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Evidence from a neurophysiological perspective

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Research article

Cognitive load during planned and unplanned virtual shopping: Evidence from a neurophysiological perspective

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ABSTRACT

Rapid adoption of virtual-reality-assisted retail applications is inadvertently reshaping consumer buying patterns, making it crucial for businesses to enhance their shopping experience. This new scenario challenges marketers with unique hurdles in both the commercialization of products and in managing information cues derived via VR retailing. Therefore, this study examined consumers' impulsive behavior and unplanned purchases in a virtual retail store, using self-reports and electroencephalography. Borrowing assorted perspectives from retailing, virtual reality, and neuromarketing literature, we extended the stimulus-organism-response framework to evaluate how unplanned behavior evolves through conscious and unconscious measures. We found that consumers' impulsiveness was significantly associated with their unplanned expenditure and the number of unplanned purchases. Using mediation analysis, we observed that flow experience during shopping partially mediated the relationship between the sense of presence and the desire to stay longer in a virtual shopping store. Desire to stay in the virtual store positively influenced store satisfaction, basket-size deviation, and budget deviation. Additionally, cognitive workload obtained via electroencephalogram revealed significant differences during both planned and unplanned purchases. These findings provide fresh opportunities for retailers to leverage the disruptive potential of immersive and interactive virtual technology to transform consumer shopping experiences.

1. Introduction

Over the past decade, the landscape of consumer retail experience has rapidly evolved, including the expediting of consumer rates of adopting extended reality technologies, due to continuous improvements in retailing solutions and artificial intelligence ecosystems (i.e., hardware, software, and applications) (Dwivedi et al., 2022; Grewal et al., 2017; Koohang et al., 2023). Recent reports estimate that the global market for the metaverse will reach $678 billion in U.S. dollars by 2030 (Alsop, 2022), with more than 25% of consumers worldwide anticipated to spend time regularly in the metaverse by 2026 (Alsop, 2022). In contrast to augmented-reality (AR) environments, users wear head-mounted display (HMD) glasses and experience virtual reality (VR) as a replacement for the local physical environment, ranging from low-level to high-level degrees of telepresence (Rauschnabel et al., 2022). Utilizing VR technology to partake in retailing activities, under

the ambit of metaverse retailing i.e., retail-related activities in virtual spaces, is an emerging distribution channel that offers a unique setting for marketing research (Dwivedi et al., 2022). The challenge therein lies in businesses capturing, analyzing, and inferring consumer spending patterns in VR-based shopping environments, to enable crafting management-level strategies (Blasco-Arcas et al., 2023; Giang Barrera & Shah, 2023).

Unplanned shopping poses challenges for retailers because it affects overall cart value at the point of purchase, management of assortments, and sale of new products (Kato & Hoshino, 2021; Nigam et al., 2022). A recent report on social media consumers suggests that a staggering 63% of purchases are unplanned, 23% are impulsive, and only 14% are planned (Chevalier, 2021). Arguably, encouraging unplanned purchases may be of greater significance to retailers in ascertaining higher profit margins. However, retailers need a better understanding of unplanned purchases, one that embraces consumers' explicit opinions and implicit

subconscious decision-making.

Consumer research defines unplanned purchases as those undetermined at the brand or category level prior to the store visit (Abratt & Goodey, 1990; Inman et al., 2009; Streicher et al., 2021), whereas impulse purchases occur due to the spontaneous urge to buy a product (Rook & Fisher, 1995). Consumer decision-making for impulsive and unplanned purchases can differ depending on whether the consumer uses a deliberative or an implementing mindset (Sohn & Ko, 2021). Notwithstanding the differences between these two approaches, prior works have used appropriate insights from impulse-buying literature to explain unplanned buying behavior. In this sense, multiple reviews and meta-analyses of impulsive buying (see Iyer et al., 2020; Mandolfo & Lamberti, 2021) constitute a reference for our research. Regarding the outcome of unplanned buying, the literature is prone to focus on sales as a key variable (Hui, Huang et al., 2013). However, three intermediate variables may contribute to explaining sales volume: the number of products or the number of units per product bought, the desire to stay at the store, and the amount of time spent in the store (Park et al., 1989). Desire to stay and time spent are of chief interest, as they can explain purchase behavior and provide intrinsic value in cases where consumers do not buy. Moreover, the interaction between price levels and the available shopping budget shapes final purchase decisions.

Although knowledge of explicit unplanned buying behavior is valuable, scant literature addresses the neural mechanisms that influence such behavior. From a methodological perspective, most of the published research on impulse buying and unplanned purchases has utilized questionnaires and experimental designs (Mandolfo & Lamberti, 2021). In contrast to such research, we use an electroencephalogram (EEG) to complement the survey data, as it provides a superior temporal sequence in the context of dynamic consumer decision-making (Lin et al., 2018). Further, electroencephalography serves as a unique, non-invasive physiological index for continuously measuring cognitive workload (Antonenko et al., 2010) during planned versus unplanned purchases within a consumer shopping journey. Therefore, this study integrates in-store observational variables and unconscious responses, to provide an integrative explanation of their influence on purchase decisions.

Developing VR technology can help businesses to better understand consumers' in-store shopping patterns and to explore its potential as a major distribution channel (Barrera & Shah, 2023). In this study, we present consumers with a shopping task in a simulated virtual environment whose resemblance to a physical supermarket has three benefits for our research. First, it increases the study's ecological validity because it provides a realistic depiction of product assortment, store layout, and shopping experience (hedonic and utilitarian values) (Alcañiz et al., 2019), as well as comparable information-seeking (Xu et al., 2021) and choice behavior (Fang et al., 2021), and holistic means of capturing cognitive workload (Xi et al., 2022). Second, observing and monitoring subjects in such a scenario helps to test variables that are difficult to observe in physical environments (Schnack et al., 2020; Wang et al., 2021). Third, recent developments in VR complement the use of neurophysiological tools (e.g., EEG) in examining accurate measures of brain responses when shopping, allowing for better experimental control of variables and, thereby, better internal validity (Wajid et al., 2021; Wedel et al., 2020).

Understanding the reasons behind consumers' unplanned buying is fundamental to outlining theoretical implications and managerial insights for businesses. Thus, we aim to contribute to the existing literature, first by integrating dispersed elements of unplanned buying that pivot on consumer traits (e.g., impulsivity), store experience (e.g., desire to stay and flow experience), and available consumption resources (e.g., budget and time) in unplanned purchases. Next, we measure implicit brain responses (e.g., cognitive workload) via EEG, so this study expands on the current knowledge of the internal mechanisms that differentiate between planned and unplanned buying at a neural level. Finally, we consider the influence of VR characteristics (i.e., sense of presence) and psychological mechanisms (e.g., impulsivity and flow experience) on

planned and unplanned shopping behavior in a stimulus-organism-response (SOR) framework. Such an integrative approach will lead to a better understanding of the dimensions that influence unplanned buying and contribute to the development of virtual commerce as a distribution channel. Finally, this study addresses the call for further research that Hilken et al. (2022) and Dwivedi, Hughes, Wang et al. (2022) outline, to investigate consumer behavior vis-à-vis VR marketplaces. From a managerial point of view, marketers can benefit from this approach by identifying information signals (i.e., behavioral cues at the store) that produce insights about unplanned purchases at the point of sale, which may ultimately lead to better assortment configuration and product disposition.

The remainder of the article will unpack the following topics. Section 2 outlines the prior research on impulsive, planned, and unplanned shopping behavior. In addition, the section discusses cognitive load during shopping and introduces the SOR framework. Section 3 provides theoretical support for the hypotheses. Section 4 details the study methodology and provides a sample profile. Section 5 reports the data analysis results of the experiment. Section 6 discusses theoretical and practical implications, limitations of the study, and the scope of future research. We conclude the study with key takeaways in Section 7.

2. Literature review

2.1. Impulsive, planned, and unplanned shopping behavior

In the past, researchers have distinguished between impulsive, planned, and unplanned purchases. This distinction between planned and unplanned purchases has been studied in a retail context (Abratt & Goodey, 1990). Planned purchases are those for which consumers deliberate and make a list of products they want, prior to reaching the point of purchase, whereas in unplanned purchases occur when consumers stroll past the point of purchase and recognize that they need or desire the product they see. Piron (1993) studied variations in shoppers' emotional reactions to unplanned, planned, and impulsive shopping. Compared to planned shoppers, impulsive shoppers experienced a greater desire to purchase and a greater feeling of helplessness, whereas unplanned shoppers felt significant differences in desire to purchase, but also feelings of guilt (Piron, 1993). Verplanken and Sato (2011) reason that "purchases may be unplanned but not impulsive, such as habitual purchases, purchases that unexpectedly solve an existing problem, or purchases that are simply too unimportant to plan or think about." Therefore, unplanned purchasing is not a necessary condition of impulsive buying (Rook & Hoch, 1985). According to regulatory focus theory, promotion-oriented consumers engage in more unplanned buying; prevention-oriented consumers avoid impulse purchases (Kato & Hoshino, 2021). Shoppers engage in unplanned buying when they see the product and recognize the need for it (Bellini et al., 2017), whereas impulse purchases occur with no established need for it (Amos et al., 2014). Factors that drive unplanned buying behavior include the overall shopping-trip goal, store-specific goals, promotions, time spent shopping, and convenience (Bell et al., 2011). As a result, unplanned purchase behavior is triggered at subconscious level (Ozkara & Bagozzi, 2021; Saffari et al., 2023).

