using a 7-point scale (i.e., 1 = not at all easy to visualize/not at all straightforward to imagine, 7 = very easy to visualize/very straightforward to imagine, Zhao et al., 2014, Cronbach's α = .966). These results confirmed our predictions. Participants' perceived easiness was higher in the easy-to-visualize (vs. difficult-to-visualize) condition (F (1, 114) = 10.72, p < .001, η^2 = .086; $M_{easy\ NFT}$ = 5.03, SD = 1.65 vs. $M_{difficult\ NFT}$ = 3.98, SD = 1.81).

6.3. Results and discussion

The manipulation of product type was successful in that the perceived newness was higher in the brand new (vs. used) condition ($M_{brand\ new}$ = 6.36, SD = 1.08 vs. M_{used} = 3.82, SD = 2.03, F (1, 394) = 246.13, p < .001, η^2 = .384). The main effect of NFT (p = .619) and the interaction effect (p = .225) were not significant.

We also found a main effect of product type (F (1, 394) = .64, p = . 4231, η^2 = .002) and the interaction effect (F (2, 394) = .22, p = . 801, η^2 = .001) were not significant for attitude toward the luxury bag. Similar results were found for perceived authenticity (main effect of product type: F (1, 394) = .43, p = . 514, η^2 = .001 and the interaction effect: (F (2, 394) = .44, p = . 647, η^2 = .002). Therefore, we excluded this factor in subsequent analyses.

The main effect of NFT was marginally significant for attitude toward the luxury bag (F (2, 397) = 2.45, p = . 087, η^2 = .012). Planned contrast confirmed that the attitude toward luxury bags was higher with the easy-to-visualize NFT than with no NFT ($M_{easy\ NFT}$ = 5.75, SD = 1.04 vs. $M_{no\ NFT}$ = 5.49, SD = 1.23, F (1, 397) = 3.44, p = . 064) and that the attitude to the luxury bag was higher with the easy-to-visualize NFT compared to the difficult-to-visualize NFT ($M_{easy\ NFT}$ = 5.75, SD = 1.04 vs. $M_{difficult\ NFT}$ = 5.46, SD = 1.23, F (1, 397) = 3.96, p = . 047), as shown in Fig. 4. Furthermore, the attitude toward the luxury bag was similar when comparing difficult-to-visualize NFT to no NFT ($M_{difficult\ NFT}$ = 5.46, SD = 1.23 vs. $_{no\ NFT}$ = 5.49, SD = 1.23, F (1, 397) = .02, p = . 884).

Second, for perceived authenticity, we found that the main effect of the NFT was significant (F (2, 397) = 10.69, p < .001, η^2 = .051). Planned contrast confirmed that the perceived authenticity of the luxury bag was higher with the easy-to-visualize NFT than with no NFT ($M_{easy\ NFT}$ = 6.22, SD = .96 vs. $M_{no\ NFT}$ = 5.58, SD = 1.26, F (1, 397) = 21.37, p < .001) and that the perceived authenticity of the luxury bag was higher with the easy-to-visualize NFT than with the difficult-to-visualize NFT ($M_{easy\ NFT}$ = 6.22, SD = .96 vs. $M_{difficult\ NFT}$ = 5.90, SD = 1.17, F (1, 397) = 5.46, p = . 020), as illustrated in Fig. 4. In addition, the perceived authenticity of the luxury bag was unexpectedly higher with difficult-to-visualize NFT than with no NFT ($M_{difficult\ NFT}$ = 5.90, SD = 1.17vs. $M_{no\ NFT}$ = 5.58, SD = 1.26; F (1, 397) = 5.28, p = .022).

Finally, to test the mediation analysis (type of NFT → perceived authenticity →attitude toward luxury bags), we conducted a Hayes macros analysis #4 with 5000 bootstrapping. For the comparison between the easy-to-visualize NFT and no NFT conditions, the indirect effect was significant (index [a * b] = .193, se = .079, 95% CI [Confidence Interval] = [.043, .349]). In contrast, the direct effect was not significant (index [c'] = .094, se = .119, 95% CI = [.140, −.329]), supporting full mediation results for perceived authenticity. For the comparison between easy-to-visualize NFT and difficult-to-visualize NFT conditions, the indirect effect was significant (index [a * b] = .210, se = .051, 95% CI = [.112, .314]). In contrast, the direct effect was not significant (index [c'] = −.077, se = .056, 95% CI = [-.187, .033]), supporting full mediation results for perceived authenticity.

