Enhancing User–Game Engagement Through Software Gaming Elements

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Abstract: User–game engagement is vital for building and retaining a customer base for software games. However, few studies have investigated such engagement

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Journal of Management Information Systems / Spring 2014, Vol. 30, No. 4, pp. 115–149.

ISSN 0742–1222 (print) / ISSN 1557–928X (online)
DOI: 10.2753/MIS0742-1222300405

during gameplay and the impact of gaming elements on engagement. Drawing on the theoretical foundation of engagement, we meticulously deduced two cognitive-related gaming elements of a software game, namely, game complexity and game familiarity, and argued that these elements have individual and joint effects on user–game engagement. This research adopted multimethod empirical investigations to validate our conceptions. The first investigation used electroencephalography and a self-report survey to study quantitatively the cognitive activities of user–game engagement. The second investigation adopted the qualitative interview method to triangulate the findings from the quantitative data. This research contributes to theory in two ways, namely, conceptualizing and empirically examining user–game engagement as well as theorizing and demonstrating how the two gaming elements affect user–game engagement. This work contributes to the gaming practice by providing a set of design principles for gaming elements.

KEY WORDS AND PHRASES: electroencephalography, NeuroIS, online games, software games, user–game engagement.

USER–GAME ENGAGEMENT IS THE EXTENT TO WHICH A SOFTWARE GAME cognitively immerses users into the game during gameplay. It is an important indicator of the success of building and retaining a customer base for a software game [16]. Software game refers to an application installed and played in an electronic device such as a smartphone. User–game engagement is a vital factor for a company in pursuit of success in a highly competitive gaming market, in which hundreds of companies compete for a share in the market worth $5.3 billion in 2010 [3]. Companies must find ways of enhancing game design to entrench user–game engagement and to survive the competition [57].

Aside from the hot pursuit of user–game engagement in the software game industry, traditional nongaming companies are becoming increasingly interested in introducing software games to foster a closer relationship with their customers. This phenomenon is best echoed by Volker Hirsch, Chief Strategy Officer of Scoreloop: “What happened in recent years is that brands have realized the stickiness—or, as they would call it, engagement—games provide. People finally noticed that it is not only pale loners playing games but virtually everyone.”[1] However, users are likely to remove a software game from their devices with ease when they are not enticed (i.e., mentally engaged) into playing the application [34]. This abandoning behavior is devastating for companies seeking to establish brand image and conducting marketing campaigns [50].

In contrast to the solutions of practitioners, academic efforts toward empirical investigations on user–game engagement in software games have been limited [17]. Two plausible reasons can explain this shortage. First, prior research has centered on examining the antecedents of the motivations for playing games, such as psychological needs, norms, and utilitarian needs [52]. However, investigating the highly abstract level of perceptual constructs is distant from the fundamental design issue of a game [63]. Such investigation is not in line with recent research on user–game engagement, which argues that engagement is shaped during gameplay [44]. An investigation method with good temporal resolution to understand the differences of various gaming element implementations is also lacking [33, 41]. User–game engagement involves users playing with a game application; in this sense, measuring engagement only after the game is played might not present a complete picture. In other words, user–game engagement is a "process-oriented" construct, which may not be best reflected solely through retrospective measurement such as a self-report survey.

Second, researchers have generally agreed that a well-designed game can enhance user–game engagement [40]. However, a game differs in several aspects, such as complexity, which renders its conceptualization theoretically challenging. Prior research has provided few insights into the gaming elements [16]. This limitation is best understood by the mixed views of the prior literature from our literature review. For instance, some scholars found that competence, autonomy, and relatedness are the three necessary and basic perceptual manifestations of user–game engagement [63], whereas others argue that enjoyment, satisfaction, and involvement represent user–game engagement [19]. The thrust of these studies is on the adoption of a perceptual perspective to inform the design of a game, but such acquired knowledge may not be practical for direct applications.

