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Wearable gaming technology: A study on the relationships between wearable features and gameful experiences

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ABSTRACT

With the parallel advancement and evolution of psycho-physiological sensors, haptics, and overall wearable computing, wearable devices have become a mainstay in everyday life. While gaming is one of the most intuitively appealing areas for using wearable devices, most gaming concepts relying on wearable devices have had only moderate success. Therefore, further knowledge is needed by game developers for innovating new gaming concepts, by wearable designers to innovate new affordances for gaming in wearables, and by gamers for seeing the possibilities of what wearables can bring to gaming. To address this research problem, we combined vignette and survey studies ($N = 289$) to investigate which features of wearables (integrability, wearability, modularity, sociability, programmability, bio-adaptability, audiovisuality, and embodied modality) would lead to gameful experiences. Overall, the results indicate that integrability to games, wearability, modularity, and sociability were dimensions of wearables which were most strongly connected with the expectation of a heightened game experience. The findings of the study contribute to the current understanding of the experiential value of gaming wearables, as well as providing practical guidance for gaming wearables designers and marketers.

1. Introduction

The global gaming market size is continuing to grow, and is expected to reach USD 545.98 billion by 2028.[1] However, beyond simply growing, the gaming sector, culture, and related technologies are also diversifying. Games are increasingly being played pervasively (e.g., location-based games and AR games), on new platforms (e.g., mobile and VR platforms, Xbox, Playstation), and with new modalities of interaction (wearables, novel controllers, and output modalities). One of the more prominent novel developments has been the introduction of wearables into the palette of overall game design and experience. The use of wearables in gaming is a major step towards gaming without the need for external controllers, as well as towards a richer use of output modalities of the game (i.e., using the body as a "controller" and as such bolstering performativity, degrees of freedom, social interaction), as well as distinct interaction modalities (Buruk et al., 2021). Wearables can be worn while engaging in games, and this often includes detecting, tracking, and analyzing information regarding players' biological and physiological data (Peng et al., 2022).

However, regardless of the promising premise of wearables, the use of wearables in gaming has had little success. Currently, wearables are still inching towards their maturity (Buruk et al., 2021), and their possible benefits for the player experience in a wider scope are underexplored. Specifically, there is a scarcity of design research that would provide in-depth information about the possible features of gaming wearables. It should be noticed that the adoption of wearable technologies for gaming has been significantly slower than expected (Kalantari, 2017). One important reason for this might be associated with the low degree of scalability. Devices such as gaming bracelets (Pokémon GO) are commonly related to only a handful of games, and have only a thin integration into the mainstream game's mechanics (Buruk et al., 2021). Additionally, the high economic cost is often an important factor that poses a barrier to the use of gaming wearables, and players don't usually perceive a high-cost performance towards such products. For example,

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[1] https://www.globenewswire.com/news-release/2021/09/22/2301712/0/en/Gaming-Market-Worth-545-98-Billion-by-2021-2028-Fortune-Business-Insights.html

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the most common gaming wearables have been gaming virtual/augmented reality (VR/AR) glasses (Buruk et al., 2021) which mainly provide visual and auditory experience, and understandably, consumers expect more functionalities from such expensive devices. Another factor that has often been overlooked is related to gaming wearables' social value. When using wearables which only consider utilitarian functions such as performance and efficiency without considering their social acceptability, players may feel embarrassed in scenarios of pervasive gaming with social settings (Dagan et al., 2019a). Therefore, without an in-depth understanding of the gaming values provided by wearable features, many gaming wearables have failed to achieve commercial success.

In academia, previous literature has examined the relationships between different aspects of wearables and users' experiences (see e.g., tracking and bio-sensing: Hassib et al., 2016; Maher et al., 2017; privacy perception: Motti and Caine, 2015; interactivity: Benbunan-Fich, 2020; perceived quality: Karahanoğlu and Erbuğ, 2011; comfort: Beuthel and Wilde, 2017). However, most of the existing studies have focused on a single attribute or limited features of specific wearable devices. These scattered studies have, therefore, not been able to paint a holistic view of understanding the different dimensions of users' feelings, perceptions and evaluations while using wearable products, and especially for playing games. More importantly, research related to wearables has commonly been conducted in the domain of health management (e.g., for chronic disease prevention: Bardhan et al., 2020; Phillips et al., 2018; for improving lifestyle-related disorders: Cho et al., 2020; for personal fitness and care: Asimakopoulos et al., 2017; Canhoto et al., 2017). Therefore, it is difficult to generalize and apply the results of user experience from non-game contexts (e.g., health management) to players' experiences. For example, compared with fitness trackers, users might expect gaming wearable products to provide more interactive functions with the systems, and a higher usability that can lead to better gaming performance as well as increasing the social value for facilitating role-playing and social interaction. More importantly, it can be seen that in the current literature, the majority of previous studies related to gaming wearables are practice-oriented rather than studies that empirically and holistically investigate the value of the gaming experience brought by different wearable features (see e.g., performativity, sociality, and interactivity, Buruk et al., 2019; interdependent functionality and collocated interaction, Isbister et al., 2017; affective embodiment, belongingness, extended body affordances, sensing capabilities, Jung et al., 2021; supporting emotional resonance, social signaling, spectator sensitivity, supporting authentic self-presentation and choice, Márquez Segura et al., 2018). Even though a few design principles for wearables aimed for playing and gaming based on user experience have been mentioned, these features are still mainly developed for specific games, or have been presented in the form of speculative design concepts.

Therefore, there is a pertinent research problem that stems from these hindrances to the diffusion of wearables into gaming: *How are different affordances of wearables associated with heightened game experience?* In order to address this research question, in this vignette study (16 vignettes), we extract (via exploratory factor analysis) 8 dimensions of wearable affordances from a total set of 20 specific features, and investigate which affordances (namely audiovisual modality, embodied modality, game integrability, modularity, sociability, wearability, programmability, and biodaptability) of wearables would lead to a gameful experience (using the 7 dimensions of the GAMEFULQUEST measurement instrument: accomplishment, challenge, guided, competition, immersion, playfulness and social experience), based on the data of 289 users. To be more specific, each participant would receive a random wearable technology as a vignette out of the collection of 16, and rate 20 specific wearable attributes. The contribution of this study is two-fold. On one hand, it fills the research gap by providing a holistic view of understanding the experiential value of wearables in the game context, which contributes to the game and wearables research field. On the other hand, the results may provide practical guidance to designers, developers and marketers on designing and developing wearable products to satisfy specific users' psychological needs, especially for playing games.

2. Background

2.1. Wearable technologies

Wearable technologies are electronics and computers incorporated into clothing and other accessories which can be worn comfortably on the body. They include a wide variety of devices such as smart-watches, smart glasses, activity trackers, head-mounted displays, contact lenses, smart garments, smart jewelry, headbands, bracelets, etc. (Wright and Keith, 2014). Wearables are progressively becoming an integral part of everyday lives, and this requires their designers and manufacturers to consider certain key attributes, including physical and multi-functional capabilities in their design and production in order to attract consumers. Consumers' perceptions of the novelty of the wearable plays a key role in their adoption intention and purchase decisions (Kalantari, 2017). Generally, an ideal wearable needs to possess physical attributes such as being lightweight, aesthetically pleasing, its visibility and shape conformability, and multi-functional attributes such as configurability, responsiveness, and having a sufficient data bandwidth for interactivity (Park et al., 2014).

Among attributes in the existing literature on wearables, wearability-related (Section 2.1.1), functionality-related (Section 2.1.2), interactivity-related (Section 2.1.3), sociality-related (Section 2.1.4) wearable affordances have been widely mentioned in the relevant literature (Buruk and Ozcan, 2018; Davis et al., 1989; Dvorak, 2008; Faust and Yoo, 2006; Havlucu et al., 2017; Houzangbe et al., 2018; Högberg et al., 2019; Jing et al., 2017; Nacke et al., 2011; Park et al., 2014; Wright and Keith, 2014). In the following subsections, we review specific wearable features as exhaustively as possible, so as to provide a more comprehensive view of the understanding of wearable technologies for gaming.

2.1.1. Wearability-related features

Wearability is defined as the notion of a device being wearable while the body is in motion (Gemperle et al., 1998; Knight et al., 2006), which addresses the physicality of wearing equipment and highlights that the wearer is the focus of the design in such devices, and the safety, satisfaction, and usability of the wearable should be ensured. Assessing the wearability of a given wearable device includes an evaluation of physiological, biomechanical, and comfort effects (Knight et al., 2006). According to Dunne et al. (2014), the "wearability" of wearable technology has to do with the factors that affect the degree of comfort the wearer experiences while wearing a device, such as the physical, psychological, and social aspects of the device. Typical features connected to wearability in the literature include comfort, fashionability, coolness, softness, and flexibility (Bodine and Gemperle, 2003; Dunne, 2010; Dunne et al., 2014).

Quite many studies related to wearability have been conducted in the XR (xReality[2]) context. Chuah (2019) argues that the wearability aspect is very important for users who regard XR from a fashion perspective. He considers that individuals with a higher fashion awareness prefer to wear an XR device which is visually appealing, while maintaining its sophisticated features and a sense of realism. Rauschnabel (2017) has explored the expected gratifications of using augmented reality smart glasses (ARSG), and proposed that wearable comfort and impression management are two important factors that are associated with users' needs. Wearable comfort is a determining factor for use (Kalantari,

[2] X – in XR – represents a placeholder for any form of new reality, including e.g. Augmented, Assisted, Mixed, Virtual, Atomistic Virtual, Holistic Virtual, or Diminished Reality (Rauschnabel et al., 2022).

2017; Rauschnabel, 2018), which is related to the user's satisfaction with the design of a wearable, and with the physical characteristics of a device, including the size, weight, pressure, and other physical properties of the device affecting wearable comfort. In addition, impression management or positive self-image (or visibility in the work of Kalantari, 2017) related to social wearability is also important in adopting wearables, and many people use wearables for symbolic reasons to be accepted by a group, to express their identity, and to display their power, social status, or their coolness (Rauschnabel, 2017; Chuah, 2019).

Wearability is also critical for the playful applications of wearables. First of all, wearables are often part of movement-based and bodily demanding games (Buruk and Özcan, 2018; Abe and Isbister, 2016; Dagan et al., 2019a), where the factor of physical comfort comes as an important criterion for the ideal play experience. Moreover, wearables can be an important part of in-game identity, by connecting players to their imaginary avatars (Tanenbaum et al., 2015), and they can even extend the identity of being a gamer beyond screens to daily life by signaling about the favorite games of a player or creating belongingness towards a certain game world or brand (Buruk et al., 2021). Therefore, the wearability-related issues mentioned in this section and examined in the survey are an integral part of wearable play, and contrary to previous work, we aim to explore the implications of these dimensions in the context of games that are oriented towards home entertainment rather than games designed for specific purposes.