2.2. Cognitive load during shopping

Examining the role of cognitive load on consumers is critical for information science and management research (Eberhard, 2021). It is a multidimensional construct that reflects the cost (i.e., mental, physical, temporal demand) that the focal task imposes on working memory (Hart, 2016; Sweller, 2011). Individuals have only limited workload capacity to expend. With an increase in task complexity, performance can suffer if it exceeds the individual's workload capacity (Xi et al., 2022). Concurrently, excessive or complex information can overwhelm individuals and lead to information overload, especially in the case of

sensory information (Malhotra, 1984; Malhotra et al., 1982). Presumably, different situations and tasks require varied working-memory resources and can be intrinsic or extraneous in a shopping context (Schmutz et al., 2009). According to Plass and Kalyuga (2019), if search processes are not at least minimally guided or explicit instructions are not provided during the task, a significant effect on working-memory load occurs, hindering meaningful (or optimal) learning. Borrowing perspectives from cognitive load and information overload theories, exerting greater mental efforts will yield a suboptimal shopping experience, leading to less time spent in the environment, dissatisfaction with the product or service, shopping cart abandonment (Mirhoseini et al., 2021; Schmutz et al., 2009), social media fatigue (Guo et al., 2020), affecting working memory's usability during consumption, the "feature fatigue effect" (Thompson et al., 2005). Huang (2000) identifies complexity and novelty as two dimensions of information overload applicable to online shopping behavior. While information complexity reduces consumer desire to visit a shopping site, information novelty increases customer intent to visit it (Huang, 2000). Additional

consequences include risk-averse behavior and impatience with money (Deck & Jahedi, 2015), decision quality (Zhang et al., 2018), and decision difficulty (Hu & Krishen, 2019). Consumers exploring the VR version of a physical shopping environment with which they are familiar are likely to experience low cognitive load and positive impacts on their attitude toward shopping in VR (Luna-Nevarez & McGovern, 2021). While studies on cognitive load have relied more on subjective self-reports than using objective physiological techniques (Krell et al., 2022), EEG is a direct and valid method for capturing cognitive load, unhindered by the individual's biases resulting from cognitive limitations or preferences (Schapkin et al., 2020). Using EEG, cognitive load can be predicted by analyzing the change in relationship between power spectrums (Antonenko et al., 2010; Schapkin et al., 2020). Prior studies in marketing (see Table 1) have utilized neurophysiological tools (i.e., EEG) to measure cognitive load, while others have estimated cognitive load via EEG in VR (Tremmel et al., 2019) and multimedia learning environments (Murtazina & Avdeenko, 2020).

Table 1

Summary of prior empirical works using cognitive load and information load theories in consumer research.

Study	Objective	Use of immersive technology / Context.	Implicit measures to record cognitive load.	Design (*)	Theoretical (or framework) support	Key findings
Lee and Sergueeva (2017) ~ Study 3	To examine the association between chewing gum and consumer thought-engagement.	No. Airport retail elements.	No. Questionnaire.	BS	Chewing effect; Cognitive load theory	When cognitive load is high, the chewing effect is mitigated.
Zhang et al. (2018)	To analyze the relationship between quality (enablers and inhibitors) of online product recommendations and online product brokering efficiency and loyalty.	No. E-commerce shopping.	No. Questionnaire.	WS	Information overload theory; Cognitive load theory	Information overload was found to be positively associated with product screening cost and product evaluation cost, and negatively associated with decision-making quality.
Huang and Zhou (2019)	To investigate impact of personalized product recommendations on consumer decision quality.	No. Online shopping.	No. Questionnaire.	BS	Information overload theory	Personalized product recommendations can reduce information load effect on (perceived) information overload.
Aydınoğlu and Krishna (2019) ~ Study 4	To analyze the impact of verbal communication of retail store deals on consumer's consumption imagery.	No. Retail-store deals.	No. Questionnaire.	BS	Imagery theory	Cognitive load disrupts consumption imagery effectiveness of retail store deals.
Fan et al. (2020)	To analyze the influence of AR adoption in online retail on consumer product attitudes.	Yes. Augmented reality. Product category.	No. Questionnaire.	BS	Cognitive load theory; cognitive theory of multimedia learning; Situated cognition theory; and cognitive fluency theory	Cognitive load is lowered by environmental embedding and simulated physical control.
Mirhoseini et al. (2021)	To investigate the influence of product type and arithmetic task complexity on consumer's perceived satisfaction and mental effort.	No. Online grocery.	No. Questionnaire.	WS	Cognitive absorption theory	Experience product types exert higher perceived mental effort than search products, and arithmetic complexity is positively associated with perceived mental effort.
Bigne et al. (2021)~ Study 1	To examine online advertising effectiveness on social media.	No. Online advertisement.	Yes. EEG	WS	Cognitive load theory	Viewing user-generated content when the advertisement is embedded in social media did not increase the cognitive load.
Arghashi (2022)	To examine influence of AR attributes (positive and negative) on consumer purchase intention	Yes. Augmented reality.	No. Questionnaires.	BS	SOR framework; Information overload theory; Wow-effect	Contrasted with non-AR apps, AR apps lessen information overload, and information overload positively influences perceived distraction of the consumers.
Xi et al. (2022)	To examine the distinct effects of immersive technologies on workload.	Yes. Virtual reality and Augmented reality. Record shop.	No. Questionnaire.	BS	Cognitive load theory	VR had no significant effect on subdimensions of workload but AR significantly related to overall workload.
Kim (2022) ~ Study 4	To analyze the effect of cognitive load on product evaluations when primed.	No. Product evaluation	No. Questionnaire.	BS	Priming effect; Cognitive load theory	Inducing cognitive load can mitigate the effects of happiness primes on product evaluation.
This Study	To examine differences between cognitive load during planned and unplanned shopping.	Yes. Virtual reality. Supermarket.	Yes. EEG	WS	SOR framework; Cognitive load theory	Cognitive load was higher during planned purchases as compared to unplanned purchases.

(*) WS: within-subjects; BS: between-subjects

2.3. Applying the SOR framework in VR-based shopping

Previous research has utilized virtual environments to understand the influence of product types (e.g., food and beverage, wine, electronics), types of stores (e.g., supermarket, dressing room), and intrinsic and extrinsic cues (e.g., product attributes and in-store promotions) on shopper behavior in retail (Xi & Hamari, 2021; Xu et al., 2021). However, the use of the SOR framework in VR has been limited and scattered. Mehrabian and Russell (1974) introduced the seminal SOR framework, widely employed to examine consumer behavior in information science, virtual reality, neuroscience, and retailing contexts (Daisy et al., 2022; Suh & Prophet, 2018; Vieira, 2013; Xiong & Zuo, 2020). It comprises three interrelated components. The first, stimulus (S), is the consumers' shopping environment (i.e., a conventional physical store, an online store, or a fully immersive virtual store). These environments contain a range of cues acting as antecedents, affecting an individual's internal state (Jacoby, 2002). Environmental stimulus in a retail context includes a mix of store atmosphere, technical features, and situational cues (Buckley, 1991; Daisy et al., 2022). Previous studies in VR have used technological (e.g., visual display, movement tracking, interactivity) and content-based (e.g., virtual journey, gaming) stimuli to prompt psychological and behavioral responses (Suh & Prophet, 2018). In our study, we use sense of presence as a core aspect of stimulus components, for two interlinked reasons. First, it is considered to be the primary aim of virtual experiences that seek to engage users to interact and simulate in the environment (Grassini & Laumann, 2020). Second, it influences elements of an individual's internal processing of the VR shopping environment, such as flow experience, as well as organism's response, such as purchase intention (Shen et al., 2021, pp. 112311087). Taken together, sense of presence appears to be a critical variable for the VR shopping experience. Sense of presence refers to a feeling of "being there" in an artificial environment that can imitate certain qualities of reality, offering individuals a sense of being in a different place where they actually are (Grassini & Laumann, 2020; Scarfe & Glennerster, 2019).

The next element comprises the individual's internal state, including emotional and cognitive processing vis-à-vis the environmental stimuli, known as the organism (O) (Vieira, 2013). In a VR context, Kim et al. (2020) used cognitive and affective (enjoyment, emotional involvement, and flow state) responses; Jin et al. (2021) used arousal and pleasure; Chen et al. (2022) used telepresence, perceived diagnosticity, and playfulness as organism components. In our framework, we use consumers' impulsiveness and flow experience as elements of organism components. Consumer's impulsive behavior involves the complex interplay of personal and in-store factors (Redine et al., 2023), making it critical for investigation during a virtual shopping scenario (Suh & Prophet, 2018). Previous studies in VR have examined the role of the impulsivity trait in the urge to buy impulsively (Chen et al., 2022) and of shopper personality traits in impulse purchases (Schnack et al., 2021). However, research has scarcely pursued associating consumers' impulsiveness and unplanned purchases in a VR context. With this perspective, our framework allows validating the role of impulsivity during virtual shopping, extending previous research by Schnack et al. (2020) and Vrechopoulos et al. (2010). Next, a VR shopping experience elicits a flow experience (Cowan & Ketron, 2019), immersing a person in the

activity in which they are participating (Nakamura & Csikszentmihalyi, 2009), intrinsically an enjoyable state (Hoffman & Novak, 1996) with a positive relationship with behavioral intention to use VR technology for shopping (Han et al., 2020). To analyze the organism component of the SOR framework and consequently optimize the customer experience requires examining the consumer flow experience in a VR environment and its subsequent influence on behavioral intentions (Kim et al., 2020). VR environments provide greater perceptual and cognitive benefits compared to real environments (Xi et al., 2022) and promote a sustainable method of shopping (Laukkanen et al., 2022). In this regard, sense of presence and flow experience emerge as two critical factors associated with technological and psychological mechanisms that explore consumer behavior when engaging with immersive technology (Suh & Prophet, 2018; Wedel et al., 2020).