Anchoring on the theoretical foundation of engagement, we propose a new conceptualization of user–game engagement and the consideration of two primary cognitive-based gaming elements that can potentially affect game engagement: game complexity and game familiarity. Game complexity refers to the extent to which the game demands human cognitive capacity [4]; game familiarity reflects the degree to which a user is familiar with the schemata of a game [50]. We propose these gaming elements by inferring from prior studies that a cognitive approach is of paramount importance in studying user–game engagement and in the game design that facilitates such an engagement, which is how a game is perceived and played [7, 26]. We argue that these gaming elements can invoke cortical activities in the prefrontal cortex, and thus lead to engagement [56].

In this paper, we conduct sequential multimethod investigations involving quantitative and qualitative empirical studies: (1) a quantitative investigation using electroencephalography (EEG) and a self-report survey to investigate quantitatively the neural activities and perceptions generated from playing software games, and (2) a qualitative interview to triangulate the findings from the quantitative data. Our findings contribute to knowledge in three ways. First, our study proposes and empirically validates gaming elements as important determinants of user–game engagement. Such examination of gaming elements is rare in the prior literature and is important for software game designers. Second, the current paper conceptualizes user–game engagement from the process-oriented and game design perspective, as opposed to measuring user–game engagement after gameplay (e.g., post hoc survey). Third, EEG is adopted and supplemented by other traditional postgame data collection methods. The multimethod approach allows us to triangulate and better understand the relationship between gaming elements and user–game engagement.

Research Background

In this section, we review the extant literature on user–game engagement and cognitive-related gaming elements.

User–Game Engagement

Researchers note that user–game engagement is a process-oriented variable. This "process-oriented" perspective is best reflected in a study by Jennett et al. [44] on game engagement in the desktop gaming context. They found that game engagement significantly influences the psychological process of immersion as a result of gameplay. With this perspective in mind, we review the extant literature on user–game engagement. Three primary research streams are related to the topic of game engagement [10]. Table 1 summarizes these research streams.

The first research stream examines user–game engagement from the motivational standpoint [52, 62]. Essentially, this research stream proposes that the intrinsic purpose of satisfying various needs can drive an individual to play a game. Following the self-determination theory, Przybylski et al. [63] found that competence, autonomy, and relatedness are the three basic requirements for game engagement. Other studies proposed another list of needs that includes psychological needs (e.g., need for challenge and competence), utilitarian needs (e.g., time and seeking of information), and social closeness (e.g., social reasons and norms), suggesting that these needs may be key determinants of the intrinsic motivation to feel engaged in a game [71]. In this research stream, game engagement is often conceptually equivalent to a user's decision to play a game, which is an "outcome-oriented" rather than a "process-oriented" variable [63].

The second research stream examines game engagement from the perspective of user perception, such as enjoyment, satisfaction, and involvement [59]. The central premise of this research stream is that if game-related characteristics result in a user experiencing joy and pleasure from playing a game, then the user is likely to be engaged in this game. Jennett et al. [44] investigated game engagement with the immersion concept during gameplay, an approach that is closer to our conceptualization of game engagement as a process-oriented variable. The majority of studies in this research stream typically adopt a self-report survey as the research methodology by identifying factors that influence users' cognitive status.

The third research stream emphasizes the utilization of neurophysiological measurements to investigate game engagement [9, 27]. From this neurophysiological perspective, game engagement can be reflected in the density of theta oscillations from the left side of the dorsolateral prefrontal cortex (DLPFC) [15]. This area on the left side of the prefrontal human brain serves as the highest cortical area responsible for creating thoughts, perceptual consciousness, and attention [47]. The theta oscillations of this area are associated with environmental information processing (e.g., declarative and episodic memory processes) and sense identification (e.g., successful memory encoding) [67]. Several studies have examined the correlation between the

Table 1. Research Streams on Game Engagement and Research Design

Research stream	User–game engagement-related concepts	Related to gaming elements?	Research method	Papers reviewed
Motivational perspective	Antecedent: competence, autonomy, relatedness	No	Survey	7
	Antecedent: psychological needs, utilitarian needs, social closeness	No	Survey	6
Cognitive status of being	Associated factor: enjoyment, satisfaction	Plausible; not clear	Survey	5
	Associated factor: immerse, involvement	No	Survey/ experiment	4
Neurophysiological responses	Associated factor: cerebral cortex activities	No	Experiment	3
	Antecedent: game design, control	Plausible; not clear	Experiment	2
Total				27

cortical activities in the left side of the DLPFC and the cognitive/emotional behavior of individuals [11]. These cortical activities can be captured by EEG [32].