2.1.2. Functionality-related features

The main functionality of wearables has been defined as assisting individuals to reach "a state of connected-self by using sensors and software that facilitate data exchange, communication and information access in real-time" (Kalantari, 2017). The perceived functionality is relevant to how well a user can use a wearable product to achieve a defined goal effectively and efficiently (Frances-Morcillo et al., 2020), which is associated with the perceived usefulness (enhancing performance) and perceived ease of use (being free of effort) towards a technology (Davis, 1989). Although these qualities are essential for an ideal user experience for any kind of wearables, when it comes to gaming wearables, they have an additional layer of importance for the player experience. Immersion and flow, which are defined as critical experiences for gaming (Jansson et al., 2020), can be affected by the usability of the control devices to a large extent. According to Brown and Cairns (2004), to reach full immersion, players should go through phases of engagement and engrossment. While engagement defines the moment where players are convinced to spend more time with the game, engrossment refers to the stage where players start to be kinesthetically involved (Calleja, 2011) in the game, which happens after a proficiency in game controls has been achieved. Here, the controls should work flawlessly, and the players should be certain that they can perform the moves they want without hesitation. Therefore, regarding gaming wearables, functionality is not only related to the ease of use, but is also largely related to the users' performance when playing games, which represents the features facilitating any playing behaviors such as giving commands (game input), receiving information (game output), or manipulating and identifying virtual identities (role-playing). In this study, game integrability is used to refer to functionality. Previous work such as WEARPG (Landers et al., 2019) and True Colors (Dagan et al., 2019a) has used wearables for giving commands, reading output, and role-playing purposes. However, they did not specifically investigate how these features or the usability of the devices affected the player experience. With this study, we aim to learn the opinions of a wide user base regarding the possible influence of these features on their gaming experience.

2.1.3. Interactivity-related features

The experience of playing digital games is originated and appreciated as an action that arises from the player as a "situated embodied subject in-the-world" (Nielsen, 2010). Technologies enabling tracking the player's body, detecting hand gestures, or recognizing eye movements by means of eye tracking can all be used as game interaction modalities. Multimodality forms of interactions with or via an avatar and embodied digital representations of physical artifacts, or tangible interfaces foster greater interactions in games (Maurer, 2016). The concept of embodied interaction which is a kind of 'somatic experience' (Hook, 2018) initially introduced by Dourish (2004) focuses on designing interactions that are meaningful for humans as social creatures with emotional bodies. Games as a means of creating bodily interactions bring about somaesthetic reflections by raising awareness in people of their own body and senses, and create new game experiences (Maurer, 2016), and wearables have been designed in various ways to create somatic experiences (Jung and Ståhl, 2018).

Embodied interaction helps us to understand the relationship between physical and symbolic representation. While probing interactive gaming experiences, Ko and Hsieh (2016) developed a visual and musical method to boost in-game body movement control and map multiplayers' physical movement, so as to transform them in a digital virtual reality environment. Players embody musicality and become involved in the attunement of their body movements by perceiving audiovisual feedback. Here, the lived experience of hearing the music and harmonizing the body with it by being audiovisual feedback is an example of the interplay between 'Körper' and 'Leib' as mentioned by Mueller et al. (2018). Mueller et al. (2018) assert that we both "have" a body and "are" a body, and facilitating the engagement of the human body through games and play will contribute to a more humanized technological future. Following this, Mueller et al. (2018) propose a vision where bodies are experienced *as* digital play (Körper and Leib), which means not only are we engaging our 'Körper' (corpus or body), but we also experience play through our 'Leib' (living body or emotions), collectively called "body as play".

Wearables can play an important role for evoking someaesthetic experiences during gameplay, and be part of the interplay between Körper and Leib by augmenting the body with various types of interactive modalities. Visual, audio and haptic-related sensory information (e.g. vibration, texture, pain, and force) can be delivered via wearable technologies that keep players safe, make players interact with each other, and present themselves in the games (Cho et al., 2019; Shull and Damian, 2015). Audiovisual and haptic modalities have an important role in facilitating somaesthetic experiences during game play. For example, Buruk et al. (2021) speculated that these modalities might be an effective way of providing Subtle Guidance, which is one of the elements of someaesthetic appreciation design (Höök et al., 2016) that would facilitate affective embodied experiences in gaming wearables. Moreover, the designers of WEARPG (Buruk and Özcan, 2018) suggested that audiovisual and haptic modalities which can guide body movements should be designed in a way that would not disrupt the attention of the player from the bodily play.

Wearable sensors have recently provided researchers with the opportunities to achieve embodied interactions in human-computer interaction, and to be able to track and monitor physiological and biological data such as heart rate, respiratory rate, blood pressure, oxygen saturation, and muscle activity (Patel et al., 2012). Bioadaptive features of wearables have been used for controlling games (Byrne et al., 2016; Robinson et al., 2017), and have also been suggested to be used for integration to daily activities or to the physical gaming environment (Buruk et al., 2021). The challenge which is created by the effort of controlling bodily reactions such as heartrate or body temperature may also lead to further socially embodied playful experiences by shifting the attention between the body, the game, the environment, and other players (Dagan et al., 2019a).

With the ability to collect versatile information about the body, and by guiding the body with audiovisual, tangible and haptic modalities, wearables are an important part of bodily play and experience, and these aspects might also be relevant to mainstream games. However, their possible role in commercial games has not been studied with a wide user participation as done in this study.

2.1.4. Sociality-related features

The facilitation of social interaction has been an integral part of wearable design because wearables can be configured in ways that can show/hide information and be adjusted to different social situations (Vidergor, 2021), and can promote many different ways of social communication such as signaling (Dagan et al., 2019a) or bodily touch (Canat et al., 2016; Abe and Isbister, 2016). Wearability and interactivity-related features facilitate the social value of wearables and social networking (Isbister et al., 2017; Tanenbaum et al., 2015 and Adapa et al., 2017). Dagan et al. (2019a) studied social wearables and found the following social affordances to be relevant in creating and designing wearables: social signaling ("supporting and augmenting the expressivity and readability of verbal and non-verbal cues"); social appropriateness (signal the type of interaction considered acceptable); and spectator sensitivity ("facilitating spectatorship"). In playful contexts, Buruk et al. (2021) have also suggested that social interaction is one of the main dimensions of playful wearables, and can lead to social interactions on a wide spectrum, from tight to relaxed. As shown by this previous work, wearables have a strong effect on social interactions both by adorning the body with social signals, and also with their impact on the wide variety of embodied interaction configurations. Still, most of the studies were made on games where social interaction was already an important part of the game setting, such as tabletop or live-action role-playing games. The facilitation of social interaction in the context of mainstream and commercially available games has not been studied in-depth by previous studies, and with this study we aim to understand the possible impact of wearables on the social interaction that occurs in mainstream games.

2.1.5. Other features

In addition, other important features of wearable technologies can be grouped into programmability, customizability and modularity. Programmability means the capability of a device or a network to accept a new set of instructions that may alter the device or network behavior (Borges, 2015), and which allows the consumer to program different features for different actions, and permits design upgrades (Bellis et al., 2005). Customization or customizability as an important feature of wearables enhances the enjoyment of the technology, and increases the efficiency of use (Page et al., 1996) by customizing technologies to match the user's preferences. Customizability is defined as "an attribute that lets users take control and make changes to the presentation and functionality of the interface" (Marathe and Sundar, 2011), and is maintained to boost user experience with technologies by "supporting situatedness, dynamics, ownership, sense of control, and sense of identity" (Marathe and Sundar, 2011). Customizability could transform a general technology to one that is personalized, and is connected to both hedonic and utilitarian facets of the user experience (Hassenzahl and Tractinsky, 2006). Finally, modularity is another critical feature of wearables which not only improves mass customization capability for the organization (Zhang et al., 2014), but also affects users by simplifying their solution space for innovation (Naik et al., 2020). Modularity addresses "how to simplify by making complexity manageable, enable parallel work, and accommodate future uncertainty" (Baldwin and Clark, 2006). These features might especially be important for adjusting wearables to a wide variety of games. Previous projects on playful wearables mentioned throughout this section were mostly designed for one specific game, and features such as customizability were used to role-play different characters rather than be adapted to different kinds of games. Thus, with this study, we want to understand how important these features are for players when it comes to playing games in more mainstream media.

In this subsection, we have elaborated on the roots of the constructs introduced in our vignette study. Gaming wearables have many important affordances that should be used for their detailed assessment and integration into playful contexts, which expands the evaluation universe dramatically. Thus, we summarized 20 evaluation criteria by drawing on the important features of wearables as indicated in the extant literature, which are: 1) sound feedback, 2) visual feedback, 3) voice control, 4) gesture control, 5) tactile feedback, 6) touch control, 7) ease of use, 8) game input, 9) game mechanics, 10) game output, 11) role-playing, 12) comfort, 13) coolness, 14) fashionability, 15) flexibility, 16) customizability, 17) modularity, 18) sociability, 19) programmability, and 20) bio-adaptability. In addition to the theoretical basis, we also provide the empirical evidence for grouping these 20 features into the mentioned eight categories, based on exploratory factor analysis (EFA) – see Section 3.4 Measurement.

2.2. Gameful experience

In the current game and gamification-related literature, a game or gameful experience has been considered as a multidimensional experience of the user's sensations, thoughts, feelings, and actions in a gameplay or game-like settings (Ermi and Mäyrä, 2005; Högberg et al., 2019). Psychological constructs such as immersion (Pasch et al., 2009), the immersive tendency (Witmer and Singer, 1998), presence (Takatalo et al., 2010), absorption (Eppmann et al., 2018), engagement (Brockmyer et al., 2009), skill and challenge (Csikszentmihalyi, 1975), flow experience (Cowley et al., 2008; Csikszentmihalyi, 1975), fun (Rauschnabel et al., 2017), enjoyment (Mekler et al., 2014), and sensory experience (Ermi and Mäyrä, 2005) have been often investigated; while among these measures, only scales including GAMEX (gameful experience scale, Eppmann et al., 2018), CEGEQ (Core Elements of the Gaming Experience, Calvillo-Gámez et al., 2010) and GEQ (Game Experience Questionnaire, Ijsselsteijn et al., 2008) aim to holistically describe the gaming-related experience.