The third element is the individual's response (R) to the combination of stimulus and organism components (Vieira, 2013). VR studies have used store attractiveness (Jin et al., 2021), urge to buy (Chen et al., 2022), and behavioral intentions (Loureiro et al., 2021) as response elements in a retail context. The SOR framework has served mainly to produce behavioral and observational outcomes in VR, such as shopping time and amount spent (Schnack et al., 2021), but unconscious outcomes have rarely been used as response measures. While the VR environment is suitable for directly capturing consumers' experience, studies have rarely evaluated consumers' desire to stay in a virtual store in conjunction with explicit and implicit shopping outcomes. Data obtained from EEG provide objective interpretations of consumers' subjective evaluation of multisensory stimuli (Bazzani et al., 2020). In this regard, using EEG-derived cognitive load as a proxy for the shopping experience provides novel implicit measures by which to expand the SOR framework. Given these gaps, our conceptual framework (Fig. 1) uses sense of presence in the virtual store as stimulus, consumers' dispositional trait of impulsivity and their flow experience as organism, and implicit (cognitive load during planned and unplanned shopping) and explicit (unplanned shopping expense, number of unplanned purchases, time spent in purchasing planned and unplanned products, budget deviation, basket-size deviation, desire to stay, and store satisfaction) metrics as response in the shopping journey.

3. Theoretical background and hypotheses development

3.1. Consumer impulse buying during shopping

Consumers' impulsiveness is often described as their disposition to purchase on an urge, with little reflection. Rook and Hoch (1985) identified five elements of impulsive behavior to distinguish it from non-impulsive behavior: (1) sudden desire to act, (2) urge to buy, (3) possible psychological conflict, (4) reduced cognitive evaluation of product attributes, and (5) no consideration of the consequences. Consumers' impulse buying can qualify as a complex mixture of their conative, visceral, and cognitive factors (see Mandolfo & Lamberti, 2021). Previous literature has also identified the factors that influence impulse buying behavior, including individual characteristics, demographics, and personality traits; economic resources, such as available budget (Iyer et al., 2020); product category variables; situational factors of the store; and marketing-driven actions (Bellini et al., 2017;
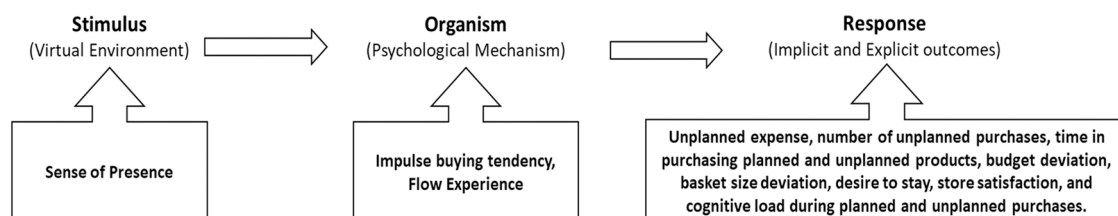

Fig. 1. Conceptual framework.

Iyer et al., 2020). Previous studies have shown an association between the consumer's impulsivity and unplanned purchase behavior (Streicher et al., 2021). The urge to buy impulsively often leads to a consumer's unplanned purchases during shopping (Bellini et al., 2017). In their work, Paul et al. (2022) highlighted significant antecedents to the urge to buy, including perceived enjoyment, perceived usefulness, hedonic and utilitarian values, positive and negative affect, scarcity, and impulsive buying tendency. In the context of virtual-reality-based shopping, previous studies have found that telepresence, perceived diagnosticity, and playfulness positively influence an urge to buy impulsively (Chen et al., 2022). Consequently, higher impulsivity leads to more unplanned purchases (Santini et al., 2019) and sometimes unplanned purchases act as an indicator for quantifying consumers' impulse buying (Mandolfo & Lamberti, 2021). While the association between consumers' impulsive and unplanned behavior has scarcely been studied in a virtual commerce context, we posit that consumers will reflect purchase patterns analogous to e-commerce (Chan et al., 2017) and physical store environments (Amos et al., 2014), as follows:

H1 . Consumers' impulsivity positively influences their (a) number of unplanned product purchases and (b) unplanned purchase expenses.

3.2. Cognitive load during planned and unplanned purchases

Planned purchases are the result of a previously recognized problem or a buying intention formed prior to entering the store (Piron, 1993). During a planned-purchase scenario, consumers carry shopping lists that act as a physical cue for products and brands they desire to purchase (Suher et al., 2019). Unplanned purchases occur due to the lack of a purchase decision before the shopping trip. This means that during a shopping trip, consideration of unplanned purchases tends to occur later than planned purchases (Hui, Huang et al., 2013). Unplanned purchases are of high economic value (i.e., revenue) and are also the flagship for retailers in managing the store products portfolio. Previous studies have concurred that information load during shopping is inextricably linked to the length of time spent (Jacoby et al., 1976). Additionally, from a subconscious perspective, goal-directed (top-down attention) vs. stimulus-driven (bottom-up attention) behavior interacts with cognitive load and temporal boundaries during decision-making (Orquin & Mueller Loose, 2013), and previous research has shown that shopper's use of shopping lists is a goal-directed behavior (Ahmed & Ting, 2018). From our study's perspective, goal- vs. stimulus-oriented behavior can be analogous to *predefined* planned vs. *non-specific* unplanned shopping tasks (Bialkova et al., 2020; Huddleston et al., 2018). In contrast to unplanned purchases, where consumers do not have predetermined specific subgoals, consumers undertaking planned purchases have multiple smaller goals that they achieve by adding items present on the shopping list to the basket (Suher et al., 2019). Consumers with a higher-level motivation to fulfill their goal pursuits (i.e., products on the shopping list) are faster at finishing their in-store shopping (Suher et al., 2019). Both perspectives affirm that cognitive load during unplanned and planned purchasing will be significantly associated with the time spent in each phase. Therefore, our hypothesis is as follows:

H2a. Cognitive load during planned and unplanned purchase phases will positively influence the duration of time spent in planned and unplanned purchases, respectively.

Because the amount of time available for shopping regulates shoppers' information processing of items and related in-store cues (Bettman, 1979), we anticipate that once planned purchases are completed, consumers may experience less cognitive load when shopping for unplanned items. Previous research has shown that individual involved in a task with high motivation can temporarily increase cognitive load (Mutlu-Bayraktar et al., 2019), such as for a goal-oriented planned task. Saffari et al. (2023) found a significant association between higher cognitive load and a low frontal asymmetry score during planned decisions,

whereas a higher frontal asymmetry score and lower cognitive load occur during unplanned decisions. We posit that cognitive load during unplanned purchases will vary from that during planned purchases, due to the lack of goal specificity (Sweller, 2011). Consequently, our hypothesis is as follows:

H2b. Cognitive load during unplanned purchases will significantly differ from that during planned purchases.

3.3. Presence and flow experience as aspects of VR shopping

Sense of presence is an innate part of the virtual experience and serves as a quality assessment of the virtual shopping experience (Alcañiz et al., 2019; Xi & Hamari, 2021). Immersion, engagement, and sensory fidelity are chief determinants of presence, whereas emotional responses and behavioral intentions are consequences of presence in virtual experiences (Yung et al., 2021). Pizzi et al. (2020) reported that compared to traditional store environments, subjects perceived a stronger sense of presence in VR retail environments, but the effect was not dependent on the technological self-efficacy of the individual subjects. Additionally, individuals in virtual environments report greater feelings of immersion and perceived naturalness compared to a desktop shopping experience, leading to enhanced telepresence (Schnack et al., 2019). We expect that due to the immersive nature of VR enhancing the psychological feeling of engagement with the environment (Wang et al., 2021) and the amount of involvement a task in a virtual environment requires (Witmer & Singer, 1998), shoppers will desire to stay longer in the virtual environment.

Previous research has shown flow experience as a critical diagnostic cue in virtual experience because it significantly elevates satisfaction from VR spectatorship (Kim & Ko, 2019). Flow experience is described as a holistic sensation from which an individual feels absorbed, with complete involvement in an activity (Csikszentmihalyi & LeFevre, 1989). Accordingly, when immersed in VR, the user exhibits concentration on the task, with a feeling of positive gratification (Suh & Prophet, 2018). Furthermore, flow experience is a crucial mediator for consumers' continued intent to utilize an information system (Dincelli & Yayla, 2022; Yan et al., 2021). Antecedents to flow experience include easiness, usefulness, and enjoyment, which consequentially influence subjective well-being and the continued intention to use VR technology (Kim & Hall, 2019). Flow experience is positively associated with exploratory shopping behavior and positive affect (Novak et al., 2000), purchase intention and loyalty to an online supermarket (Morales-Solana et al., 2021), psychological ownership (Yuan et al., 2021), and consumer enjoyment of a retail store (Wang & Hsiao, 2012) during shopping activities. We believe that will positively influence consumers' desire to stay longer in the virtual shopping environment. Presence and flow experience are distinct but interconnected constructs involving immersion, such that the presence has been showcased as an antecedent to flow experience (Bachen et al., 2016). We argue that flow experience will mediate the association between sense of presence and the desire to stay to shop in a virtual environment (Fig. 2). Therefore, we state our hypothesis as follows:

H3 . Flow experience will mediate the relationship between sense of presence and the desire to stay in the virtual shopping environment.
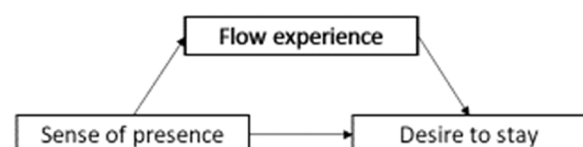

Fig. 2. Proposed mediating effect of the flow experience.