The use of EEG data to interpret user–game engagement is grounded on prior literature [18, 47]. EEG data, such as data from alpha and theta oscillations, are used to examine user attention and immersion [18]. Specifically, studies on attention deficit hyperactivity disorder support the use of theta oscillation data to examine adult attention [20]. User immersion refers to “the sensations of being surrounded by a completely other reality that takes over all of our attention” [55, p. 68]. When users feel immersed in gameplay, they usually receive environmental information that they process to generate the “status of being” [17]. During this process, cortical theta oscillations are associated with environmental information processing (e.g., declarative and episodic memory processes) and sense identification (e.g., successful memory encoding). These cognitive processes are the building blocks of user perception such as immersion [67]. Building on the link of “immersion,” we thus extend the association of cortical activities in the left side of the DLPFC to user–game engagement.

Other EEG data, such as alpha oscillation data, can indicate cortical activities in the left side of the DLPFC as well [67]. Alpha oscillation data are indicators of the perception of “happiness” [47]. Such emotional valence cannot represent game engagement for two reasons. First, happiness is a kind of pleasant feeling [41]. This emotional sense may not be the cognitive immersion of the game by which we conceptualize user–game engagement in the present paper. Second, happiness may be endowed before a game is played. Hence, we cannot ascertain whether such happiness derives purely from gameplay.

Software Gaming Elements

A game is made up of gaming elements [26]. Our review of the extant literature on game design has drawn our attention to two key gaming elements: game complexity and game familiarity [50]. From a cognitive standpoint, game complexity refers to the extent to which a game demands human cognitive capacity [4] while game familiarity refers to the extent to which a user is metaphorically conversant with the game schemata [50].

Game Complexity

This concept captures the essence of intellectual calculation and motor activity consumption during gameplay (e.g., avatar control, objective recognition, and in-game object maneuverability). For instance, high game complexity means that the game has difficult avatar control and that the game objective is difficult to identify.

Studies found that the higher the level of game complexity, the greater the difficulty a user experiences in operating the game [66]. From the neurophysiological perspective, game complexity is highly associated with intensive cortical activity in the left side of the DLPFC, which denotes thoughtful planning and comprehension [18]. For example, a high level of game complexity requires users to expend more effort mentally calculating, planning, or devising a strategy during gameplay. Although a debate exists over whether a high level of game complexity results in poor gameplay performance [59], scholars generally conclude that game complexity has a significant impact on gameplay performance and game operationalization [74].

Game Familiarity

Our paper defines game familiarity as the extent to which users recognize the schemata of a game, in contrast to other studies that define game familiarity as prior knowledge of the game [50]. For example, the schemata of the game Need for Speed revolve around car driving (i.e., from driving a car on a highway to driving a car downtown). When users have a high level of familiarity with this game, they perceive the car-driving schema of this game as being relatively conversant because they can instantly associate their car-driving experience with the schema of the game.

From the neurophysiological perspective, game familiarity is prone to inert cortical activities in the left side of the DLPFC [25]. When users have a high level of game familiarity, they are familiar with the schemata (e.g., plot and scenario) of the game. As a result, they do not need to process game plot information. Inert cortical activities will then be saturated in the left side of the DLPFC [11]. Otherwise, users must