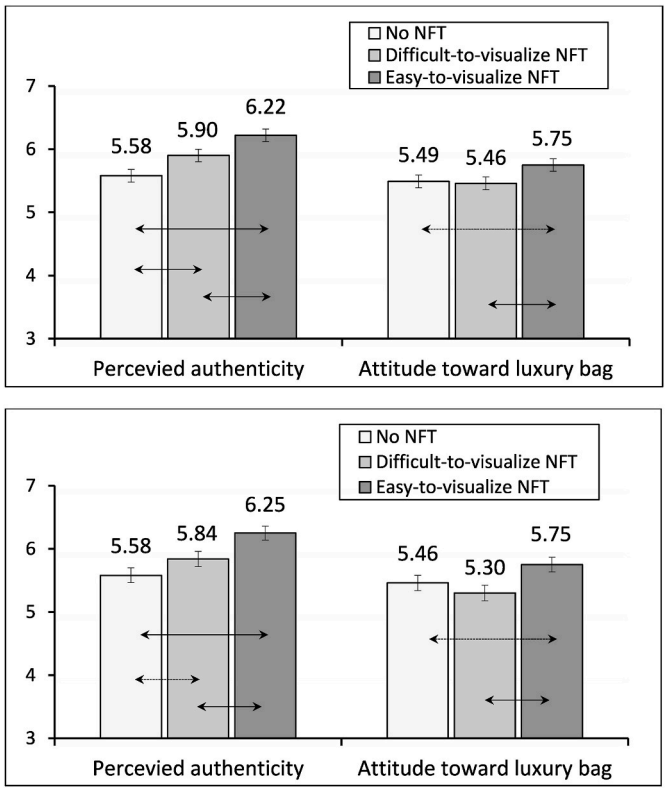

Fig. 4. Results of Study 2.
Note: Error bars represent standard errors; "<↔>" and "<↔>" represent significance at p < .05 and p < .10, respectively.

6.4. Additional analysis

We investigated the impact of the knowledge level on the above results. Of the 400 participants, 308 (77%) chose the correct answers to the NFT questions. The results of these 308 participants (47.4% female, M_{age} = 42.89, SD = 12.60) were quite similar to previous results. The main effect of NFT was significant for attitude toward the luxury bag (F (2, 305) = 3.81, p = . 023, η^2 = .024). In addition, for the perceived authenticity, we found that the main effect of the NFT was also significant (F (2, 305) = 8.85, p < .001, η^2 = .055). The detailed results are presented in Fig. 4.

In addition, we conducted an ANCOVA with knowledge as a covariate for all participants (N = 400). The main effect of NFT was still significant for attitude toward the luxury bag (F (2, 396) = 3.06, p = . 048, η^2 = .015), whereas the covariate was marginally significant (F (2, 396) = 3.47, p = . 063, η^2 = .009). Planned contrasts confirmed that the attitude toward the luxury bag was higher with the easy-to-visualize NFT compared to the difficult-to-visualize NFT or no NFT ($M_{easy\ NFT}$ = 5.78, SE = .10 vs. $M_{difficult\ NFT}$ = 5.45, SE = .10, [p = . 026] vs. $M_{no\ NFT}$ = 5.48, SE = .10 [p = . 039]). Similar results were found for perceived

authenticity. The main effect of NFT was still significant for the perceived authenticity of the luxury bag (F (2, 396) = 19.58, p <. 001, η^2 = .051), whereas the covariate was not significant (F (2, 396) = .12, p = . 903, η^2 < .001). Planned contrasts confirmed that perceived authenticity was higher with the easy-to-visualize NFT compared to the difficult-to-visualize NFT or no NFT ($M_{easy\ NFT}$ = 6.23, SE = .10 vs. $M_{difficult\ NFT}$ = 5.89, SE = .10, [p = . 020] vs. $M_{no\ NFT}$ = 5.58, SE = .10 [p <. 001]). In sum, the additional data analysis suggests that consumers may be more favorable toward luxury goods with easy-to-visualize NFTs, regardless of their level of prior knowledge about NFTs.