3.4. Influence of consumers' desire to stay and the impact of time on shopping behavior

We examine desire to stay as a response variable and a component of consumers' approach behavior, linked with behavioral intentions (Wakefield & Baker, 1998). From the perspective of SOR theory, consumers' affective responses in traditional retail stores influence approach behavior, which, in turn, might strongly influence unplanned shopping behavior (Donovan et al., 1994). Previous studies have examined the influence of time spent on a shopping trip on consumers' budget deviations, which is defined as the amount spent from the total budget during a shopping trip (Stilley et al., 2010). Due to depletion of the self-regulatory process during in-store shopping, consumers can have less inclination to stay within a predetermined budget as the length of the shopping trip increases (Stilley et al., 2010). We define basket-size deviation as the quantity of unplanned products in excess of planned product purchases during a shopping trip (i.e., basket-size deviation = total products bought – planned products bought). .

In the online retail context, Kim et al. (2007) found that a high level of image interactive technology (i.e., 3D virtual model) positively influenced the desire to stay on the retail website, which, in turn, strongly influences patronage intentions. Satisfaction is a central concept in retailing literature, and is described as a multidimensional experience influenced by the quality of the store and the merchandise available (Oliver, 2014). From roots in expectancy disconfirmation theory, Bloemer and de Ruyter (1998) conceptualized store satisfaction as the "outcome of the subjective evaluation that the chosen alternative (the store) meets or exceeds expectations." Using the SOR framework, Elmashhara and Soares (2022) linked consumers' desire to stay with shopper satisfaction in a retail atmosphere. Therefore, we hypothesize the following:

H4. . Consumers' desire to stay in a virtual store will positively influence (a) budget deviation, b) basket-size deviation, and (c) satisfaction with the store.

Availability of time is a critical factor that affects unplanned shopping behavior and sales in a retail context (Davydenko & Peetz, 2020). Time considerations can result in negative effects, such as failure to purchase intended products, brand switching, and purchase-volume deliberations (Park et al., 1989), and positive effects such as in-store explorations of different product categories (Hui et al., 2009), accelerated information acquisition (Pieters & Warlop, 1999), and brand choice (Bigné et al., 2016). Under limited time constraints, shoppers can only process limited information available to them (Bettman, 1979), and thus, they rely on internal memory more than externally available cues (Park et al., 1989). Alternatively, shoppers encouraged to choose products without time constraints can explore more aisles (Granbois, 1968), which incentivizes unplanned buying (Bell et al., 2011). Therefore, we concur that the quantity of unplanned items bought positively correlates with the duration of time spent during an unplanned shopping phase without time pressure or constraints. Therefore, we hypothesize the following:
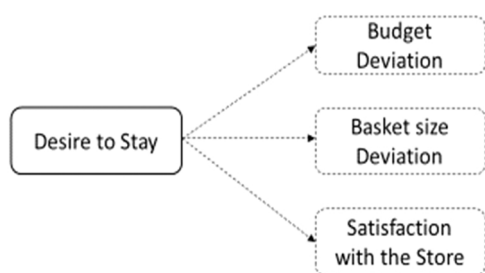

Fig. 3. Schematic representation of the effect of desire to stay on budget deviation, basket size deviation, and satisfaction with the virtual retail store.

H5. : The length of time spent during unplanned shopping is positively associated with the number of unplanned products bought.

4. Methodology

4.1. Research design and study context

In a typical shopping trip, consumers purchase a mixture of planned and unplanned items. Therefore, this study found within-subject design to be suitable for exposing all participants to the same shopping scenario, i.e., planned and unplanned shopping phases. Within-subject designs provide repeated measures per participant; therefore, researchers commonly use them for capturing consumers' brain activity continuously during decision-making, using EEG (Ozkara & Bagozzi, 2021; Saffari et al., 2023). Furthermore, compared to between-subject designs that require a larger sample size for adequate statistical power and are sensitive to interindividual differences, within-subject designs provide greater statistical power and increase the probability of capturing true differences between experimental conditions (Viglia et al., 2021; Viglia & Dolnicar, 2020). Given the focus of our study—i.e., to examine the differences between (sub)conscious planned and unplanned shopping measures—a within-subject design is preferable to a between-subjects design.

4.1.1. Conceptualization and implementation of VR shopping experience

We focused on consumer shopping behavior in a virtual supermarket. For this, a three-dimensional VR supermarket (see Appendix A.1) consisting of more than 20 product categories was developed using UnrealEngine software V4.1 (Epic Games, United States) and run on a Windows 10 desktop using Steam (Valve Corporation, United States). We used the HTC Vive 5 (HTC Corporation) HMD, and two hand controllers for interaction and instant teleporting (see Appendix A.2) as the indirect walking technique (Prithul et al., 2021). Layout of the supermarket, appearance of virtual items, and their digital prices closely resembled local Danish supermarkets. Like physical stores, participants could stand facing the shelves and reach out to specific products by extending their arms or bending down to retrieve items placed on upper and lower shelves. The items listed on the planned list were strategically placed, to force the participants to move around the entire store. To complete the shopping trip, participants had to step on the indicated red circle (see Appendix A.4), at which point the duration of the shopping trip stopped recording. Participants received basic training before the beginning of the main experiment. An example of participant shopping in a virtual retail store can be seen here: *https://imgur.com/a/f1tcZGr*.

4.1.2. Experimental routine

Participants were informed that they had to purchase a prescribed list of products before purchasing other products they desired, with a budget of 260 Danish kroner (approx. 35 euros). Planned product expenses were roughly one-third of the overall budget provided to the participant. This order of purchase sequence mimics natural shopping behavior (Hui, Huang et al., 2013). The experimental routine was divided into three phases, as Fig. 4 shows. In the first phase, the participants signed the consent form clarifying the purpose of the study and approving the usage of their demographic data. They were then asked to complete an impulsivity questionnaire, after which an EEG cap was applied while they read the task instructions (Appendix B). A 30-second baseline (or resting state) EEG was recorded. In the second phase, participants were set up with an HMD and provided with basic training and familiarization with the environment before the start of the experiment, to mitigate the influence of having used VR on subsequent tasks. The researchers emphasized to the participants that they should behave as though they were spending their own money. The EEG instrumentation continuously recorded each participant's cognitive load throughout the entire shopping trip. To indicate the desired product for purchase, participants had to extend their arm toward the product until it turned
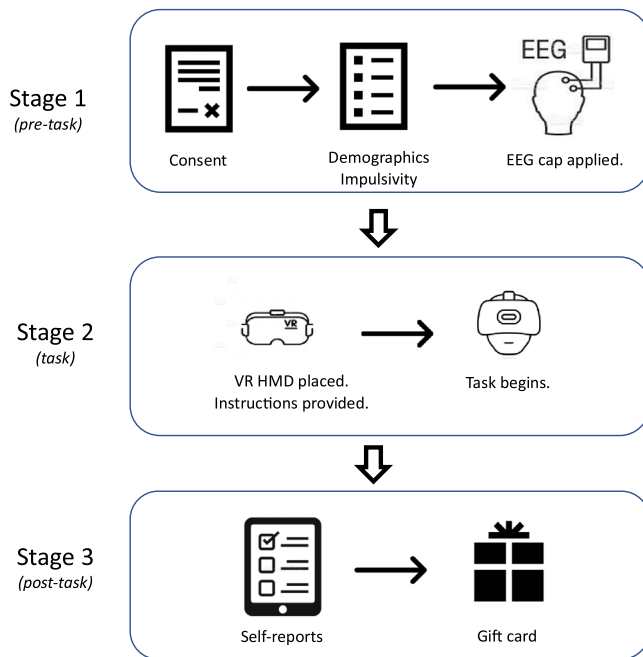
Fig. 4. Schematic representation of the three experimental phases.

green (see Appendix A.3)**.** Meanwhile, the researchers manually entered the indicated product as purchased and the virtual amount left for shopping. In the third phase, participants filled out a self-report survey, before they received a gift voucher for 250 Danish kroner (approx. 35 euros) via email, as compensation.

4.2. Measurement of variables

Response measurements were obtained from three complementary data sources. The first consisted of self-report measures (see Appendix C) that included a 9-item impulsiveness scale from Rook and Fisher (1995), a 3-item flow experience scale adapted from Kim et al. (2020), a 2-item desire to stay scale from Elmashhara and Soares (2022), a 1-item store satisfaction scale adapted from Pizzi et al. (2019), an 11-item sense of presence scale from van Herpen et al. (2016), and demographic details for each participant. The second source of data comprised common observational measures derived from the virtual shopping trip, used to capture shopping behavior (Schnack et al., 2020). These included overall time spent, time spent during planned purchases and unplanned purchases, respectively, overall expense, unplanned purchase expense, and number of unplanned purchases. The third source of data was derived from electrophysiological recording (EEG), which measures brainwave activity and has been recognized as a reliable tool for obtaining insights into the underlying unconscious mechanisms of consumer decision-making during shopping (Golnar-Nik et al., 2019; Lin et al., 2018). We captured cognitive workload for both planned and unplanned purchases by placing electrodes on the scalp. We adapted a reference for simultaneous development of explicit and implicit data collection from Wang et al. (2021).