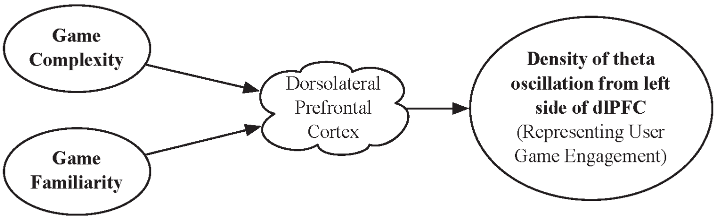

Figure 1. Research Framework

mentally work on the processing of external stimuli and become familiar with the plot of the game. For example, the plot of the software game James Bond 007: Night Fire is about sneaking into enemy headquarters, stealing top-secret documents, killing people, and detonating explosives. Most users are not familiar with these game plots. Hence, users need to respond to these external stimuli by cognitively processing the upcoming game plot and scenario.

Theoretical Lens and Hypotheses Development

Figure 1 shows our research framework. This paper is anchored on the theoretical foundation of engagement to develop its hypotheses. Engagement is an established concept in the neurophysiology discipline [15], which is also increasingly being used in information systems (IS) research [1, 8, 73]. In prior studies scholars used neuroscience techniques such as EEG to investigate engagement [36]. They found that information from the external world can invoke cortical activities in the prefrontal cortex, and thus lead to engagement [56]. In the same vein, we argue that game complexity and game familiarity can serve as incoming information for the game player. This information will activate the top-down control/bottom-up control activity in the left side of the DLPFC [72]. As a result, by measuring the density of theta oscillations from the left side of the DLPFC we can examine the user–game engagement [5, 6].

Our study adopts the density of theta oscillations from the left side of the DLPFC to demonstrate the "process-oriented" perspective of user–game engagement [61]. In particular, a reduction in the density of theta oscillations from the left side of the DLPFC represents an increase in game engagement [13]. The rationale of this negative association is established by the theorem that states that when users process information, two kinds of cortical activity take place [18, 47]. The first kind is top-down control activity, such as mental calculation, purposeful planning, and reasoning. Top-down control activity can inhibit users from being mentally immersed into the gaming process by consciously executing high-order information encoding that prevents user–game engagement [18]. In the case of a game that requires strong maneuverability skill, users must focus on game control activities that prevent them from getting into the game itself.

The second kind is bottom-up control activity, which refers to sensation-invoked response behavior such as attention seeking and attraction [13]. Bottom-up control activity can strengthen immersion in games by subconsciously reacting to external information from the game [18]. Consequently, users can completely immerse themselves in the game and play with the game per se. When the top-down control activity becomes strong, the density of theta oscillations from the left side of the DLPFC increases [67]. When the top-down control activity is weak, the bottom-up control activity prevails in the left side of the DLPFC [18]. These two types of activity constitute cortical activity in the left side of the DLPFC [11]. At one end are the high-density theta oscillations, which indicate low user–game engagement typically characterized by strong top-down control activity and impedance of bottom-up control activity [12]. At the other end are the low-density theta oscillations, which indicate high user–game engagement represented by weak top-down control activity and intense bottom-up control activity.

Game Complexity (Main Effect)

Game complexity is a prominent gaming element that can potentially influence user–game engagement [26]. Buschman et al. [18] posited that game complexity can invoke a top-down control activity in the left side of the DLPFC. Similarly, Gevins et al. [38] demonstrated that the provision of difficult tasks of different levels can trigger top-down activity. Gundel et al. [39] conducted a laboratory experiment to illustrate the activation of cortical activity in the left side of the DLPFC when a user is faced with external information (e.g., a difficult task requiring mental calculation). Garris et al. [37] found that game complexity can induce users to focus on comprehending and processing cognitive information during gameplay, thereby increasing cortical activity. Based on these findings, we posit the following hypothesis:

> *Hypothesis 1: A lower level of game complexity results in a lower density of theta oscillations from the left side of the DLPFC (i.e., higher user–game engagement).*

Game Familiarity (Main Effect)