7. Study 3: testing boundary condition

This study aimed to test the moderating role of product type. Specifically, we predicted that the positive effect of an easy-to-visualize NFT on product evaluation would be stronger for luxury products than for non-luxury products.

7.1. Method: participants, design, and procedure

In total, 205 US adults (63.4% female, M_{age} = 44.18, SD = 14.53) recruited from Amazon's MTurk participated in this study. Participants were randomly assigned to one of the two (product type: luxury vs. non-luxury) × 2 (NFT: without NFT authentication vs. easy-to-visualize NFT) between-subjects designs.

The general procedure was similar to that used in Study 2 but with a few modifications. First, participants were asked to read information about either a luxury Prada bag or a non-luxury Kenneth Cole bag by manipulating the product type. In addition, for NFT manipulation, participants in the without-NFT condition were not provided with any information regarding the authentication system, whereas those in the easy-to-visualize NFT condition were given relevant information and the visualized code, as illustrated in Fig. 5.

All participants were then asked to rate their attitude toward the luxury bag using the same scale as Study 3 (α = .946). They were also asked to state their perceived luxuriousness on a 7-point scale (1 = not at all luxurious, 7 = very luxurious, Moreau et al., 2020).

7.2. Results and discussion

The manipulation of luxury was successful in that perceived luxuriousness was higher in the luxury (vs. non-luxury) condition (M_{luxury} = 6.04, SD = 1.35 vs. $M_{non\ luxury}$ = 5.29, SD = 1.04, F (1, 201) = 19.95, p <. 001, η^2 = .090). The interaction effect (p = .463) was not significant, whereas the main effect of NFT was unexpectedly significant (F (1, 201) = 6.53, p = . 011, η^2 = .031) in that the perceived luxuriousness was higher in the easy-to-visualize NFT (vs. no NFT) condition ($M_{easy\ NFT}$ = 5.85, SD = 1.21 vs. $M_{no\ NFT}$ = 5.42, SD = 1.26).

In the main analysis of attitude toward the bag, the main effect of product type was significant in that attitude was higher in the luxury (vs. non-luxury) condition (F (1, 201) = 5.36, p = . 037, η^2 = .021; M_{luxury} = 5.90, SD = 1.19 vs. $M_{non\ luxury}$ = 5.57, SD = 1.04). The main effect of NFT was not significant (F (1, 201) = .47, p = . 495, η^2 = .002). More importantly, the interaction effect was significant (F (1, 201) = 6.19, p = . 025, η^2 = .025), as illustrated in Fig. 6. The planned contrast confirmed that the attitude toward the bag was higher in the easy-to-visualize NFT (vs. no NFT) condition (F (1, 201) = 4.03, p = . 046, η^2 = .020; $M_{easy\ NFT}$ = 6.12, SD = .95 vs. $M_{no\ NFT}$ = 5.66, SD = 1.37) for the luxury bag. On the other hand, the attitude toward the bag was the same for the easy-to-visualize NFT and no-NFT conditions (F (1, 201) = 1.34, p = . 249, η^2 = .007; $M_{easy\ NFT}$ = 5.44, SD = 1.18 vs. $M_{no\ NFT}$ = 5.69, SD = .89) for the non-luxury bag. In summary, the results support the moderating effect of the product type.