In order to provide a high psychometric validation and reliable measure, referring to previous scales, Högberg et al. (2019) developed the GAMEFULQUEST (Gameful Experience Questionnaire), which considered gameful experience as co-created (in the interaction between the game and the gamer) and multidimensional. To be more specific, in total seven dimensions are identified in the GAMEFULQUEST scale: accomplishment, challenge, guided, competition, immersion, playfulness, and social experience (see Table 1). Accomplishment is related to goals and completed tasks, and drives individuals to keep progressing and improving (Santos et al., 2021; Vidergor, 2021). Challenge is related to the difficulty of a task and can be described as a test of the user's ability which further allows players to strive for achievement (Vorderer et al., 2004). Competition represents the feeling of pride related to self, the service, and other people (Högberg et al., 2019) and usually involves individual competition (i.e., against a virtual opponent, against time, and against a single player) and team competition (Chen et al., 2020). Guided is related to the feeling of being helped with different tasks and getting feedback, and an active process of guidance (Hassan et al.,

Table 1
Seven dimensions of gameful experience (Högberg et al., 2019).

Dimension	Definition
Accomplishment	The feeling of having successful performance and goal achievement
Challenge	The feeling of making a great effort in order to be successful
Competition	The feeling of rivalry towards one or more actors to gain a scarce outcome
Guided	The feeling of being guided on how, what, and when to do and improve the target behavior
Immersion	The feeling of being absorbed in what the individual is doing and that all attention is taken over
Playfulness	The feeling of being involved in voluntary and pleasurable behaviors that are driven by imagination or exploration
Social experience	The feeling originating from the direct or indirect presence of people, service-created social actors, and service as a social actor

2020). With the guided experience, one knows what to do and how to proceed with the target activities (Jansson et al., 2020). Immersion represents the cognitive and emotional state of being somewhere (e.g., being in the game) and a sense of being disconnected from the real world (Brown and Cairns, 2004; Cairns et al., 2014; Patrick et al., 2000). Playfulness is the perception towards voluntary and pleasurable behaviors (Hamari and Koivisto, 2015), and such a playful experience is based upon users' own internal drives and motivations (Landers et al., 2019). Lastly, Social experience is drawn from direct and indirect social interaction with others, including the feeling of belonging in a social environment and making meaningful social connections with others (Xi and Hamari, 2019; Sailer et al., 2017; Ryan et al., 2006).

In the design principles of gaming wearables, whether players' subjective experiences when playing games can be successfully evoked is the key indicator to evaluate the importance and value of specific features (Jung et al., 2021; Buruk et al., 2021; Van Goethem et al., 2021). Based on the review of literature, we can reasonably speculate that in the gaming context, these different wearable features are expected to satisfy all kinds of needs of players, and are positively associated with gameful experiences. According to the self-determination theory (SDT), the prerequisite for getting a good experience and taking further action is to satisfy users' three basic psychological needs of autonomy, competence, and relatedness (Deci and Ryan, 2004; Ryan et al., 2006). Autonomy represents the subjective experience of psychological freedom and choice when participating in activities (Van den Broeck et al., 2010); Competence is more related to the desire to feel self-mastery and growth (Rigby and Ryan, 2011; Ryan et al., 2006); while the need of relatedness refers to making meaningful social connections with others (Sailer et al., 2017). It is evident that the proposed wearable features can help players improve their gaming performances, self-efficacy, and social interaction to a large extent, and further lead to optimized gameful experiences such as accomplishment, challenge, guided, competition, immersion, playfulness, and social experience. However, the relevant existing literature were primarily conducted qualitatively, and there is still a lack of empirical evidence on how different attributes and affordances of wearables influence certain gaming experiences. Therefore, to deepen our understanding of players' psychological responses towards using wearable technologies, in this study we conduct a granular analysis of how different wearable features influence each dimension of gameful experience, and aim at providing a holistic view of perceptions of wearable affordances and the gameful experience stemming from them.

3. Method

3.1. Participants

Only respondents who had played video games or mobile games in the 12 months prior to conducting the survey were qualified for this study. In total, we collected 311 respondents between January 2020 to February 2020. Eight responses were excluded due to a wrong answer to the filter question (if you are still paying attention to what you are responding, please choose "Agree") and 14 patterned responses were further detected and omitted (choosing an identical answer to a series of questions). Moreover, we controlled that no respondent had previously used the device they were assigned to evaluate.[3] The final sample of valid responses was $N = 289$.

77.2 % of respondents were from the United States and the average time spent playing games among the respondents was 11.7 h per week. 80 % of respondents had use experience of wearable products. Table 2 describes the demographic characteristics of the respondents. Among the 289 respondents, 59.5 % were male. Most of the respondents were between 26 and 40 years of age, representing 61.2 % of the total sample. 82.4 % of respondents were employed full time, 73 % of respondents' total annual household income was lower than 70,000 US dollars. In terms of education, over half of respondents held bachelor's degrees and 12.5 % held master's degrees.

Table 2
The demographic information.

Gender	N	%	Total annual household income (pre-tax, US dollar)	N	%
Male	172	59.5	Less than 10,000	20	6.9
Female	116	40.1	10,000 to 19,999	26	9.0
Intersex	1	0.3	20,000 to 29,999	41	14.2
Age			30,000 to 39,999	41	14.2
16–20	2	0.7	40,000 to 49,999	28	9.7
21–25	8	2.8	50,000 to 59,999	26	9.0
26–30	57	19.7	60,000 to 69,999	29	10.0
31–35	72	24.9	70,000 to 79,999	25	8.7
36–40	48	16.6	80,000 to 89,999	11	3.8
41–45	36	12.5	90,000 to 99,999	8	2.8
51–55	46	15.9	100,000 to 109,999	12	4.2
56–60	18	6.2	110,000 or more	22	7.6
61–65	1	0.3	**Education**		
more than 65	1	0.3	Primary school or below	2	0.7
Employ status			High school/vocational education	62	21.5
Full time	238	82.4	Associate's degree	34	11.8
Part time	26	9.0	Bachelor's degree	150	51.9
Unemployed	12	4.2	Master's degree	36	12.5
Students	2	0.7	Doctoral degree	5	1.7
Retired	3	1.0	**Nationality**		
Other	8	2.8	United States	223	77.2
			India	59	20.4
			Other country	7	2.4

3.2. Procedure

An online vignette-based study was conducted among Amazon's Mechanical Turk (MTurk)[4] users to address the research question of how wearable device features influence different dimensions of gameful experiences. Prior research has shown that MTurk respondents yield high-quality responses and the platform offers more advantages than other methods of data collection (Acikgoz and Vega, 2022). The survey was implemented in the SurveyGizmo[5] online survey platform. MTurk respondents were compensated fairly based on an estimate of the average time to complete the survey. Before the formal survey, a pre-survey ($n = 50$) was conducted in October 2019 to evaluate the quality and validity of the questionnaire. Some measurement items were revised according to issues identified in the pilot data to ensure the face validity and content validity. In total, 289 valid samples were collected in the formal survey. Data collection followed a seven-step process: ***1)*** Demographic information and previous experience of playing games and using wearable products were asked at the beginning of the questionnaire. ***2)*** In order to control previous product knowledge, respondents were required to indicate whether they had used any of the 16 wearable products we selected for this vignette study (see Appendix A) .[6] ***3)*** Respondents were randomly assigned to evaluate one of the unused products. ***4)*** In order to help respondents understand and be engaged in

[3] In the final sample, 229 respondents had never used any of the 16 wearable products.

[4] MTurk is Amazon's crowdsourcing marketplace that allows researchers to crowdsource the survey, collect the data, and compensate workers (Pittman and Sheehan, 2016).

[5] SurveyGizmo was renamed as Alchemer in October 2020.

[6] Regarding the numbers of participants who evaluated each wearable product used in this study, Emotiv, n = 16; Focals Smart Glasses, n = 17; Myo, n = 24; Nubia Alpha, n = 17; Nex Band, n = 19; Blocks, n = 19; Xenxo Ring, n = 17; HaptX, n = 23; Foci, n = 14; Google Jacquard, n = 17; BCON, n = 17; Nike Adapt BB, n = 25; Tesla Suit, n = 18; Misfit Bloom, n = 9; Bragi Dash Pro, n = 15; Vinci, n = 22.

the hypothetical scenario, they were asked to provide at least three different ways of using the presented wearable for playing games in the textbox. In addition to their proposed ways, we provided extra information regarding the use of the shown wearable in games. ***5)*** After this step, each respondent was requested to evaluate the assigned wearable device along the twenty items corresponding to the relevant wearable technology dimensions from 1 (extremely low) to 7 (extremely high). ***6)*** Each respondent was also asked to envisage the imaginary experience of using the assigned wearable product with playing games, ***7)*** and evaluate the perceived gameful experience that the wearable device would afford from 1 (strongly disagree) to 7 (strongly agree) when playing games (see 3.4 Measurement). This method might be associated with design fiction (Dunne and Raby, 2013), however, design fiction represents methods that allow painting a comprehensive picture of fictional contexts through world building (Coulton et al., 2017), character creation (Baumer et al., 2020), fictional studies (Lindley and Coulton, 2015), and mainly aims at questioning the state of society by situating fictional designs and the interactions with them in these fictional contexts (Blythe, 2014). Our method is closer to user elicitation studies where users are presented with design concepts, and evaluate the possible imaginary scenarios with these concepts (Bostan et al., 2017; Ali et al., 2019). Appendix B provides a detailed flow diagram regarding the vignette study design and procedure.

3.3. Materials

Three experts were invited to summarize the existing wearable devices on the market, and to analyze their functions and features.[7] Finally, a total of 16 different wearable products were extracted that can be used for playing games (Emotiv, Focals Smart Glasses, Myo, Nubia Alpha, Nex Band, Blocks, Xenxo Ring, HaptX, Foci, Google Jacquard, BCON, Nike Adapt BB, Tesla Suit, Misfit Bloom, Bragi Dash Pro, Vinci) which represented the basis of the 16 vignettes featured in this study. The presented wearable devices were selected according to the body parts that they are worn on, and the different interaction modalities they provide (see Fig. 1 for the body parts and interaction modalities represented). The final list of devices included wearables that are worn on the head, arms, wrist, ears, hands, neck, torso, and full body. They encompass a wide array of interaction modalities such as bioadaptive modalities (brain signals, heartbeat tracking, respiratory information), gestural, voice and touch controls, and visual, audial and haptic feedback. Respondents were able to see a picture of the product, a text description of product information, and different proposals for using the wearable product for playing games. In the vignette design, we followed the guidance provided by Wason et al. (2002) such as making *believable* — we ensured that respondents believed the situations were realistic and consistent by asking them to combine the use of the presented wearable with their personal playing experience, and *make adequately but not overly detailed* — the vignette was not so detailed as to overburden the respondents. Fig. 2 presents an example of the product description of the Myo wearable.