Game familiarity can negatively influence the density of theta oscillations from the left side of the DLPFC, unlike game complexity that intensifies top-down control activity. Spilich et al. [70] found that users with more schematic experience of baseball can outperform users with no schematic experience of the game in comprehending a television drama about baseball. They concluded that cortical activity in the human brain is limited in capacity. If users have a low level of familiarity with the schemata of the baseball game, users need to process information on the schemata of the game (a kind of top-down control activity). Otherwise, fully understanding the baseball game will be difficult for them. In this regard, we argue that a high level of game familiarity does not invoke top-down control activity in the left side of the DLPFC to mentally construct the context and plot of a game [72]. Consequently, the density of theta oscillations from the left side of the DLPFC should be low. Thus, we posit the following hypothesis:

> *Hypothesis 2: A higher level of game familiarity results in a lower level of density of theta oscillations from the left side of the DLPFC (i.e., higher user–game engagement).*

Game Complexity and Game Familiarity (Joint Effects)

Scholars have argued that cortical activities in the left side of the DLPFC are mutually exclusive for cognitive-related external information, such as game complexity and game familiarity. Taking a game with a high level of game complexity and a low level of game familiarity as an example, the high level of game complexity can invoke strong top-down control activity. In addition, the low level of game familiarity will require users to strive to process information on the schematic formation of the game. Consequently, such a combination results in the highest density of theta oscillations from the left side of the DLPFC.

When users play a game with a combination of a low level of game complexity and a high level of game familiarity, the low level of game complexity can invoke weak top-down control activity in the left side of the DLPFC. Such a level of game complexity will result in low-density theta oscillations from the left side of the DLPFC [12]. A high level of game familiarity also requires low activation of the top-down control activity in the left side of the DLPFC to formulate the schemata of the game [72]. In this regard, the overall cortical activities in the left side of the DLPFC should not register any significant increase. Thus, we posit the following hypotheses:

> *Hypothesis 3: A game with a higher level of game complexity and a lower level of game familiarity results in the highest density of theta oscillations from the left side of the DLPFC (i.e., poorest user–game engagement) compared with games that combine a different set of game elements.*

> *Hypothesis 4: A game with a lower level of game complexity and a higher level of game familiarity results in the lowest density of theta oscillations from the left side of the DLPFC (i.e., highest user–game engagement) compared with games that combine a different set of game elements.*

Under the joint effect of a low level of game complexity and a low level of game familiarity, the former will not create a strong top-down control activity [13]. Consequently, high-density theta oscillations from the left side of the DLPFC will not be generated. With the mutually exclusive utilization of the cortical resource for the cognitive stimuli, the low level of game familiarity can activate strong top-down activity to process information on the schematic formation of a game [42, 72]. Thus, the overall density of theta oscillations from the left side of the DLPFC should be greater than the joint effect of a low level of game complexity and a high level of game familiarity, but should be lower than the joint effect of a high level of game complexity and a low level of game familiarity. In a similar vein, we argue that a high level of game complexity and a high level of game familiarity can result in a modest density level of theta oscillations from the left side of the DLPFC. Thus, we posit the following hypotheses:

Hypothesis 5: A game with a lower level of game complexity and a lower level of game familiarity can have lower-density theta oscillations from the left side of the DLPFC than a game with a higher level of game complexity and a lower level of game familiarity. However, such a game can have higher-density theta oscillations from the left side of the DLPFC than a game with a lower level of game complexity and a higher level of game familiarity.

Hypothesis 6: A game with a higher level of game complexity and a higher level of game familiarity can have lower-density theta oscillations from the left side of the DLPFC than a game with a higher level of game complexity and a lower level of game familiarity. However, such a game can have higher-density theta oscillations from the left side of the DLPFC than a game with a lower level of game complexity and a higher level of game familiarity.

Research Methodology

We utilized both quantitative (EEG and survey) and qualitative methods (interview) to validate our hypotheses. Notably, both sets of empirical investigations were conducted in collaboration with a leading professional executive-training institute in Mainland China. This institute focuses on providing intensive, short-term professional courses for working professionals. At the time of our study, the institute was exploring the option of launching mobile software games as part of a large-scale marketing recruitment campaign to attract young working adults. On our part, we focused on conducting empirical assessments of user engagement regarding software games to advise the institute on the specific applications to be launched.