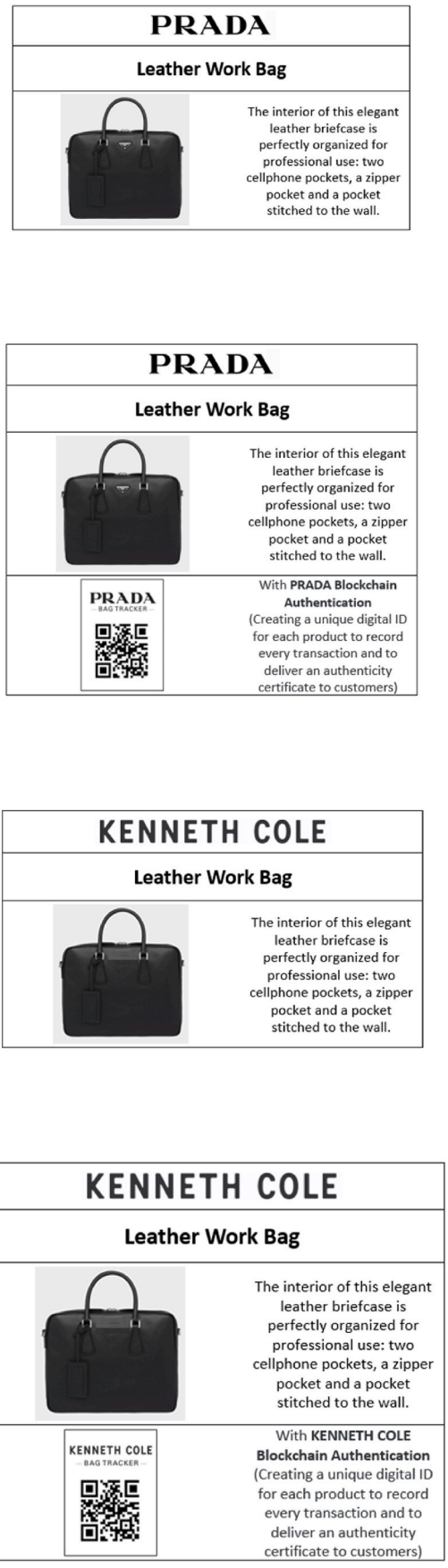

Fig. 5. Example stimuli for study 3.

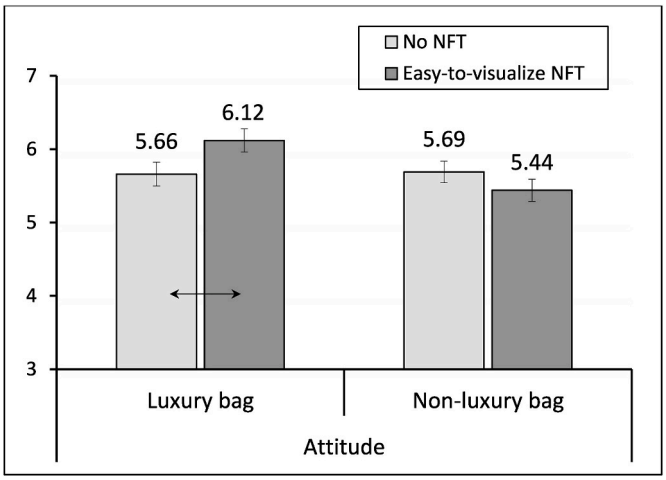

Fig. 6. Results of Study 3. Note: Error bars represent standard error; "↔" represents significance at $p < .05$.

8. General discussion and implications

8.1. Summary of findings

Compared with the immense popularity of NFTs and blockchain technology (Hofstetter et al., 2022; Tran et al., 2024; Wang et al., 2021), relatively few studies have explored the effects of this trend on consumer behavior in the context of luxury goods. To fill this gap in the literature, this study highlighted how the ease of visualization of NFTs positively impacts consumer evaluations of luxury products. The findings of the four experiments confirmed our hypotheses. Study 1A indicated that consumers preferred a visualized NFT over a non-visualized one. Study 1B further demonstrated that consumers placed more trust in visualized NFTs and were willing to pay higher prices for a product that utilized them. Study 2 showed that perceived authenticity mediated the focal effect. Finally, Study 3 demonstrated that the positive impacts of easily visible NFT cues were more significant for luxury goods than for non-luxury goods.