3.4. Measurement

Twenty features of wearable gaming devices were identified by drawing on previous studies regarding playful wearables, wearable design, and game design, as well as an examination of selected wearable products (see e.g., Buruk et al., 2019; Gemperle et al., 1998; Genç et al., 2018; Petreca et al., 2017; Ranten, 2013; Tomico et al., 2017). An expert panel consisting of three researchers with Ph.D. degrees was used to ensure the validity of the extracted 20 features and the quality of the developed measures in this study (see Table 3). The dimensionality of these measures was further investigated via exploratory factor analysis (EFA) using SPSS 27 software. By using principal components analysis and varimax rotation as well as considering the previous literature, eight factors were extracted and further used in the research model of the present study: audiovisual modality (sound feedback, visual feedback and voice control), embodied modality (gesture control, tactile feedback and touch control), game integrability (ease of use, game input, game mechanics, game output, role-playing), wearability (comfort, coolness, fashionability, flexibility), modularity (customizability, modularity), sociability, programmability, and bio-adaptability. The gameful experience was measured by adapting the items from the GAMEFULQUEST survey instrument (Högberg et al., 2019), which comprises 7 dimensions of challenge, competition, accomplishment, guided, immersion, playfulness, and social experience. Accordingly, we examine the relationships between 8 extracted categories of wearable features and 7 dimensions of gameful experiences.

4. Results

4.1. Measurement model

The reliability and validity of the measurement were assessed by conducting a confirmatory factor analysis (CFA) with Smart-PLS 3.0. The reliability was verified by using three criteria of internal consistency reliability (Cronbach's α), composite reliability of the latent variable (CR), and average variance extracted (AVE). The validity was verified by assessing convergent validity and discriminant validity.

Internal consistency reliability is a form of reliability assessing the consistency across items comprising the measures of the focal latent variable (Hair et al., 2006). Cronbach's α is the most often used criterion of internal consistency reliability, and consistency is considered unacceptable when the value is less than 0.5 (Walters, 2009). CR is defined as a summation of individual item reliability (calculated by its true score variance divided by the total variance) over the items comprising the measures of the focal latent variable, and its value should exceed 0.7 (Nunnally, 1978; Bagozzi and Yi, 1988). AVE represents the average amount of the total variance of a latent variable that is explained by the variance of the comprising items, and should exceed the value of 0.9 (Fornell and Larcker, 1981). As Table 3 shows, the values of Cronbach's α for all latent variables exceed 0.5 (range 0.577 to 0.945). The values of CR criteria for all latent variables exceed 0.7 (ranging from 0.777 to 0.955). The AVEs for all latent variables were higher than 0.5 (from 0.523 to 0.729). These results suggest that all of the constructs had adequate reliability.

Convergent validity was assessed by checking the outer-loadings of the items on the focal latent variable. The outer-loading represents the variance of an item explained by the latent variable; a high value of outer-loadings (which should usually exceed 0.6) indicates the item is highly associated with the latent variable (Hair et al., 2006). As shown in Table 3, for the 17 latent variables (with three variables only containing one item), the outer-loadings of all the items had values exceeding 0.6, indicating the measurement used in this study had a satisfactory convergent validity.

Two approaches were used to assess the discriminant validity. The first approach is a dominant approach by examining the cross-loadings of the items (Hair et al., 2013a). Cross-loadings represent the extent to which an item is correlated with other latent variables (Hair et al., 2013a). According to Farrell (2003), all items should be correlated weaker with all other variables than the one variable to which it is theoretically associated, which means the loading of the item should be greater than all of its cross-loadings. A loading difference of 0.20 between the primary and alternative variables is recommended (Hinkin, 1998). Based on these considerations, items GEAC5, GECH2, GECH5, GECH6, GECH8, and GECO5 were omitted due to the lack of discriminant validity. The second approach of assessing discriminant validity is

[7] In this study, three researchers with PhD degress who had expertise on playful wearable design, gamification and marketing identified different wearables with distinct functions which can be relevant to gaming.

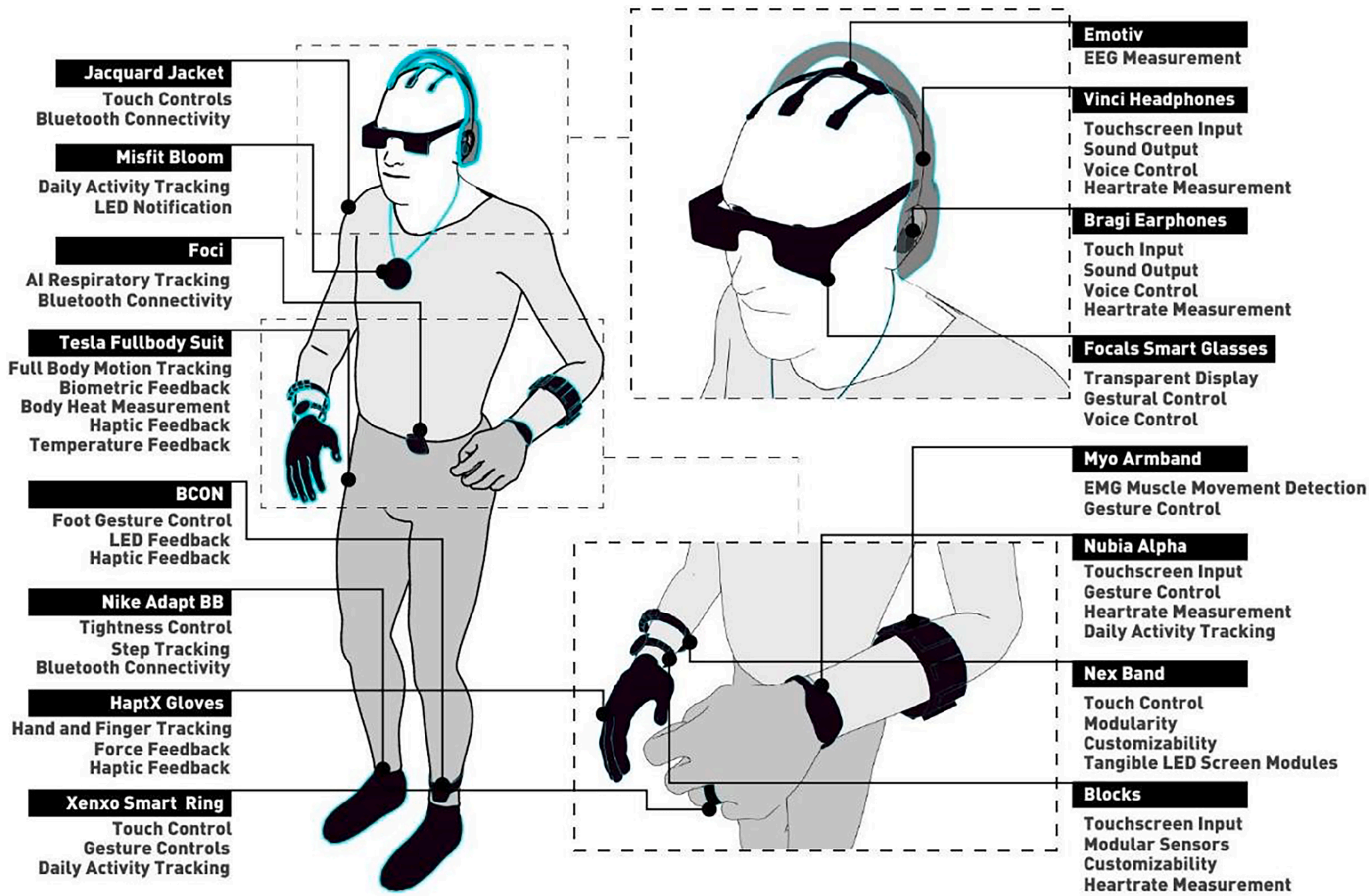

Fig. 1. The body diagram of the 16 wearables used in this study as research materials.

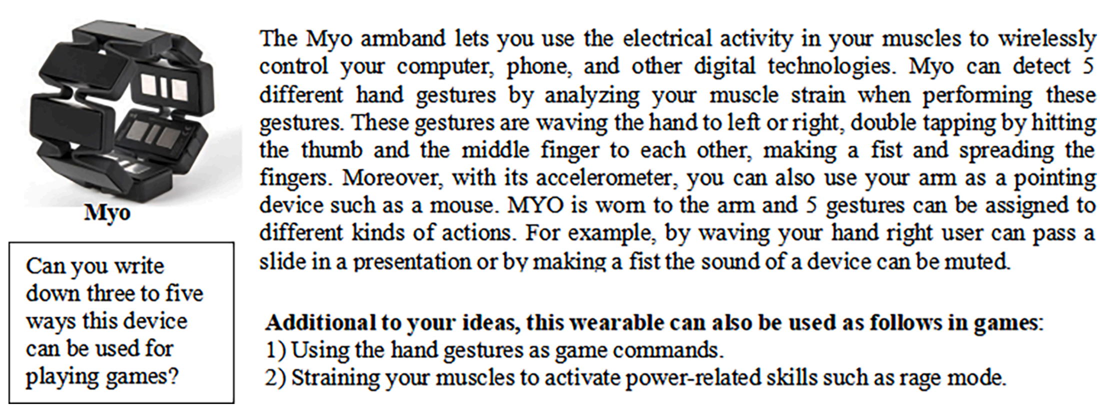

Fig. 2. The example of the description of the Myo wearable.

examining the heterotrait-monotrait ratio of correlations (HTMT), recommended by Henseler et al. (2015). This approach is derived based on the classical multitrait-multimethod (MTMM) matrix according to Campbell and Fiske (1959), when the monotrait-heteromethod correlations (i.e., the correlations of indicators within the same construct) are larger than the heterotrait-heteromethod correlations (i.e., the correlations of indicators across constructs measuring different phenomena), and discriminant validity is achieved. The value of the criterion should be no higher than 0.85 (Henseler et al., 2015). As Table 4 shows, all HTMT values were lower than 0.85 (ranging from 0.155 to 0.838), exhibiting adequate discriminant validity.

4.2. Structural model

A structural equation model was conducted with Smart-PLS. The effects of wearable features on expected gameful experiences were assessed using a full model specification. The R^2 examines the variance for each construct and is normally used to describe the model's explanatory power. The acceptable level of R^2 depends on the research context (Hair et al., 2013a). In disciplines such as consumer-related studies, a value of 0.20 is considered high (Hair et al., 2013b). In this study, the R^2 of the affordances of the wearable devices is 23.6 %, as for the dimension of gameful experience: challenge, indicating that affordances of the wearable devices explain 23.6 % of variance of this dimension of the gameful experience. Similarly, the affordances of the

Table 3
Constructs, measurement items, and their loadings.