Game Selection and Manipulation of Gaming Elements

Four games were jointly selected by the first two authors of this research and by the collaborating institute. The authors and the institute initially short-listed 20 different software games whose licenses could be secured for marketing purposes. The common theme of these games is to “find and conquer.” For instance, players are required to find and identify the target in each game. Players tap on the screen of the mobile device and move their fingers to control the objects of the game and conquer the target. This theme was chosen not only to meet the gaming interests of the young professionals but also to harmonize the central marketing campaign message of “identifying self-interests and professional advancement needs, and learning to overcome barriers.” Two actions were performed to validate the focal cognitive-related gaming elements of game complexity and game familiarity. First, we engaged five veteran gaming experts to sort the list of games along with the two gaming elements. Only games rated at the extreme ends (i.e., high versus low game complexity; high versus low game familiarity) were identified. The test ensured the stability of these two gaming elements over the duration of gameplay. Hence, four games with different combinations of the cognitive-related gaming elements were identified.[2] Table 2 shows the factorial design.

Table 2. The Selection of Games

Game complexity	Game familiarity: High	Game familiarity: Low
Low	Group 1	Group 2
High	Group 3	Group 4

Table 3. Descriptive Statistics of Pretest Ratings of Mobile Game Complexity and Game Familiarity

	Low game complexity		High game complexity	
	Game familiarity			
Ratings of participants	High (Group 1)	Low (Group 2)	High (Group 3)	Low (Group 4)
Perceived game complexity	1.949 (0.682)	3.205 (0.999)	5.603 (1.252)	4.782 (1.909)
Perceived game familiarity	4.731 (0.935)	3.410 (0.780)	5.308 (1.272)	3.756 (0.628)

Note: Mean (standard deviation).

Second, we invited 78 consumers to prerate the four games based on the gaming elements. The definition of each gaming element was explained in detail alongside gameplay demonstrations. All the participants' questions were answered before they were asked to rate the four games based on a Likert scale of 1 to 7. Table 3 presents the means and standard deviations of the perceptual measures. We also performed *t*-test comparisons among the gaming groups. The pretest ratings of game complexity and game familiarity, as well as the *p*-value between each group, were below the significant level (0.05). Overall, the results were consistent with our intended manipulations of the gaming elements.

Investigation 1: Quantitative Research

Investigation 1 obtained EEG data of users during gameplay and their postplaying evaluations of user–game engagement.

Participants

A total of 48 working professionals were recruited by an open recruitment advertisement in local print media. Four participants were excluded from the analysis: two left-handed participants were precluded owing to differences in hemispheric specifications for emotions [32] and two participants failed to complete the questionnaires.

The remaining 44 participants (21 males and 23 females, with ages ranging from 23 years to 30 years) were found to be without medical implants, mental disorders, and physiological problems and were treated based on screening guidelines. The temporal mood of each participant was recorded as a control variable for further analysis. The participants were compensated with payments equivalent to national average wages for three days.

Gaming Platform

All four games were presented and played using a smartphone with a 3.5-inch screen. Earphones were provided.

Post-Game-Playing Survey

We adopted the user–game engagement questionnaire from a previous study [17]. Following that study, we first translated the survey items into Mandarin while maintaining maximal consistency with terminology and sentence structures. A third-party, bilingual (fluent in English and Mandarin) IS professor translated the questionnaire into Mandarin and then back into English. The retranslated version was found to be consistent with the original (Appendix). The Cronbach's alpha value was 0.883, which is close to the recommended Cronbach's alpha value of 0.83 [17].

EEG Observation During Gameplay

An Emotiv EPOC 14-channel (AF3/4, F7/8, F3/4, FC5/6, T7/8, P7/8, and 01/2) wireless EEG system (www.emotiv.com) was used to track and record the EEG data at 128 Hz. The headset enabled access to 14 data channels incorporating two bipolar references with electrodes positioned based on the International 10/20 Electrode Placement System [32]. Figure 2 presents the channel layout, with the tested channels positioned as orange circles.