4.2.1. Cognitive load via EEG

The EEG signals were continuously recorded from the scalp using the portable 32-channel wireless Brain products LiveAmp (Brain Products©) device with standard 10–20 electrode placement. The online reference is located at prefrontal (Fpz site), and we used common average referencing for the offline analysis. Further technical details appear in Appendix D. The initial phase in the analysis of EEG signals is the pre-processing stage, wherein the acquired signals are cleaned in order to remove artifacts before transforming time series into the frequency

domain for spectral analysis (Lin et al., 2018). For this, we used a Python library called MNE (version 0.23.1). The EEG signals were filtered with a bandpass of.1–100 Hz and a sampling rate of 500 Hz. Meanwhile, we used event-related desynchronization and synchronization (ERD/ERS index) (Murtazina & Avdeenko, 2020) with frontal and parietal locations, to assess cognitive load during planned and unplanned purchase phases. This popular method calculates the percentage change in frequency band power during tasks relative to the baseline state (Antonenko et al., 2010). The number of trials for the planned phase was the same for each participant (M= 6) but differed for unplanned purchases (M= 5.8, SD= 2.9). Participants who did not purchase (n = 3) in unplanned conditions were removed from the EEG analysis.

4.3. Data gathering and sample profile

From November to December 2021, we recruited 32 participants (M_{age}= 31.5 years, S.D. = 6.5) through advertising on social media and convenience sampling techniques. Convenience sampling allowed us to recruit healthy participants with no clinical neuropsychological preconditions for recording EEG, in addition to a balanced gender ratio and representation of students to non-students in our study. Forty-seven percent of participants were employed, 53% were male, 44% were students, 75% had a university degree, and 91% visited the supermarket frequently. Participants with no previous VR shopping experience represented 72% of the sample. A recent systematic review of the usability of EEG in marketing research reported that previous studies have used an average sample size in the range of 16–42 (Bazzani et al., 2020, pp. 10–11). Moreover, recent studies using VR to capture shopper behavior have used sample sizes similar to this study's, such as Zhao et al. (2017) (n = 24, within-subject design), and Schnack et al. (2020) (study 2, n = 46, between-subject design). Moreover, using regular shoppers as participants improves the experiment's external validity (Xi & Hamari, 2021). Additionally, the use of VR reduces non-representative sampling bias (Cowan & Ketron, 2019) and hypothetical bias (Fang et al., 2021), providing a realistic decision-making context for capturing cognitive workload during shopping (Xi et al., 2022).

5. Results

All shopper-related measures indicated acceptable reliability scores (Table 2). Cronbach's alpha (α) is a measure of reliability of a scale, evaluated using the mean of bivariate correlations between the items, with adjustment for the number of items, to determine if the items assess the same construct (Cronbach, 1951). It ranges from 0 to 1, and values greater than 0.7 are considered satisfactory (Mazzocchi, 2011, p. 10). The score for one participant was omitted for sense of presence and store satisfaction, due to a technical error. Out of 32 participants, 3 did not make any unplanned purchases, finishing the shopping trip after only purchasing the items on the list.

Descriptive analysis of time spent and expenses incurred during planned and unplanned phases, across gender and previous shopping experience, appear in Fig. 5a and 5b. Average length of time spent shopping was 501.5 s, the average amount spent was 207.03 Danish kroner (approx. 27.8 euros), the number of unplanned items bought outside the planned list averaged six per individual, and the average

Table 2
Reliability and descriptive analysis of scales used in the study.

Scales	# Items	α	N	Mean	S.D
Impulsiveness (Rook & Fisher, 1995)	9	.74	32	3.36	0.7
Flow experience (Kim et al., 2020)	3	.77	32	4.66	1.1
Desire to stay (Elmashhara & Soares, 2022)	2	.80	32	4.50	1.4
Sense of presence (van Herpen et al., 2016)	11	.80	31	5.04	0.8
Store satisfaction (Pizzi et al., 2019)	1	-	31	2.65	0.9
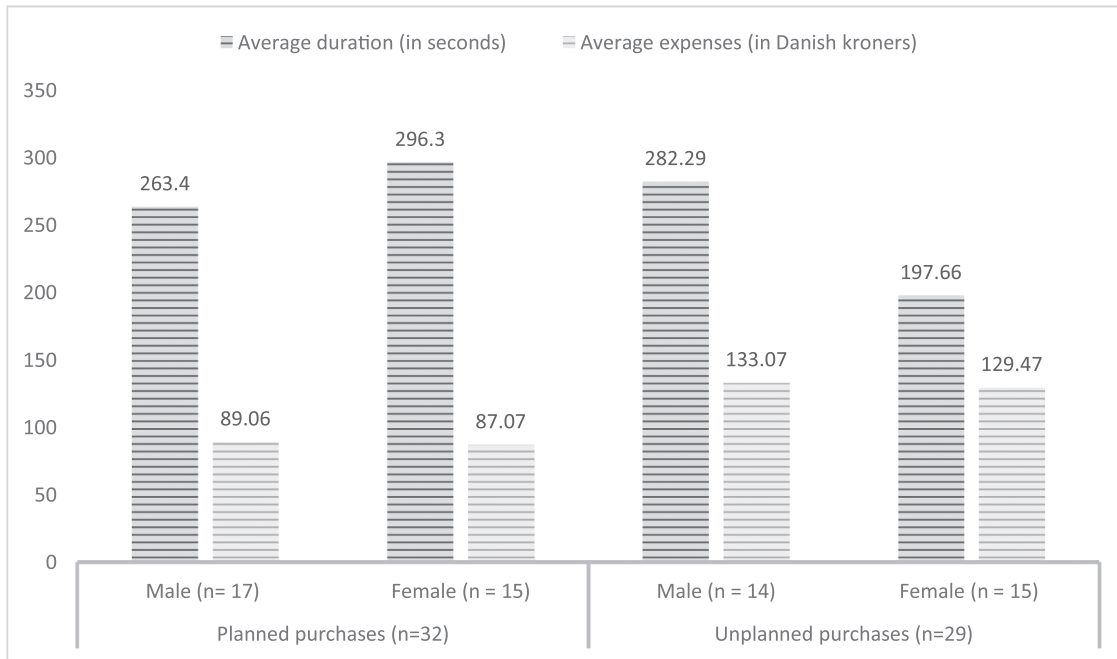
(a)
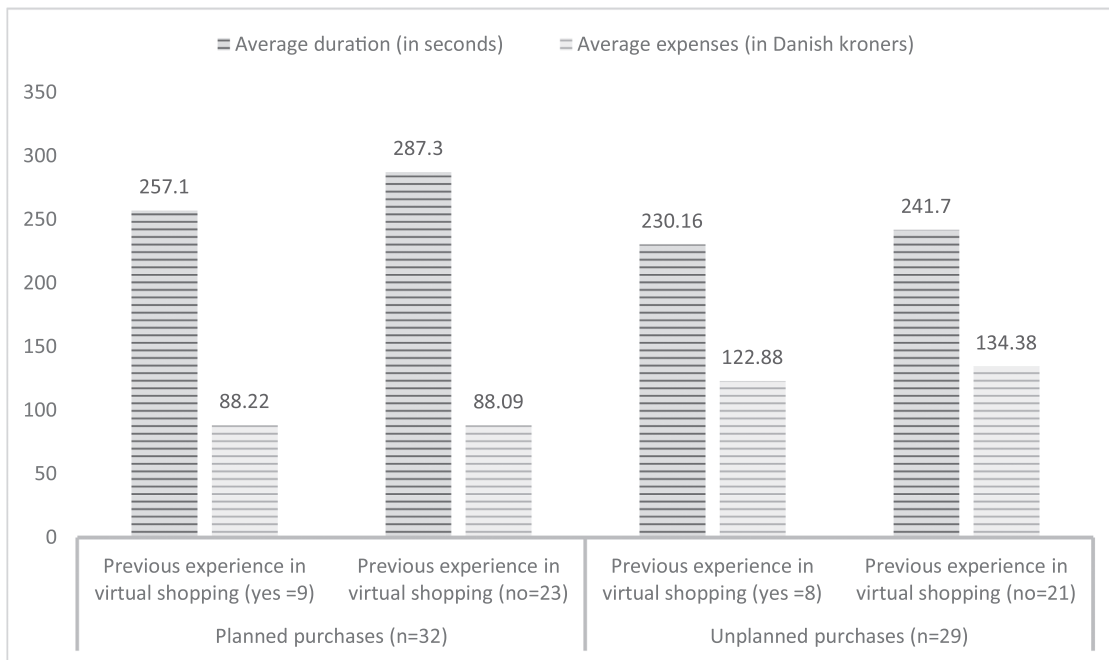
(b)

Fig. 5. a. Differences in average time spent and expenses during planned and unplanned phases across genders. **b.** Differences in average time spent and expenses during planned and unplanned phases, based on previous virtual shopping experience.

time spent purchasing planned and unplanned items were 37.12 and 38.9 s, respectively. There were no significant gender differences in overall time spent ($t(30) = 1.943$, $p=.061$) and overall expenses ($t(30) = .384$, $p=.704$). Furthermore, impulsiveness scores did not vary significantly across genders ($t(30) = .972$, $p= 0.339$). Finally, previous virtual shopping experience had no significant impact on overall time spent ($t(30) = .469$, $p=.643$) and overall expenses ($t(30) = .580$, $p = .566$).

Table 3 provides a summary of hypotheses tested using linear regression, a common predictive analytical technique to evaluate a bivariate relationship between the continuous predictor (independent) variable and continuous outcome (dependent) variable (Mazzocchi, 2011, p. 179). Results of linear regression analysis showed that impulsivity scores significantly predicted the number of unplanned purchases ($F (1, 30) = 7.446$, $p=.011$, $R^2 = .199$) and unplanned purchase expenses ($F (1, 30) = 5.191$, $p=.030$, $R^2 = .148$). Thus, H1$_{a,b}$ is supported. This result shows that consumer impulsiveness explains 19.9% of unplanned purchases and 14.8% of unplanned expenses. Previous studies have documented similar inferences, positively associating higher impulsivity with unplanned spending behavior in retail (Hui et al.,

Table 3
Summary of hypothesis testing using linear regression. (* $p < .05$).