Independent variables		Loadings
Wearable feature: Audiovisual modality ***α = 0.744 CR = 0.851 AVE = 0.656***		
WF1	Sound Feedback: The device can give feedback by producing sound	0.824
WF2	Visual Feedback: The device can show feedback that can be perceived visually	0.783
WF3	Voice Control: The device can be controlled by voice commands	0.822
Wearable feature: Embodied modality ***α = 0.577 CR = 0.777 AVE = 0.539***		
WF4	Gesture Control: The device can be controlled through body movement either with the movement hand, feet, head or other body parts	0.692
WF5	Tactile Feedback: The device can give tactile feedback such as vibration or other tactile feedback such as force feedback	0.814
WF6	Touch Control: The device can be controlled by touch modality such as tapping, swiping etc	0.690
Wearable feature: Game integrability ***α = 0.774 CR = 0.846 AVE = 0.523***		
WF7	Ease of use: The device feels like its functions would ease my life or increase the user experience of the products which I interact with	0.738
WF8	Game Input: The device can be used to give commands to a game in a meaningful way	0.677
WF9	Game Mechanics: If used in a game, this device would change how the game is played in a meaningful way	0.755
WF10	Game Output: The device can be used to get meaningful information from the game	0.756
WF11	Role-Playing: The device could help transform myself into a fictional character and I can perceive this device as a costume of my avatar if used in a game	0.687
Wearable feature: Wearability ***α = 0.729 CR = 0.825 AVE = 0.545***		
WF12	Comfort: The device looks as if it is comfortable to wear	0.826
WF13	Coolness: The device is unique and original	0.677
WF14	Fashionability: I would wear the device to express myself in the public; it would fit my or other particular style	0.803
WF15	Flexibility: It looks like that it is easy to wear and take off this device	0.628
Wearable feature: Modularity ***α = 0.596 CR = 0.831 AVE = 0.711***		
WF16	Customizability: I can change the device's look and feel according to my own personal preferences	0.818
WF17	Modularity: The device has more than one part that can be combined to introduce new features	0.868
The following wearable features only contain one item		
Wearable feature: Sociability ***α = N/A CR = N/A AVE = N/A***		
WF18	Sociability: The device can facilitate social interaction or help in social relations	–
Wearable feature: Programmability ***α = N/A CR = N/A AVE = N/A***		
WF19	Programmability: The device allows me to program different features for different actions	–
Wearable feature: Bio-adaptability ***α = N/A CR = N/A AVE = N/A***		
WF20	Bio-adaptability: The device can track my body data such as heart rate, brain signals	–
Dependent variables		**Loadings**
Gameful experience: Accomplishment ***α = 0.881 CR = 0.909 AVE = 0.626***		
GEAC1	I would feel that I need to complete things	0.803
GEAC2	I would be pushed to strive for accomplishments in games	0.750
GEAC3	I would be inspired to maintain my standards of performance	0.804
GEAC4	I would feel that success comes through accomplishments	0.780
GEAC5	I would strive to take myself to the next level	omitted
GEAC6	I would have the motivation to progress and get better	0.816
GEAC7	I would feel like I have clear goals	0.794
Gameful experience: Challenge ***α = 0.794 CR = 0.866 AVE = 0.619***		
GECH 1	I would push my limits	0.807
GECH 2	I would feel being drove in a good way to the brink of wanting to give up	omitted
GECH 3	I would feel being pressured in a positive way by its high demands	0.769
GECH 4	I would feel being challenged	0.776
GECH 5	I would make a lot of effort in order to be successful	omitted
GECH 6	I would be motivated to do things that feel highly demanding	omitted
GECH 7	I would feel like I continuously need to improve in order to do well	0.794
GECH 8	I would work at a level close to what I am capable of	omitted
Gameful experience: Competition ***α = 0.896 CR = 0.921 AVE = 0.660***		
GECO 1	I would feel like participating in a competition	0.838
GECO 2	I would be inspired to compete	0.835
GECO 3	I would be involved by its competitive aspects	0.837
GECO 4	I would want to be in first place	0.836
GECO 5	I would feel the victory important	omitted
GECO 6	I would like I was in a race	0.727
GECO 7	I would feel that I need to win to succeed	0.794
Gameful experience: Guided ***α = 0.885 CR = 0.910 AVE = 0.559***		
GEGU 1	I would feel guided	0.833
GEGU 2	I would have the sense of being directed	0.767
GEGU 3	I would feel like someone is keeping me on track	0.747
GEGU 4	I would get help to get where I want to be	0.766
GEGU 5	I would have the feeling that I have an instructor	0.794
GEGU 6	I would have the sense that I am getting help to be structured	0.773
GEGU 7	I would have the sense of knowing what I need to do to do better	0.608
GEGU 8	I would be given useful feedback so I can adapt	0.668
Gameful experience: Immersion ***α = 0.891 CR = 0.911 AVE = 0.533***		
GEIM 1	I would have the feeling that time passes quickly	0.716
GEIM 2	All of my attention would be grabbed	0.776
GEIM 3	I would have the sense of being separated from the real world	0.746
GEIM 4	I would lose myself in what I am doing	0.741
GEIM 5	My actions would seem to come automatically	0.621
GEIM 6	I would stop noticing when I get tired	0.661
GEIM 7	I would forget about my everyday concerns	0.781
GEIM 8	I would ignore everything around me	0.747
GEIM 9	I would be fully emotionally involved	0.765
Gameful experience: Playfulness ***α = 0.891 CR = 0.912 AVE = 0.539***		
GEPL 1	I would have an overall playful experience	0.639
GEPL 2	The wearable would leave room for me to be spontaneous	0.618
GEPL 3	The wearable would tap into my imagination	0.760
GEPL 4	I would feel that I can be creative	0.746
GEPL 5	I would have the feeling that I explore things	0.800
GEPL 6	I would feel like having mystery to reveal	0.649
GEPL 7	I would have the feeling that I want to know what comes next	0.736
GEPL 8	I would feel like I discover new things	0.813
GEPL 9	My curiosity would be appealed	0.814
Gameful experience: Social experience ***α = 0.945 CR = 0.955 AVE = 0.729***		
GESE 1	I would feel that I'm not on my own	0.635
GESE 2	I would have the sense of social support	0.921
GESE 3	I would feel like I am socially involved	0.898
GESE 4	I would have the feeling of being connected to others	0.896
GESE 5	I would get a social experience	0.889
GESE 6	I would have the sense of having someone to share my endeavors with	0.891
GESE 7	The wearable would influence me through its social aspects	0.898
GESE 8	I would have the sense of being noticed for what I have achieved	0.761

wearable devices explained 27.1 % variance of competition, 21.2 % variance of accomplishment, 32.1 % variance of guided, 24.4 % variance of immersion, 33.7 % variance of playfulness, and 49.7 % variance of social experience. All the R^2 values for the seven dimensions of gameful experience were acceptable.

Table 4
The HTMT value of each construct.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Wearability															
Embodied modality	0.362														
Modularity	0.516	0.513													
Bio-adaptability	0.346	0.169	0.440												
Game integrability	0.485	0.686	0.652	0.359											
Programmability	0.330	0.374	0.479	0.166	0.521										
Sociability	0.427	0.338	0.560	0.320	0.501	0.274									
Audiovisual modality	0.470	0.338	0.672	0.498	0.412	0.388	0.699								
Challenge	0.477	0.342	0.410	0.228	0.525	0.261	0.286	0.269							
Competition	0.391	0.202	0.497	0.194	0.508	0.182	0.274	0.217	0.830						
Accomplishment	0.358	0.341	0.204	0.234	0.493	0.212	0.238	0.193	0.838	0.701					
Guided	0.472	0.355	0.464	0.258	0.529	0.347	0.441	0.468	0.622	0.544	0.552				
Immersion	0.305	0.312	0.279	0.195	0.528	0.155	0.303	0.227	0.684	0.463	0.549	0.568			
Playfulness	0.363	0.348	0.346	0.276	0.656	0.315	0.267	0.230	0.718	0.492	0.720	0.696	0.773		
Social experience	0.515	0.274	0.697	0.326	0.587	0.288	0.575	0.523	0.555	0.655	0.418	0.674	0.418	0.480	

Table 5 shows the results of the standardized path coefficients, associated p-values, and the 90 % confidence intervals. We can see that although three features (bio-adaptability, programmability, and audiovisual modality) among the eight wearable features were not found to be statistically associated with any of the seven dimensions of gameful experiences, the other four features (game integrability, wearability, embodied modality, modularity, sociability) were found to be statistically associated with some (or all) of the seven dimensions of gameful experiences.

More specifically, the feature of game integrability was observed to significantly positively influence all seven dimensions of gameful experiences. Specifically, the feature of game integrability was significantly and positively associated with challenge ($\beta = 0.288$, $p < 0.001$), competition ($\beta = 0.356$, $p < 0.001$), accomplishment ($\beta = 0.338$, $p < 0.001$), guided ($\beta = 0.233$, $p < 0.001$), immersion ($\beta = 0.427$, $p < 0.001$), playfulness ($\beta = 0.505$, $p < 0.001$), and social experience ($\beta = 0.261$, $p < 0.001$), respectively.

Furthermore, the features of wearability were observed to significantly increase six dimensions of gameful experiences except for immersion. Specifically, the feature of wearability was significantly and positively associated with challenge ($\beta = 0.234$, $p = 0.002$), competition ($\beta = 0.199$, $p = 0.019$), accomplishment ($\beta = 0.146$, $p = 0.064$), guided ($\beta = 0.176$, $p = 0.007$), playfulness ($\beta = 0.116$, $p = 0.093$), and social experience ($\beta = 0.200$, $p = 0.001$), respectively. However, the effect of wearability on immersion was insignificant ($\beta = 0.093$, $p = 0.102$).

Regarding the relationships between the embodied modality-related features and the seven dimensions of gameful experiences, only the relationship between embodied modality-related features and social experience was negatively and marginally significant ($\beta = -0.099$, $p = 0.078$); there was no significant association found between embodied modality-related features and any other dimensions of gameful experiences. Regarding the relationship between the feature of modularity and the seven dimensions of gameful experiences, the results showed that modularity was only significantly and positively associated with competition ($\beta = 0.226$, $p = 0.012$), and social experience ($\beta = 0.237$, $p < 0.001$). As for the relationship between the feature of sociability and the seven dimensions of gameful experiences, the results showed that sociability could significantly increase guided ($\beta = 0.135$, $p = 0.047$) and social experience ($\beta = 0.277$, $p < 0.001$), respectively.