8.2. Theoretical implications

This study had several theoretical implications. First, it adds to the growing body of literature on RNPs (Pun et al., 2021; Shahzad et al., 2023; Urban et al., 1996) by investigating the role of NFTs in evaluating luxury products. Previous studies have suggested that using visual cues (e.g., pictograms) can enhance the understanding of RNPs compared to merely using words because they communicate the potential benefits of RNPs to consumers more effectively (Feiereisen et al., 2013; Majer et al., 2022; Park et al., 2023; Zhao et al., 2012). However, the crucial role of visual cues in understanding complex subjects has been neglected (Klein et al., 2019; Park et al., 2023). We extend the research on the moderate incongruity effect (Jhang et al., 2012; Mandler, 1981) by highlighting the role of ease of visualization in the context of NFTs. Our findings suggest that consumers are willing to pay a premium for luxury products using an NFT that is easier (versus more difficult) to visualize. We also demonstrated that perceived authenticity underlies the advantage of easy-to-visualize NFTs for luxury consumption. We contribute to the literature on the determinants of consumer acceptance of revolutionary-technology-driven products (Park et al., 2015; Sestino, 2024) by focusing on how the integration of novel technologies can influence consumer evaluations of luxury brands.

Second, our study adds to the literature on the application of NFTs in retail, marketing, and consumer behavior contexts (Chohan and Paschen, 2021; Hofstetter et al., 2022; Saxena and Sarkar, 2023). Prior research has investigated the application of NFTs and blockchain technology in the retail, art, and fashion contexts (Alexander and Bellandi, 2022; Chakrabarti and Chaudhuri, 2017; Park and Lim, 2023; Whitaker, 2019). These studies suggest that NFTs add value to multiple businesses by offering novelty, easing transactions, and creating opportunities to generate additional revenue from new products sold in metaverse markets. The current research builds on this line of literature by focusing on how NFTs can prevent counterfeiting and improve the sense of authenticity of luxury products, which, in turn, increases purchasing intentions. By examining the impact of the ease of visualization of NFTs on consumers' evaluations of luxury products, our research advances the understanding of when and why consumers' acceptance of NFTs can be facilitated (Montecchi et al., 2019; Tran et al., 2024; Treiblmaier and Garaus, 2023; Wang et al., 2021).

Third, our research adds to the literature on retail and consumer services of luxury products (Hajian et al., 2024; Ko et al., 2019; Ngo et al., 2020; Thaichon and Quach, 2016; Vhatkar et al., 2024). Previous studies have identified various contextual factors influencing consumer evaluations of luxury products. For example, recent research has demonstrated that experiencing art can reduce the desire for luxury goods (Wang et al., 2023). Additionally, retail rejection can counterintuitively increase the aspirations of luxury brands (Ward and Dahl, 2014). More relevant to our research, key website characteristics, such as a transparent authentication system, can increase consumers' purchase intentions for online pre-owned luxury products (Pandey et al., 2024). Our study extends this line of literature by focusing on another contextual factor: the use of NFT technology. We demonstrate that using NFTs in retail can enhance consumers' purchase intentions for luxury products, especially when their visual representation is straightforward. In particular, our findings provide novel insights into how the use of NFT technology can safeguard luxury products from counterfeits by assuring consumers of the product's authenticity, which is a crucial factor in luxury marketing (Fontana et al., 2019; Nunes et al., 2021; Song et al., 2021).

8.3. Practical implications

This study offers several practical implications for marketing managers. First, marketers should more effectively integrate NFTs into their product development strategies and marketing campaigns. As brands, especially luxury brands, face challenges distinguishing counterfeits from authentic items, the growing demand for counterfeit products poses a serious threat. Given the critical role NFTs can play in preserving authenticity, luxury brands should leverage these digital assets to enhance the value and legitimacy of their offerings. Our findings emphasize the importance of developing visually appealing and easily understandable NFT designs for product authentication. Marketing managers must recognize how visual appeal influences consumer perceptions and ensure these designs are intuitive. For instance, NFTs with tags featuring QR codes should be highly visible to maximize their impact. By prioritizing the visual aspects of NFTs, luxury brands can capitalize on the research finding that consumers prefer and trust visualized NFTs more, potentially leading to a greater willingness to pay for authenticated luxury products.

Second, marketers should customize their NFT strategies based on product characteristics. As counterfeits and authenticity are particularly important for luxury brands (Fontana et al., 2019), we found that the visual appeal of NFTs had a more substantial impact on luxury products than on non-luxury brands. More broadly, our research indicates that NFTs significantly influence the perceived authenticity of products facing challenges related to counterfeiting or a robust second-hand market. This may involve highlighting additional value propositions that resonate with consumers, addressing authenticity concerns, and complementing NFT integration. Overall, our findings suggest that marketers should prioritize integration and investment in NFTs, particularly in areas where authenticity and counterfeiting concerns are most prominent.