	Predictor	Outcome	R^2	F-statistic	p-value
H1	Impulsivity score	a. Number of unplanned purchases	.199	$F(1,30) = 7.449$	$p = .011$ *
		b. Unplanned purchases expense	.148	$F(1,30) = 5.191$	$p = .030$ *
H2a	Cognitive Load (planned shopping)	Duration of time spent during planned purchases	.192	$F(1,27) = 6.409$	$p = .06$
	Cognitive Load (unplanned shopping)	Duration of time spent during unplanned purchases	.262	$F(1,27) = 9.583$	$p = .03$ *
H4	Desire to stay	a. Budget deviation	.361	$F(1,30) = 16.915$	$P < .00$ *
		b. Basket-size deviation	.284	$F(1,30) = 11.898$	$p < .00$ *
		c. Satisfaction with the store	.086	$F(1,29) = 2.745$	$p = .01$ *
H5	Length of time spent	Number of unplanned purchases	.453	$F(1,30) = 24.8$	$p < .00$ *

2013). To examine H2, we used only 29 participants, as 3 participants did not purchase in the unplanned condition, effectively excluding them from statistical tests. Results of a 5000-sample bootstrapped regression indicated partial support for H2a, confirming the significant effect of cognitive load during unplanned purchases on time spent during unplanned purchases ($F(1,27) = 9.583$, $p=.031$, $R^2 = .262$), whereas only marginal effect was observed for the influence of cognitive load during planned purchases on time spent during planned purchases ($F(1,27) = 6.409$, $p=.062$, $R^2 = .192$). These findings exhibit that 26.2% and 19.2% of time spent during unplanned and planned purchase phases are due to cognitive load experienced during each phase of shopping. Bootstrapping is a resampling technique using replacement required for making robust statistical inferences when the data does not reliably showcase distributional assumptions of parametric models (Lavrakas, 2012, p. 65). A Wilcoxon Signed-Ranks test indicated statistically significant differences between cognitive load during planned purchases and unplanned purchases ($Z= 109$, $p<.019$), supporting H2b. The results showed differences in cognitive load during unplanned purchases ($Mdn = -24.24$) were lower than in planned purchases ($Mdn = -18.46$). We also ran a Wilcoxon Signed-Ranks test to examine differences between time spent during planned purchases ($Mdn = 257.43$ s) compared to unplanned purchases ($Mdn = 206.93$ s), and the results indicated significant differences ($Z=141$, $p<.021$). A Wilcoxon Signed Ranks test is a non-parametric hypothesis-testing technique (Nussbaum, 2014, p. 190), used when the test of normality and homogeneity of equal variance is not held, in the case of paired observations, i.e., data has been collected from the same set of participants across all conditions. As in our study, participants performed both planned and unplanned shopping tasks. Fig. 6A and B present topographic brain maps for planned and unplanned purchases obtained from parietal and central regions. Fig. 6C highlights the differences obtained for cognitive load in planned and unplanned conditions, indicating higher cognitive load values for planned purchases. Planned purchases demand an executional task that requires brain activation to accomplish it, whereas unplanned purchases

include an explorative search, and only at peak times is there a brain cognitive load activation when any item is attracting consumer attention.

Further, our study examined the mediating role of flow experience on the relationship between sense of presence and the desire to stay in the virtual store. To test H3, we used SPSS PROCESS model 4 (Igartua & Hayes, 2021). The results showed a significant indirect effect of sense of presence on the desire to stay (b = 0.376, t = 2.636). Further, the direct effect of sense of presence on desire to stay in the presence of flow experience was also found significant (b =.7008, $p < .01$). Thus, flow experience partially mediates the relationship between sense of presence and the desire to stay. Table 4 presents a summary of the mediational analysis. Our results corroborate previous results showing the effect of sense of presence on flow experience (Shen et al., 2021, pp. 112311087). This finding attests to previous research recognizing the role of studies that have attested to flow experience as a mediator (Daisy et al., 2022).

Consumers' desire to stay significantly predicted budget deviation (F $(1, 30) = 16.915$, $p<.000$, $R^2 = .361$), supporting H4a. We also found a significant effect of consumers' desire to stay on basket-size deviation (F $(1, 30) = 11.898$, $p=.002$, $R^2 = .284$), supporting H4b. Evidently, the more consumers desired to stay in the virtual environment for shopping, the more money was spent, and the more products were purchased. To examine H4c, we ran a 5000-sample bootstrap regression to examine the influence of desire to stay on store satisfaction and found a significant positive relationship between them (F $(1,29) = 2.745$, $p=.010$, R^2 $=.086$). These results show that consumers' desire to stay in a virtual shopping store can explain their budget deviation of 36.1%, basket-size deviation of 28.4%, and store satisfaction of 8.6%. The results also showed significant support for H5, revealing a positive effect between the time spent during the unplanned shopping phase and the number of unplanned items purchased (F $(1, 30) = 24.8$, $p<.001$, $R^2 = .453$). Of unplanned purchases, 45.3% were due to the effect of time spent in the unplanned phase. Consequently, the amount spent purchasing the unplanned products significantly correlated with the number of unplanned
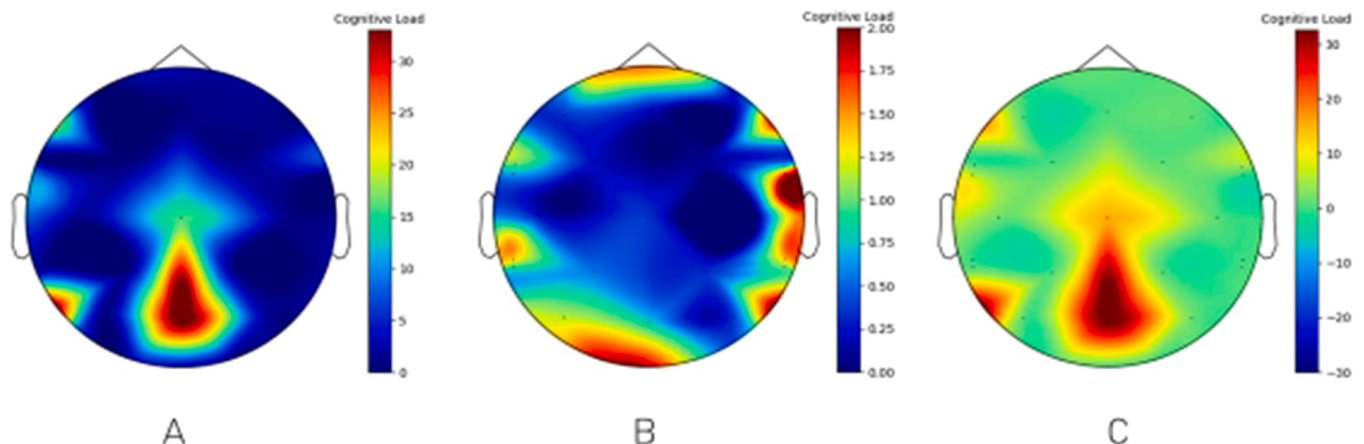

Fig. 6. Topographic scalp distributions for cognitive load during (A) planned purchases, (B) unplanned purchases, and (C) their differences.

Table 4
Mediation analysis.

Relationship	Total effect	Direct effect	Indirect effect	Confidence interval		t-statistics	Conclusion
				Lower bound	Upper bound		
Sense of presence -> Flow experience -> Desire to stay	1.077 (*p* < .00)	.7008 (*p*<.01)	.3765	.0636	.8744	2.636	Partial Mediation

items purchased (r(32) = .864, *p*<.001). The greater the time duration in the store after purchasing planned products, the greater was the expenditure in purchasing unplanned products.

6. Discussion

In this section, we outline the key findings that have emerged from our analysis, highlight theoretical and managerial implications, and recommend future research prospects by underscoring a number of this study's limitations. We conclude by summarizing three key takeaways, derived from our empirical study, for designers, retailers, and researchers.

Our results furthered the classical Stimulus-Organism-Response (SOR) framework (Mehrabian & Russell, 1974) by assessing the relationship between environmental and psychological factors that influence shopping behavior in a virtual retailing context. The study's virtual supermarket closely resembled local supermarkets; therefore, the findings of the study align with prior literature on shopper behavior and provide fresh insights for retailers. At the outset, our findings showed that consumer impulsiveness significantly impacts unplanned purchase behavior. This finding substantiates previous research that suggests comparing non-impulsive shoppers with shoppers who have a stronger disposition to buy on impulse, which results in more unplanned purchases and expense (Mandolfo & Lamberti, 2021). Such a comparison extends the previous literature on the influence of consumers' impulsive behavior in virtual shopping environments (Chen et al., 2022) and impulse buying on unplanned shopping (Chan et al., 2017). Prior studies on consumers' unplanned purchases in comparison with planned purchases explored the willingness to pay (Sohn & Ko, 2021), behavioral differences (using in-store video tracking) (Hui et al., 2013), purchase of new products (Kato & Hoshino, 2021), and effects of attentional breadth during in-store shopping (Streicher et al., 2021). Our study sought to examine neurophysiological correlations of consumer decision-making during planned and unplanned purchases. To differentiate between them, we used EEG measurements to capture cognitive load at the neural level. Cognitive load hampers individual task performance when information processing exceeds working memory capacity (Sweller, 2011). We found significant differences in cognitive workload between consumers purchasing products on the shopping list and those shopping outside the list. Interestingly, our results also reveal that the cognitive load that shoppers experience during each phase of shopping positively impacts the time they spend on it. This finding extends the previous consumer research (see Table 1) and information systems research (Brachten et al., 2020; Dincelli & Yayla, 2022) on the effect of cognitive load. Next, our study revealed flow experience as an organism component that partially mediated the relationship (see Table 4) between the stimulus component (i.e., sense of presence) and behavioral component (i.e., desire to stay). Fig. 1 highlights the sense of presence, an individual's sense of "being there" in an immersive environment, as a stimulus component of the framework. Pertinent to virtual environments (Grassini & Laumann, 2020; Skarbez et al., 2017), it is a critical metric that boosts consumer involvement with the shopping experience (Pizzi et al., 2020). While our study furthers the crucial role of the consumer flow experience during virtual shopping, our results align with previous studies measuring flow experience in immersive environments (Kautish & Khare, 2022) and establishing its positive association with behavioral outcomes, such as store-visit intention (Kim et al., 2022), satisfaction (Lee, 2020), and psychological ownership (Yuan