5. Discussion

In this study, we aim to understand how different affordances of wearables are associated with heightened gameful experiences. Based on the literature review, most of the existing studies have focused on the single attribute or limited features of specific wearable devices. It is noticed that a holistic framework of generalized wearable features is still lacking, which also leads to a scarcity of empirical research on wearable features. More importantly, we identified 20 important wearable features from the scattered studies, and based on EFA results, 8 higher level constructs were further extracted, including game integrability, wearability, modularity, sociability, programmability, bio-adaptability, and audiovisuality. Although previous studies mention these dimensions in singular contexts (e.g., playful social interaction, Dagan et al., 2019a, 2019b; Abe and Isbister, 2016; modularity as a gaming feature, Buruk et al., 2018; Jung et al., 2021; close integration with game mechanics, Buruk et al., 2021), all of these studies examined those features in niche (such as Tabletop Role-Playing Games or Live Action Role Playing Games) and speculative contexts. This study presents gaming wearable dimensions in a holistic model which is based on the quantitative input of 289 users. Overall, the results imply that the extracted wearable features would differently influence the dimensions of the gameful experience. While game integrability and wearability-related features positively influenced an expected gameful experience across all or most dimensions, other affordances of wearable devices influenced gameful experience quite weakly. In the following paragraphs, we expand the discussions on these interesting and unexpected findings.

Game integrability seemed to be the most important module of wearables for leveraging gaming experiences. It represents wearables as being fully integrated with the game, meaning that the wearable can seamlessly provide interaction (through input and output) with the game and game mechanics, along with supporting role-playing and character identification. Previous research has noted that both the functionality/usability/utilitarian benefits and ease of use are positively associated with the wearable users' experiences of utilizing wearables of various kinds (see, e.g., VRSG, Herza and Rauschnabel, 2018; ARSG, Kalantaria and Rauschnabel, 2018; smartwatches, Chuah et al., 2016). Moreover, several studies focusing on role-playing suggested that wearables may strengthen the bond between imaginary characters and players (Buruk et al., 2018; Jing et al., 2017). As a study which included such a wide user-base for understanding gaming wearables, our study strongly suggests that the findings of these previous studies which were on more specialized game contexts such as role-playing games or festival games can be extended to mainstream games. These results also suggest that the potential of gaming wearables is not currently exploited by the game industry. Commercial gaming wearables that are available such as Pokemon Go Plus[8] or Adidas GMR[9] are quite limited in terms of interaction with the game (e.g., only giving simple notifications or transferring the bodily activity data to the game), and are designed for genres such as sports games. Our results suggest that a deeper connection with the game mechanics would be among the critical features of gaming wearables for player experience, and the game genres for gaming

[8] https://www.nintendo.fi/lisatarvikkeet/pokemon-go-plus
[9] https://atap.google.com/jacquard/products/gmr/

Table 5
Results from structural model (bootstrapping, sample = 2000, two-tailed test).

Path Coefficients	β	p value	90 % CI	
Wearability → Challenge	0.234 ***	.002	0.110	0.354
Wearability → Competition	0.199 **	.019	0.056	0.338
Wearability → Accomplishment	0.146 *	.064	0.018	0.276
Wearability → Guided	0.176 ***	.007	0.073	0.290
Wearability → Immersion	0.093	.102	0.007	0.192
Wearability → Playfulness	0.116 *	.093	0.003	0.231
Wearability → Social experience	0.200 ***	.001	0.100	0.303
Embodied modality → Challenge	0.033	.651	−0.083	0.160
Embodied modality → Competition	−0.101	.160	−0.212	0.021
Embodied modality → Accomplishment	0.077	.274	−0.031	0.198
Embodied modality → Guided	0.032	.601	−0.066	0.135
Embodied modality → Immersion	0.031	.613	−0.068	0.137
Embodied modality → Playfulness	−0.007	.903	−0.100	0.097
Embodied modality → Social experience	−0.099 *	.078	−0.186	−0.003
Modularity → Challenge	0.049	.552	−0.079	0.192
Modularity → Competition	0.226 **	.012	0.087	0.378
Modularity → Accomplishment	−0.122	.142	−0.245	0.022
Modularity → Guided	0.016	.803	−0.084	0.128
Modularity → Immersion	−0.047	.523	−0.166	0.077
Modularity → Playfulness	−0.043	.529	−0.153	0.065
Modularity → Social experience	0.237 ***	<0.001	0.138	0.334
Bio-adaptability → Challenge	0.015	.818	−0.097	0.120
Bio-adaptability → Competition	−0.016	.820	−0.136	0.093
Bio-adaptability → Accomplishment	0.098	.132	−0.014	0.198
Bio-adaptability → Guided	−0.003	.955	−0.111	0.094
Bio-adaptability → Immersion	0.025	.686	−0.079	0.121
Bio-adaptability → Playfulness	0.090	.117	−0.004	0.186
Bio-adaptability → Social experience	0.003	.959	−0.085	0.084
Game integrability → Challenge	0.288 ***	<0.001	0.166	0.422
Game integrability → Competition	0.356 ***	<0.001	0.207	0.499
Game integrability → Accomplishment	0.338 ***	<0.001	0.197	0.480
Game integrability → Guided	0.233 ***	<0.001	0.120	0.347
Game integrability → Immersion	0.427 ***	<0.001	0.307	0.531
Game integrability → Playfulness	0.505 ***	<0.001	0.389	0.603
Game integrability → Social experience	0.261 ***	<0.001	0.161	0.366
Programmability → Challenge	0.011	.845	−0.086	0.104
Programmability → Competition	−0.074	.243	−0.185	0.025
Programmability → Accomplishment	0.016	.788	−0.088	0.112
Programmability → Guided	0.082	.182	−0.026	0.179
Programmability → Immersion	−0.079	.169	−0.169	0.019
Programmability → Playfulness	0.064	.234	−0.025	0.152
Programmability → Social experience	−0.043	.438	−0.139	0.044
Sociability → Challenge	−0.006	.936	−0.133	0.114
Sociability → Competition	0.024	.745	−0.101	0.137
Sociability → Accomplishment	0.031	.683	−0.100	0.144
Sociability → Guided	0.135 **	.047	0.025	0.248
Sociability →Immersion	0.089	.175	−0.018	0.198
Sociability → Playfulness	−0.018	.782	−0.126	0.091
Sociability → Social experience	0.277 ***	<0.001	0.177	0.375
Audiovisual modality → Challenge	0.002	.982	−0.120	0.132
Audiovisual modality → Competition	−0.076	.257	−0.176	0.042
Audiovisual modality → Accomplishment	−0.024	.762	−0.144	0.108
Audiovisual modality → Guided	0.121	.117	−0.002	0.256
Audiovisual modality → Immersion	0.009	.908	−0.106	0.140
Audiovisual modality → Playfulness	−0.041	.528	−0.145	0.073
Audiovisual modality → Social experience	0.038	.512	−0.052	0.136

β = standard regression coefficient, CI =confidence interval.
$p < 0.1$*; $p < 0.05$**; $p < 0.01$ ***.

wearables should be extended to genres that would provide role-playing opportunities to players.

Wearability-related features were significantly associated with gameful experiences, except for immersion. Wearability is related to building quality, ergonomics, and the appearance of wearables. Wearability-related features including comfort, wearability, coolness, and fashionability have been addressed frequently in recent literature on VRSGs (Herz and Rauschnabel, 2018), ARSGs (Rauschnabel, 2018), and smart watches (Chuah et al., 2016), as the most distinguishable module of wearables attracting users when compared to other information technologies and devices (Bodine and Gemperle, 2003; Sundar et al., 2014; Chuah, 2019). This current study expanded the results to a wide range of almost all extant wearables. However, previous studies have rarely empirically investigated the associations between wearability and users' specified experiential facets regarding gameful interaction. This present study underlined that overall, wearability-related features were significantly associated with gameful experiences (except for immersion), implying that arousing users' willingness and motivations to wear and interact with the wearable products is a prerequisite for creating gameful experiences. The results imply that onboarding quickly to the game and having a comfortable and seamless experience (i.e., being easy and comfortable to wear) is a critical factor. However, fashionability and coolness are factors that quite surprisingly have an association with gameful experience. This result indicates that either players might consider gaming wearables as part of their self-expression during gameplay which is more related to role-play and mimicry (Caillois, 2001), or in out-game moments which might be associated with players' desires to present themselves with a gamer identity in public. Previous studies have speculated that gaming wearables might be used in non-game contexts to exploit the playful opportunities that lie hidden in those contexts (Buruk et al., 2021). However, the association of fashionaiblity and coolness aspects with gamefulness is a novel finding that indicates that styling wearables as gamer products might also be appealing to players and the experience they have. As for the exception that wearability did not seem bring an immersive feeling, one possible explanation is that the feeling of being immersed is more related to users' interactive experiences during the specific activities (e.g., when playing games) (Högberg et al., 2019), rather than the experience of using a certain device regarding wearability.

Sociability only significantly increased social experience and guided dimensions of gameful experience. Sociability has been highlighted in previous research as a prominent wearable feature (Rauschnabel, 2018). However, in the gaming context, this current study found that sociability's effect was limited in increasing only two experiential dimensions (social experience and guided experience). The fact that sociability enhances social experience is natural and explicit: sociability-related features can help players present themselves to others and facilitate communication with others. As being guided in a game means that the game has sufficient cues that let players understand how to proceed and how to play the game (Högberg et al., 2019), the association of sociability and guided experience might lie in the "presence" of a guide, or that users could have considered wearables as devices that would provide the guidance of a teammate (e.g., in online strategy games).

Modularity-related features only significantly affected social experience and competition. Modularity is mostly about the physical and functional design of wearable devices. However, when it comes to playful interactions, some of the ideas of using these kinds of modular devices included sharing different modules with other players as game-related items. Therefore, modularity has also been seen as a source of social experiences in gameful contexts by players, and gaming wearable designers might also consider modularity as the source of social game experiences, and not only as a functional aspect of devices. In addition, modularity could also positively influence the competition construct of gameful experience. This result needs further elaboration because the relationship between modularity and competitive game mechanics is not apparent. However, it is possible that the users might have associated specific modules with in-game skills that can gain them a competitive advantage. In the survey, modules of the devices were associated with the activation of specific skills, and this has also been implemented in previous research (Buruk and Ozcan, 2018; Buruk et al., 2021; Jing et al., 2017; Jung et al., 2021). Therefore, some of these modules might be associated with superior in-game powers, and this finding suggests that modular wearable devices, the modules of which can be mapped to in-game skills, can also be customized for competitive games. For example, players with specific modules or with multiple instances of the same modules might have more powerful characters. Although previous studies have associated modularity with adaptability and flexibility for covering a wide range of game genres (Jung et al., 2021), its relation to competition has not been raised in any of the previous work on gaming wearables, and this result suggests that one preferable way of using gaming wearables can be to position them as "on-body" vessels that can be adorned with collectables which provide a competitive advantage to players.