Third, given that consumers prefer visualized NFTs to authenticate luxury products, policymakers should consider developing clear regulatory frameworks that address the use and characteristics of NFTs to ensure that they effectively communicate authenticity. For example, policymakers may mandate clear disclosure requirements for NFT-based authentication systems, similar to those established for other digital technologies in consumer markets (Goldstein and Carpenter, 2022). This could require brands to provide comprehensive information on how NFTs function as digital certificates of authenticity, thereby empowering consumers to make informed purchasing decisions. Additionally, to further enhance consumer trust, policymakers should encourage brands to clearly communicate the operational aspects of NFTs, reinforcing their role as reliable authentication tools.

8.4. Limitations and future research

This study had several limitations that require further investigation. First, our study examined how the use of NFTs and their visual representations influence consumers' evaluation of products. Specifically, we compared the use of visible NFTs (QR codes) with invisible NFTs (RFIDs) (Study 1) and the use of NFTs in QR forms versus verbal descriptions (Studies 2 and 3). However, additional research is necessary to gain a more comprehensive understanding of the impact of visualization and its practical implications. Other aspects of visualization, such as the size or color of the visual representation, merit further investigation. For example, does a larger visual representation amplify the positive effects of NFTs compared with smaller ones? Which color, black or red, is more effective? Future studies should address these questions to deepen our knowledge of how NFT visualization influences luxury marketing.

Second, our research concentrates on authenticity as the fundamental principle driving the hypothesized impact. In this context, authenticity is primarily related to whether a product is genuine (Park et al., 2022). Our results showed that using NFTs, particularly when easily visualized, enhanced the perception of authenticity. However, there may be situations in which the use of NFTs can negatively affect luxury brands and their perceptions of authenticity. Luxury brands are often known for their long traditions, heritage, and artisanship, which are other dimensions of authenticity (e.g., Nunes et al., 2021). Incorporating the latest technology may conflict with the established images of these brands. For example, could the use of NFTs and their visual representation harm brands that emphasize tradition and heritage compared to brands that are more contemporary and targeted at younger audiences? Future research could explore situations in which the use of NFTs might harm a brand and investigate potential conflicts between technological advancements and the traditional values of luxury brands.

Third, our research highlights that consumers' prior knowledge did not significantly determine the focal effect. However, to obtain a more comprehensive understanding of this effect, future research should consider incorporating more nuanced psychological or subjective measures of knowledge rather than relying solely on simple objective questions. Additionally, future research might explore other individual differences that influence the impact of NFTs and their visual representations on consumer evaluations. For example, some individuals rely more on visual information (visualizers) when performing cognitive tasks, whereas others rely more on verbal or logical processes (verbalizers; Jonassen and Grabowski, 1993). Does this distinction moderate the impact of NFTs? Prior research also reveals that factors such as technology adoption propensity, trust, perception of advantage, and entrepreneurial passion significantly influence the adoption of NFTs (Liu et al., 2023a). Future research should examine the roles of these individual differences to provide a deeper understanding of how NFTs and their visual representations affect consumer perceptions and evaluations.

Fourth, the present research found that the positive impact of NFT visualization is less pronounced for non-luxury products compared to luxury products (Study 3). This finding is consistent with the notion that consumers are generally less concerned about counterfeiting in non-luxury markets. However, some non-luxury brands have encountered counterfeiting issues. For example, consumers may worry about counterfeit fashion brands, especially when purchasing from third-party sellers or second-hand markets (e.g., Nike). Similarly, certain product categories, such as cars, face concerns about fraud regardless of whether they are luxury brands. In these instances, although the products are not classified as luxury, they share similar concerns about authenticity and could benefit from the visualization of NFTs. Therefore, future research should explore the impact of NFT visualization in these cases.

CRediT authorship contribution statement

Jungkeun Kim: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Areum Cho:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Data curation, Conceptualization. **Daniel Chaein Lee:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jooyoung Park:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Aekyoung Kim:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Data curation, Conceptualization. **Jihoon Jhang:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Data curation, Conceptualization. **Changju Kim:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

Data availability

Data will be made available on request.

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