et al., 2021). Retailers should recognize the role of designers and developers of virtual environments in providing shoppers with high levels of presence, by exploring sensorial aspects as well as promoting their interaction with the products in the virtual shop, to heighten flow experience. Next, consumers' desire to stay in-store yielded significant budget deviation (i.e., the amount spent from the total budget during a shopping trip), basket-size deviation (i.e., total products bought, excluding planned products bought), and store satisfaction. Previous studies have shown that shopping atmospherics, enjoyment, and involvement positively enhanced consumers' desire to stay, which positively impacted consumer satisfaction, word-of-mouth, and patronage intentions (Elmashhara & Soares, 2022; Kim et al., 2007). Finally, the longer the time the shopper spent in the environment; the more unplanned purchasing occurred. Taken together, our study extracted three types of shopper data—i.e., observational metrics from virtual reality, self-reports, and neurophysiological measures—to triangulate consumer decision-making in a shopping context, useful for developing theories as well as retail strategies (Wang et al., 2021; Wedel et al., 2020). As part of the response component that has only received limited examination in virtual reality (VR) retailing, we included both implicit (i.e., cognitive load during planned and unplanned purchases) and explicit (i.e., unplanned shopping expense, number of unplanned purchases, time spent in purchasing planned and unplanned products, budget deviation, basket-size deviation, desire to stay, and store satisfaction) measures (Xi & Hamari, 2021).

6.1. Theoretical contributions

This research contributes to marketing and information systems literature in several ways. The study uses the SOR framework to highlight the interaction between technical aspects of the environment and consumers' (sub)conscious behavioral responses in a retail environment. First, we extend the framework to validate the role of impulse buying and unplanned purchases in a virtual-reality-based shopping context, previously limited to online impulse buying research (Chan et al., 2017). Our study showed a significant association between impulse buying and unplanned purchases. This finding may not come as a surprise since previous studies have established the same relationship (Mandolfo & Lamberti, 2021). However, noting that the replication of impulsive behavior extends its influence to virtual retailing as well is interesting. This finding corroborates that of Chen et al. (2022), wherein consumers' impulsivity trait affects their urge to buy impulsively during virtual shopping. Next, we further broadened the SOR framework to incorporate the role of consumers' cognitive load in making planned and unplanned purchases, highlighting the aspects of information processing in the virtual shopping context. In our study, we recorded cognitive load using EEG and found it at a higher level for planned purchases than for unplanned purchases. As such, this finding is significant for two reasons. First, it further substantiates the differences between goal-oriented (planned) shopping behavior, which, at times, requires greater mental effort to process the stimulus than stimulus-driven (unplanned) shopping behavior (Orquin & Mueller Loose, 2013). Second, earlier research indicated that shoppers who have shopping lists spend relatively less time and money and purchase fewer products than shoppers without the list (Davydenko & Peetz, 2020). Our results imply that consumers exert a relatively smaller amount of mental effort when shopping without a list than with a list, increasing their inclination to spend more money and acquire more items. Next, the study extends the research on the positive

impacts of flow experience in an immersive shopping environment. As a positively affective psychological state, flow experience prompts the individual to exhibit curiosity and heightened focus on the task and; at times, a lack of awareness of self and physical surroundings complements that state (Suh & Prophet, 2018). It emerged as an important mediator between the sense of presence the virtual system creates and consumers' desire to spend more time shopping in the environment. Consequently, it led to greater virtual consumption, such as budget and basket-size deviations indicate. Therefore, as shoppers feel it, flow experience is an appropriate addition to the "organism" element of the SOR framework. Previous research highlighted such factors as sense of presence, interactivity, skills, and intrinsic and extrinsic motivations contributing to flow experience. In turn, flow experience contributes to developing consumer brand attitude, making it a critical construct for virtual experience (Shen et al., 2021, pp. 13). Last, previous studies using the SOR framework used only explicit measures (Loureiro et al., 2021). By leveraging the VR system, our study incorporated implicit measures, to expand the framework. Xiong and Zuo (2020) have applied the SOR framework to highlight the benefits of using neuroscientific tools to explore users' cognitive and affective processes informing their behavioral responses (e.g., task performance, information handling). Thus, analyzing how unconscious information processing influences planned and unplanned purchase patterns serves practitioners and researchers equally (Ozkara & Bagozzi, 2021). Our study squarely contributes to the development of the NeuroIS (i.e., the blend of information systems and neuroscience methodologies) domain (Kirwan et al., 2023). Moreover, we respond to the need for broader behavioral science perspectives on emerging metaverse retailing (Dwivedi et al., 2022), applying a SOR framework with roots in environmental psychology (Mehrabian & Russell, 1974) to explain virtual consumption (Shen et al., 2021, pp. 112311087).

6.2. Practical implications

Notably, the components (stimulus, organism, and response) of the framework support the phases of the customer shopping journey (Chen et al., 2022) at various consumer touchpoints (Yoo et al., 2023). The study findings present multiple critical perspectives that can assist managers and information system designers in better understanding consumers' spending patterns inside a VR-enabled supermarket.

First, we extend our previous understanding of consumer impulsivity and how it impacts behavioral outcomes, such as the amount of money spent and the duration of the shopping trip. Our results show the importance of marketers noting that consumers' impulsive tendency leads to greater unplanned purchase quantity and expenditure. Retailers may nudge consumers, triggering unplanned purchases by using distinct types of incentives, such as sensory stimuli, displays, shelf design, price promotions, and technical-device salient interactions (Thaler, 2018). However, retailers must adopt incentives compatible with consumer satisfaction in stores. Previously, Hui et al. (2013) highlighted the complexity in establishing an association between length of in-store shopping trips and unplanned spending, due to methodological difficulty in measuring the in-store path accurately. However, by leveraging the potential of the VR-assisted retail environment, we found incremental differences in the consumers' desire to stay in the store, which leads to higher budget and basket-size deviations. Second, previous studies have highlighted the implications of using neuroscientific methodologies in marketing (Alvino et al., 2020), information science (Xiong & Zuo, 2020), and virtual reality research (Wedel et al., 2020) and how it can assist businesses in making informed decisions. In our study, we used EEG, which objectively assess affective decision-making and could complement self-report measures (Wajid et al., 2021). Using EEG, we determined the differences between planned and unplanned purchases. We observed lower cognitive load when consumers engaged in unplanned purchases than when they purchased products on the list. This should encourage retailers to customize the environment to

increase consumer exploration and strategize product assortment in a way that reduces consumers' cognitive workload. Unplanned purchases seem to be associated with less cognitive effort, which may relate to a pleasant in-store experience. Numerous nudges toward stores may distract a consumer from the shopping list and, ultimately, lead to regret over forgetting the main goal of the shopping visit (i.e., treating the shopping list as a main driver to visit the store). Indeed, Baymard (2020) study of online shopping points out that an abandonment rate of almost 70% occurs during online shopping (Baymard, 2020), whose cause may be the feeling of guilt resulting from an increase in unplanned purchases (Nigam et al., 2022). Prior research found that a shopping list serves as an external memory aid to help a shopper navigate the trip with the least amount of information in working memory (Block & Morwitz, 1999), reducing extra expense and time (Davydenko & Peetz, 2020). However, according to our research, shoppers' cognitive load—a proxy for mental efforts exerted in information processing—is significantly less when they shop without a list. Therefore, contrary to the conventional understanding that advises businesses to provide shoppers with more information, our research suggests that managers should give them a balanced amount of information instead of risking cognitive overload by subjecting shoppers to information processing that is not strictly necessary. Third, since our findings show that satisfaction and longer stay at the supermarket result in more unplanned purchases, retailers should deliver memorable in-store experiences—as the experience economy model (Pine & Gilmore, 2011) suggests—by delivering greater utilitarian and hedonic value that ultimately leads to more unplanned purchases. Therefore managers and designers should seek synergetic work through a design-science paradigm (Hevner et al., 2004). Here, the design considerations and business goals combine to craft the shopping experience in VR-based shopping environments (Dincelli & Yayla, 2022, p. 15). In this regard, the four-phase 3DR3CO design framework (i.e., observe navigation, engage consumer interaction, behavioral data analysis, and VR shop design) that Elboudali et al., (2020, p. 9) propose, can promote retailers and designers working in synergy for continuously tracking shopper's interaction inside a virtual environment, to develop a personalized shopping experience. Last, our study found a partial mediating effect of flow experience between the sense of presence and the desire to stay, resulting in more unplanned purchases. Designers can increase positive store-related emotions by improving flow experience, in turn affecting behavioral intention, store attractiveness, and retail choice (Jin et al., 2021) while customized implementation of virtual commerce improves customer engagement (Lim et al., 2022).