No significant correlations were revealed between embodied modality-related features and most gameful experience dimensions Generally, embodied modality-related features such as gesture, touch control, and tactile feedback can provide advanced interaction concepts for games (Faust and Yoo, 2006). However, this kind of implicit feedback (Faust and Yoo, 2006) may not have decisive impacts on gameful experiences. It can also be observed that embodied modalities may have a negative effect on social experience. One reason behind this might be that haptic feedback technologies such as force or tactile feedback enhance the player's own physical experience, thereby reducing group awareness and social relatedness. Moreover, previous studies also suggest that embodied interaction modalities such as gestural interaction might be the source of social awkwardness, and users can be hesitant to use such modalities in public environments (Havlucu et al., 2017). Similarly, touch interaction might be perceived as an interaction method that will direct the attention of the user to the device and might create more artifact-oriented interaction (Buruk et al., 2019), and thereby hinder social experiences.

Audiovisual modality, bio-adaptability, and programmability had no effect on any dimensions of gameful experiences. Noteworthy is the fact that the audiovisual feedback modality is mentioned as a prominent influencer, especially for users' immersion experience (Rauschnabel, 2018). However, in the gaming context, users might have found the feedback types included in this construct too broad or too abstract to be evaluated by just their imagination. Besides, considering users' increasing desires for reality enhancement (profoundly facilitated by advanced audiovisual modalities), auditory and visual modalities were prevalent in almost all of the presented wearable devices, yet they might not meet users' satisfactory standards, and thereby might not be perceived as strong features that can make any difference in terms of gameful experience and so need more longitudinal data for a comprehensive analysis of its impact on player experience (Karaosmanoglu et al., 2021; Rogers et al., 2018). When it comes to bio-adaptability, we believe that users did not think that using body data such as heart rate, breathing level, brain signals, or stress level would be effective in terms of increasing the game experiences directly. A previous comprehensive study on using bio-adaptive features in games also suggests that bio-feedback might be associated with more subtle game elements such as background animation, rather than the mechanics directly affecting the game outcomes (Nacke et al., 2011). Thus, a wearable that provides only bio-adaptability for controlling games might not be preferable for players. Programmability might have been interpreted as a non-game function because it mostly concerns an activity that remains outside of gameplay (e.g., Tran et al., 2020). Moreover, although programmability can lead to versatility, versatility mostly means the ability to play a variety of games, rather than referring to experiences that can be obtained by one game. Thus, it might not have been associated with a particular gameful experience.

Additionally, a reason those feature categories could not improve users' gameful experiences might lie in the risks that those features might potentially bring up. For instance, bio-feedback could enhance the impact of privacy and data collection, eliciting risks for abusive usage of personal data (Chuah, 2019). In regard to programmability and the audiovisual modality, opening the programming utilizing audiovisual devices like cameras and microphones might also challenge the privacy and security of other people (Rauschnabel, 2018).

6. Contribution and implications

6.1. Research contribution

First, the study contributes to the research field of wearable technology and design by providing valuable empirical evidence on which wearable features are important and significant for gameful experience, from a holistic perspective. More importantly, the study conducted a granular analysis and statistically explored the relationships between eight categories of wearable features extracted from existing literature and supported by empirical evidence, and seven dimensions of gameful experiences. 20 important features were clustered into eight different categories of wearable features which offers to date the most comprehensive framework identifying wearable features for playful wearables. The results based on 289 users reveal important findings regarding the role of wearable features in gaming experience, which contributes to wearables and game-related research fields. The most similar existing attempt at understanding the dimensions of gameful wearables is the design framework developed by Buruk et al. (2019) which examined wearables through three planes; performative, social and interactive. Compared to this work, we unpack the relationship between a comprehensive set of gaming wearables features and the different dimensions of gameful experience. Our contribution is complementary to the design framework of playful wearables which aims to be generative and inspirational by introducing different design spectrums, while our study helps describe the experiences that can be induced by certain gaming wearable features in a more detailed way. Our contribution can be beneficial for researchers who design and develop gaming wearables while determining their possible features and their possible impact on the player experience.

Our results also show that game integrability-related features could positively affect players' experiences in gaming to a large extent, and reveal the missing opportunities in commercial wearables with regards to their thin integration with game mechanics and being limited to genres such as bodily- or sports-oriented games. Wearability-related features representing comfort and self-expression add to the previous work by suggesting that a styling of wearables that would reflect the gamer identity in public settings can improve the post- or pre-game experiences (Calleja, 2011) of players, and that genres including role-playing can be suitable foci for gaming wearables.

Modularity and sociability-related features were positively associated with social experience, indicating that wearables might be exchanged among players for swapping skills which can also provide competitive advantages. Unexpectedly, embodied modality-related features would seemimgly decrease social experience. In addition, features including audiovisual modality, bio-adaptability, and programmability did not significantly influence any dimensions of gameful experiences. We believe that our attempt to interpret the relationships between gaming wearable features and gameful experience can help us to understand the possible underlying reasons why certain features can affect game experience in different ways, and this can drive the further development of wearables for gameful purposes.

Second, the validity and reliability of the gameful experience scale (GAMEFULQUEST) were re-examined in the study of evaluating different wearables in gaming based on the data of 289 users. As a relatively new instrument for measuring perceived gamefulness, GAMEFULQUEST requires more empirical studies to develop its generalization and robustness. According to the results of this study, most measurements for the seven dimensions of gameful experience in the research context of gaming wearables were found to be valid and reliable.

Last but not least, this study provides vignette research design guidance for use in future research in user evaluations towards wearables, products, services, systems, etc. The vignette method which was used in this study presented different hypothetical situations to respondents for eliciting their judgments and evaluations of using wearable products in gaming. Obviously, many traditional surveys and experimental designs hardly maintain high internal validity and external validity at the same time. The vignette method combines traditional survey and experimental design with all their advantages (Engelmann, 2017). In this study, we designed sixteen concrete and detailed scenarios of using wearables while playing games. After seeing the picture, and reading the text-based description and proposals of using one of the wearable products for playing games, each respondent was asked to evaluate 20 aspects of the presented wearable product and their expectations of gamefulness. We encourage future research to adopt the vignette research design to empirically investigate user experience, besides traditional survey and experiment methods.

6.2. Practical implication

The interesting findings from this study also provide implications for product developers, designers, and marketers in both the wearable and game industries. According to the empirical evidence, gaming wearable designers should pay more attention to the design and use of game integrability-related features and wearability-related features, since they influence almost all of the dimensions of the perceived gaming experience. This means that for providing a heightened gameful experience, wearables should be configured as additional controllers and feedback devices that can affect and be affected by the game content, seamlessly integrated into controls, and connected to the identity of imaginary characters. The problem of having a thin integration with games has been previously mentioned by the game press, for example in the review of the Real Pip-Boy.[10] However these observations were never confirmed by an empirical study. Also, material and esthetic properties such as comfortable placement, coolness, fashionability, and flexibility are prerequisites for an increased gameful experience, which also indicates that the self-expression of players can be an important part of the gameful experience, and which further indicates role-play possibilities during gaming and presentation of a gamer identity beyond gaming moments. Therefore, especially for practitioners who are constrained by economic costs, the design and investment of these two main wearable features can largely be seen to attract the majority of consumers of gaming wearables. Interestingly, features related to bio-adaptability, programmability, and audiovisual modality seem to have neither negative nor positive influences on the perceived gameful experience. Thus, gaming wearables designers should consider these features carefully when looking to provide additional value to consumers; for example, whether these features may increase the purchase cost and reduce usability. More importantly, given that embodied modality-related features may bring potential harm to the social experience, such features may be more applicable for those wearables that do not aim at providing social value.

The results from this study can also contribute to other non-game fields such as health management, daily personal assistance, the workplace, and education, which are now aiming to provide game-like experiences (for a wider view of gamification, see Koivisto and Hamari, 2019). Many manufacturers of wearables such as the Fitbit watch are looking for ways to provide successful wearable-based gamified services and systems in non-game contexts. However, there are a lot of concerns about the practical failures of gamification in that these services and systems hardly bring strong game-like experiences (Xi and Hamari, 2019). This study provides useful guidance on how to use different wearable features to evoke gameful experiences which further motivate users to engage in using services and systems. Therefore, wearable designers could select and use different features in accordance with the expected dimensions of gameful experiences. For example, in order to lead to a high social experience, designers and developers might consider widely using sociability, game integrability, modularity, and wearability-related features when designing wearables.

7. Limitations and future directions

Even though the vignette-based survey study was carefully designed, there are still a few limitations that should be acknowledged. The vignette study has been considered as a suitable approach to address the research question of how wearable device features influence different dimensions of gameful experiences. By following the guidelines proposed by Wason et al. (2002) the validity and reliability of the survey were ensured. However, the imaginary experience of using these wearables for playing games in hypothetical scenarios might still be different from real-life experiences of using the presented wearables. If the research conditions allow, future researchers can consider conducting laboratory experiments in which participants can physically interact with wearables to increase the internal validity by using existing wearable products which are available on the market, or designing and developing suitable prototypes as experimental materials. In the laboratory environment, other biological, psychophysiological and interview data can also be collected, and compared with self reported answers. In terms of other research questions in wearable research such as understanding the personal opinions of using a specific gaming wearable and exploring new wearable features and functions, qualitative methods such as in-depth interviews, workshops and focus groups can be considered by future researchers.

As an additional consideration, in this study, the participants were recruited online through the Mechanical Turk platform which might lead to issues of respondent bias. Firstly, research has shown that MTurk workers can differ from the general population, in that they are generally more educated, but more likely to be unemployed and less religious (Goodman et al., 2013; Lim et al., 2021). Secondly, 77.2 % of the investigated respondents in this study were from the US. As a consequence, the findings may not be fully generalized to general gamers and consumers; and might also be limited to samples from a Western cultural background. Cultural factors have been shown to play important roles in influencing consumers' preferences and acceptance of wearables (Dunne, 2010). Thus, the findings might be more applicable to gamers and consumers influenced by Western cultures. Future research could take cultural differences into consideration and conduct cross-cultural comparative studies. For example, theories such as Geert Hofstede's five dimensions of national culture (Hofstede, 2001) and Guanxi (Luo, 1997; Park and Luo, 2001) can be used to investigate the differences between consumers under Eastern cultural contexts and Western cultural contexts.

In this study, in order to answer how wearable features may differentially influence gameful experiences, only the direct effects were empirically examined. It should also be noticed that variables such as demographic factors (e.g., gender, age, income, user preference), game-related factors (type of game and gaming experience), personality, and prior knowledge of using wearables might differentiate the influence of wearable features on gameful experiences. Thus, future research can consider conducting a more granular analysis related to user characteristics and other potential moderating variables, so as to expore the possible boundary conditions such as how, when, where, and why wearable features have different effects on gameful experiences. In addition, in this study, the behavioral outcomes were not included as

[10] http://www.trustedreviews.com/opinion/why-the-fallout-4-pip-boy-edition-is-a-huge-disappointment-2926374

study factors which might be important and valuable for marketers and practitioners. Particularly, factors such as intention to use, willingness to purchase, word of mouth, and highest affordable price (price premium) can be added into future research models.

CRediT authorship contribution statement

Nannan Xi: Conceptualization, Methodology, Validation, Investigation, Writing – original draft, Writing – review & editing. **Oğuz 'Oz' Buruk:** Investigation, Methodology, Data curation, Writing – review & editing, Project administration, Funding acquisition. **Juan Chen:** Investigation, Methodology, Writing – original draft, Visualization. **Shiva Jabari:** Writing – original draft, Writing – review & editing. **Juho Hamari:** Conceptualization, Methodology, Resources, Writing – original draft, Writing – review & editing, Supervision, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix A. Sixteen wearable product vignettes used in the current study

Product name	Description
Emotiv 	EMEMOTIV EPOC+ 14 channel mobile EEG is designed for scalable and contextual human brain research and brain-computer interface applications and provides access to brain data. This device is worn to head and can detect mental commands, performance metrics or facial expressions. For example, users can concentrate on moving a ball in the screen and the device can transfer this information to a computer to move the digital ball inside the application. Other than that, via this device, information about the wearer such as emotional state or performance metrics during physical activity can be collected.
Focals smart glasses 	Focals are smart glasses that were designed to show notifications and also take over some of the tasks that we realize usually by using our smartphones. They can show messages, e-mails, weather conditions or navigation information. Focals are equipped with Amazon Alexa, which is a smart assistant that you can give commands by using your voice. Therefore, you can activate most of the tasks with voice commands. Other than that, Focals also includes a ring which you can use for realizing basic commands such as next-previous by using hand gestures.
Myo 	The Myo armband lets you use the electrical activity in your muscles to wirelessly control your computer, phone, and other digital technologies. Myo can detect 5 different hand gestures by analyzing your muscle strain when performing these gestures. These gestures are waving the hand to left or right, double tapping by hitting the thumb and the middle finger to each other, making a fist and spreading the fingers. Moreover, with its accelerometer, you can also use your arm as a pointing device such as a mouse. MYO is worn to the arm and 5 gestures can be assigned to different kinds of actions. For example, by waving your hand right user can pass a slide in a presentation or by making a fist the sound of a device can be muted.
Nubia alpha 	Nubia Alpha is a smartwatch, which also supports e-sim for giving calls, with a vertical 4-inch flexible display. It's a multifunctional device with a customized operating system based on android. It features touch controls over the flexible display and also gestural controls by using its cameras for actions such as swipe. Nubia functions like a smart phone and incorporates many different applications such as heart rate and step tracking, timer, checking and sending messages, 5-megapixel camera or marque features which let users put a message to display for others to see.
Nex band 	Nex Band is a modular wrist worn device. Its modules can detect touch can be swapped and programmed to many different actions. For example, one module can give a notification in a specific color when a message from a particular person is received. Or, users ncan program a particular set of colors and patterns that will be shown by the Nex Band, when the dedicated action is triggered in the connected device such as a smartphone, tablet, etc. Another example can be these modules can be programmed to be a music controller when double tapped on one of them. When they function as music controller one module can become the pause/play button while other two can function as volume buttons
Blocks 	Blocks is a modular smartwatch which you can customize by changing its modules such as battery, accelerometer, temperature sensor, heart rate sensor, etc. It runs on the Android operating system and functions as a smart watch with the addition of modularity. Users can customize Blocks according to their needs. If they to a trip in which they need more battery life, they can change particular sensors with batteries. If they use it for workout they can attach heart rate monitor.

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Product name	Description
Xenxo ring 	Xenxo smart ring is a ring that connects with your phone and lets you do actions such as checking notifications, answering phone calls, file transfer, unlocking your phone, making payments and tracking body data. It also features gestural modality to control other devices such as TV by using hand gestures.
HaptX 	HaptX is a smart glove that is designed to be used in virtual reality applications. It tracks the hand and the finger movements to transfer them to the VR environment. Moreover, it also provides haptic and tactile feedback to make users feel objects in the virtual worlds. For example, if users touch a cube in the Virtual Reality environment, HaptX gives vibration feedback and also force feedback that stops the fingers of the users as if there is a real cube they are touching.
Foci 	FOCI is a device that tracks breathing patterns and learn from those patterns by using machine learning algorithms to help users to better focus on their tasks. It is attached to the waist by being clipped to the edge of the pants. It works connected to another smart device and is controlled over an app. FOCI gives users a detailed analysis of hours and days that show how focused/concentrated users were in specific intervals. In that sense, it aims to teach its users their most productive moments in a day so that they can schedule tasks accordingly.
Google Jacquard 	Google Jacquard is a commuter jacket designed by Levi's particularly for commuters who ride a bike. It has a Bluetooth module to connect to the smartphone of the user. The lower part of the left sleeve includes conductive threads which can be used as a touch area. After connecting to the phone, users can control their phones by performing gestures on the lower sleeve of the Jacquard. For example, users can program swiping down gesture to skipping songs. Jacquard supports four gestures which are swipe down, up, tap and hold. Bluetooth module attached to the lower part of the sleeve can be removed for washing the jacket.
BCON 	BCON is a wearable device that is worn to the feet of the users. Users can define four feet gestures which are rolling left/right and pitching up/down. These gestures can be mapped to different keys or key-combinations or macros. Users can map their feet movements to a variety of actions by using the related key combinations by using its software. For example, users can map pitching up their feet to CTRL+*Z* to use this gesture for undoing commands in applications. BCON communicates states and key recognition by using LED-light feedback and haptic feedback.
Nike adapt BB 	Nike AdaptBB is a smart shoe that tracks the steps of the user. Moreover, it also arranges the fit of the shoes automatically. Shoes connect to a smartphone and users can track their steps over an app and also by using the same app they can change the fit of their shoes. For example, users can choose "tight" from the app to make the shoe fit tighter to their feet.
Tesla suit 	Tesla suit is full-body smart clothing apparel with Haptic Feedback, Motion Capture, Heat Control and Biometric Feedback systems. Therefore, it aims to provide full-body tracking and biometric tracking to transfer all the body data to the virtual environment while also giving back haptic and temperature feedback to make the user feel the events and the atmosphere of the virtual environment as realistically as possible.
Misfit bloom 	Misfit Bloom is an activity tracker and sleep monitor that features an LED-based progress definer and time telling. The round tracker module is fully waterproof and built with aircraft-grade aluminum. It connects to a smartphone to give detailed information about your activity in a day. It also shows how much you progressed in your target with the LED lights equipped in the form of a circle. For example, if users completed 25 % of their daily target, quarter of the circle will be lit. Other than that, when double tapped it shows the time of the day.
Bragi dash Pro 	Bragi Dash Pro-earphones are wireless earbuds that has built-in memory, amazon alexa smart assistant and touch controls. It also measures heartrate, speed, footsteps and breath to track your performance during workout and doing sports. Since they are waterproof they can be used underwater while swimming. Users can give voice commands to Alexa such as asking for directions or requesting a Uber.

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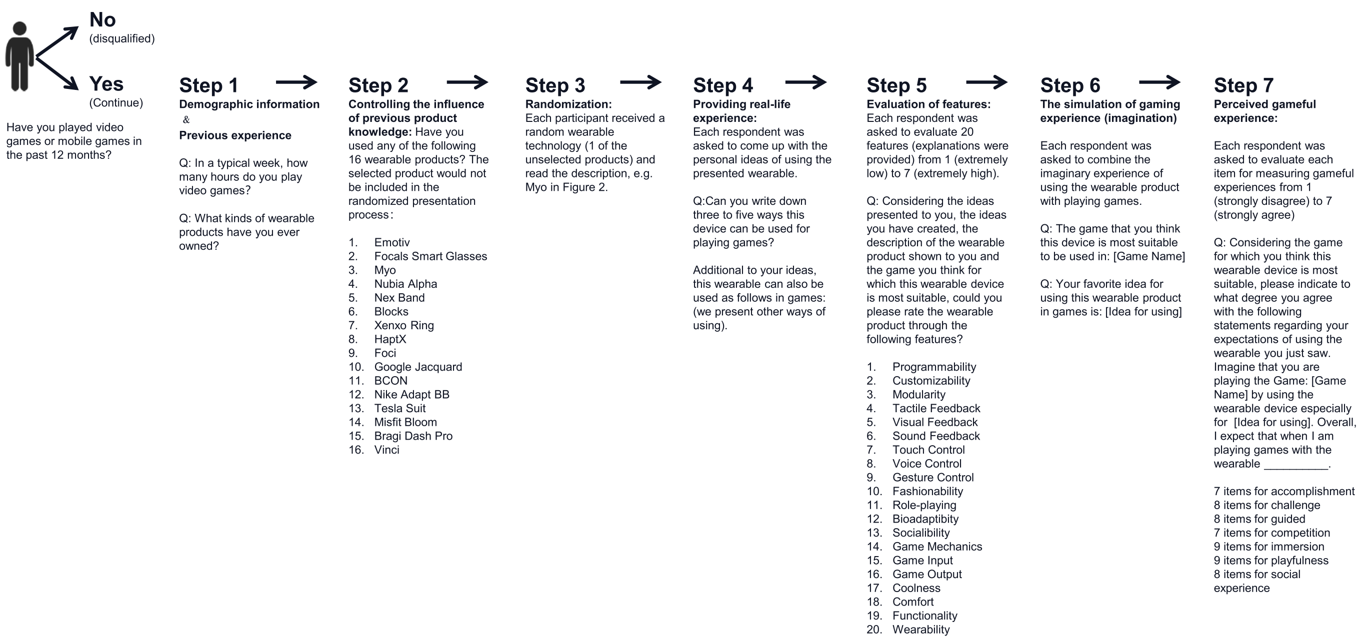
Product name	Description
Vinci 	Vinci Headphones are equipped with a touch display and an operating system on which you can play your music and give various commands to a smart assistant, Amazon Alexa. It can connect to services such as Spotify or Soundcloud without needing any external device. Its display, apart from controlling the settings, can show a music visualizaer, name of the song or a message which users can choose to show. It also tracks the heart rate of the user to propose personalized playlist according to the activity and location of the user and the time of the day.

Appendix B. The vignette study design (Flowchart)



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