6.3. Limitations and future research directions

Despite being a unique study of its kind that incorporates neurophysiological measures of cognitive load to differentiate consumer shopping patterns in a virtual reality-based supermarket context, some caution should apply to interpreting its findings. Nonetheless, in turn, its limitations provide a basis for widening the scope of future research. First, the current study assumed that unplanned buying takes place after a shopper purchases a list of planned products. Although this is realistic, some consumers may actually combine planned with unplanned purchases by category. We did not counterbalance the planned and unplanned tasks, choosing instead to follow Hui et al. (2013) by asserting that unplanned purchases tend to take place after planned purchases. Second, the present study showcases the potential use of VR technology as the venue for in-store purchase behavior, which can include designing and testing store layouts, modification of store atmosphere, and interaction with products. The virtual environment this study used only caters to one of the senses, i.e., sight. However, other modalities, such as haptics, olfactory, and auditory sensation, are major components influencing emotions and attitudes toward retail stores that the virtual shopping experience can incorporate (Biswas, 2019; Loureiro et al., 2019). In this vein, a promising line of inquiry could be to incorporate a multisensorial approach along with various atmospheric cues, such as

product-related scents, that can influence human senses in VR stores (Roschk et al., 2017). Whether different types of atmospheric cues can further increase or decrease consumers' cognitive workload is of immense importance from academic and managerial perspectives, especially for the low-involvement product category (Mirhoseini et al., 2021). As such, self-report measurements (e.g., NASA Task Load Index) can complement the use of EEG to index cognitive workload and further explore various cognitive workload dimensions in virtual commerce (Xi et al., 2022). Third, although earlier studies used similar sample sizes in EEG consumer research (Bazzani et al., 2020), we acknowledge the effect that a limited number of samples can have on the generalizability of our findings. Our results, however, seem to corroborate previous studies (i.e., Saffari et al., 2023). Fourth, our study did not control for the influence of product type nor the role of involvement. The environment we used had more than 250 products, making it impossible for the researchers and developers to expend more resources on tracking movements and interactions with each product. Fifth, while contrasting the immersive shopping experience with traditional and e-commerce shopping has been a consistent research focus in marketing over the last decade (Xi & Hamari, 2021), comparing shopping experiences beyond grocery product categories (e.g., apparel, home décor) requires further research for a comprehensive understanding of unique behavioral outcomes.

7. Conclusion

Most behavioral research focuses on opposing deliberate thinking to intuitive or unconscious decision-making (Kahneman, 2011), mainly for discrete choices. A shopping trip consists of multiple continuous choices where each path can support some decisions, and another can support others. Both slow and fast paths in a single shopping trip underlie this study, namely, purchases based on prior goal-oriented tasks (e.g., a shopping list) and unplanned purchases. The findings may be valuable for transforming virtual retail environments that seek to enhance the consumer shopping experience, thereby maximizing behavioral responses. Thus, our study explored consumers' impulsivity, flow experience, and the influence of virtual reality attributes on consumers and how these positively translate into unplanned shopping behavior in a VR environment, through such measures as duration and money spent while

shopping. The key takeaways of the study are multifaceted. First, the sense of presence that the flow experience mediates effectively increases consumers' desire to stay in the virtual environment. Thus, designers should develop environments with minimal distractions (e.g., pop-ups) and encourage seamless interaction with the environment. Second, cognitive load is greater when consumers are purchasing products on the list and is less during purchases made without a list. This should encourage managers to carefully develop strategies to highlight selective sales promotion advertisements. Besides, minimizing consumers' cognitive load can encourage them to explore the environment further, leading to improving the shopping experience and purchasing behavior. Finally, for business-to-consumer organizations planning to introduce immersive systems as distribution channels, understanding the consumer's dynamic purchase decisions necessitates insight into their unconscious and conscious metrics. This triad of data sources will draw the focus of NeuroIS scholars as they work in tandem to develop conceptual and methodological understandings of consumer shopping behavior (Kirwan et al., 2023).

CRediT authorship contribution statement

Shobhit Kakaria: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft, Writing – review & editing, Funding acquisition. **Farzad Saffari:** Methodology, Data curation, Software, Investigation, Resources, Funding acquisition. **Thomas Ramsøy:** Resources, Project administration, Funding acquisition. **Enrique Bigné:** Formal analysis, Writing – original draft, Writing – review & editing, Supervision, Resources, Funding acquisition.

Declaration of Competing Interest

None.

Appendix A. VR Images

1. Image indicating the product display in the store.

.
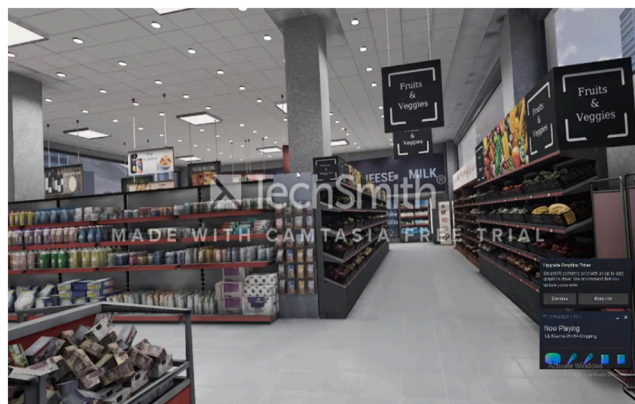
2. The blue arrow indicates instant teleporting for individuals to reach close to the desired product or section.
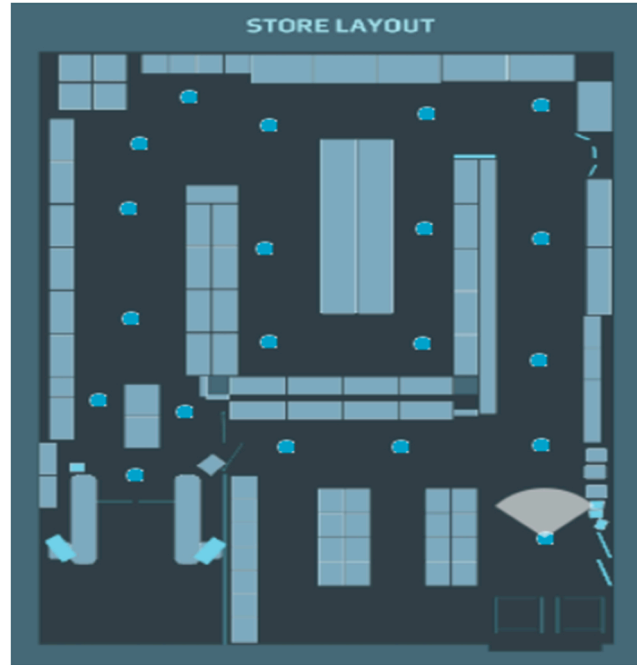

.

3. To purchase the product, participants must indicate 'grab' when the focal product turns green.

.

4. Prior to exiting the store, the participants must teleport to the red circle to indicate the end of the shopping trip.

.

5. A 2-dimensional layout of the virtual store.

.

Appendix B. Task instructions to the participants

Hi there,

Welcome to our virtual supermarket. For this shopping trip, we need you to imagine the following:

You reached home after work and found out that you needed to go grocery shopping. You go to the nearby supermarket, pick up the shopping cart and proceed with shopping. You must first purchase the indicated products on the shopping list. You have a budget of 260 DKK. With the remaining amount, you can purchase additional products if you need them. Just like in a real supermarket, feel free to explore the environment and add products to your cart that you would like to have after the shopping trip.

Have fun shopping!.

Appendix C. . Adapted scales from previous studies

Scales	Range
Impulsivity (Rook & Fisher, 1995) ($\alpha =$.74)	**1–7**
1. Sometimes I feel like buying things on the spur of the moment.	
2. "Just do it" describes the way I buy things.	
3. "I see it, I buy it" describes me.	
4. Sometimes I am a bit reckless about what I buy.	
5. I carefully plan most of my purchases.	
6. I often buy things spontaneously.	
7. I buy things according to how I feel at the moment.	
8. "Buy now, think about it later" describes me.	
9. I often buy things without thinking.	
Sense of presence (van Herpen et al., 2016) ($\alpha =$.80)	**1–7**
1. I was able to search the shopping area completely by looking around.	
2. I was able to take full control of the events that occurred while shopping.	
3. I felt involved in the shopping trip.	
4. I had all my senses fully engaged in the shopping trip.	
5. I was completely unaware of events that took place outside the shopping area.	
6. There were moments when I felt completely focused on doing the shopping.	
7. There were moments when I felt completely focused on the retail environment.	
8. I felt I could walk around freely in the store.	
9. I was able to examine the products closely.	
10. I was able to concentrate on my purchase decisions.	
11. I found it easy to move from shelf to shelf.	
Desire to stay (Elmashhara & Soares, 2022) ($\alpha =$.80)	**1–7**
1. I like to stay at this store as long as possible.	

(continued)

Scales	Range
2. I enjoy spending time at this store.	
Flow experience (Kim et al., 2020**) (α =.77)**	**1–7**
1. Do you think you experienced flow (moments when you are completely and totally absorbed in an activity) when using virtual reality for your shopping needs?	
2. Most of the time I use virtual reality for shopping I feel that I am in flow (moments when you are completely and totally absorbed in an activity).	
3. In general how frequently would you say you have experienced flow (moments when you are completely and totally absorbed in an activity) when you use virtual reality for shopping?	
Store satisfaction (Pizzi et al., 2019**)**	**1–5**
1. Are you satisfied with the store?	

Appendix D. . EEG

All electrode impedances maintained below 15 kΩ and a notch filter at 50 Hz were applied to remove powerline noise. The wireless EEG signal acquisition was sampled at 500 Hz, with low pass filter at 100 Hz and high pass filter at 0.1 Hz.

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