Procedures

A 2 × 2 between-subjects experimental design was adopted for this study. The participants were briefed on the EEG procedure and were then asked to sign a consent form. The EEG study comprised four main steps. First, the individuals were asked basic medical, mental, and physiological questions. Second, after training with the device, the research assistants conducted a trial play session (verbal explanation and 15 seconds of trial play) and equipped the EEG devices for the participants concurrently to minimize the potential biases of prior knowledge on the presented games. Subsequently, the participants were offered a three-minute rest session between the trial session and the official start of the experiment. The rest session restored the brain to tranquility and sedateness from the trial session to ensure the accuracy of EEG

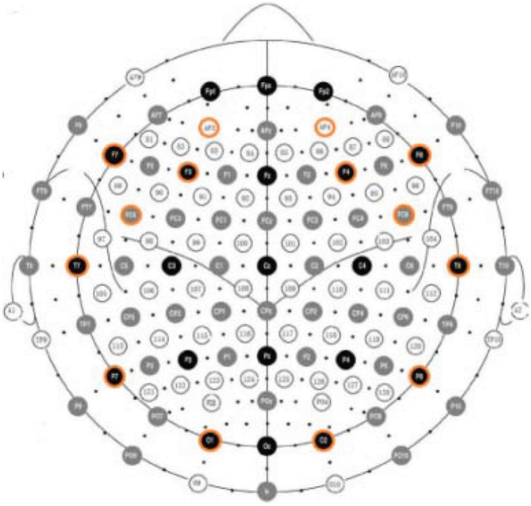

Figure 2. Electrode Placement in the EEG Study

Notes: The origin of this diagram is from the Behavioral Imaging and Neural Dynamics Center (http://bindcenter.eu/?page_id=12/). We adopted this standard 10/20 system diagram and highlighted the electrodes with orange circles.

signals in the gaming session [18] as well as allowed us to take advantage of such a period to verify and ensure stable data were read back.[3] The EEG data recorded at this stage serve as the baseline for further comparison. Third, the participants were asked to play the game, and the EEG data were recorded for three minutes [22]. We stopped the participants from playing the game three minutes after they began to control the game complexity stability issue. They were unaware of this limitation prior to playing. This approach allowed us to ascertain that the period of gameplay remained within a single round of the game. For instance, a single round in the rally racing game lasts approximately four minutes. When the participants played for three minutes within the single round, the game complexity was set by the game. In this regard, game complexity was found to be stable over the course of gameplay in our study. The game familiarity stability issue is solved by the definition of game familiarity in our study. In the experiment, the selected games had stable schemata across the entire process of the game. As a result, we could ensure the stability of game familiarity over the course of gameplay. After gameplay ceased, the participants completed a self-report survey (fourth step) to measure their game engagement. While we did not impose a time limit for the completion of the questionnaire, we noted that the average duration for each participant (including three minutes of EEG recording) was ten minutes. An audio and screen recorder program (www.techsmith.com) was utilized to track and record the experiment process. Following previous neuropsychological studies on IS and psychology (e.g., [27]), we also visualized the procedures, as featured in Figure 3.

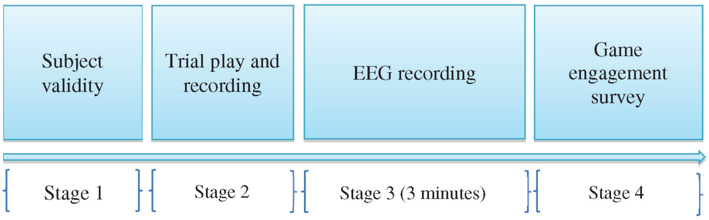

Figure 3. EEG Experimental Procedure

Analysis and Results

EEG Results of Gameplay

We decomposed the EEG data for analysis using independent component analysis, a technique employed to separate linearly mixed sources to obtain artifact-free EEG data [24]. The EEG data analysis was carried out in two steps.

Step 1: We examined the basic reflected emotion valence (positive versus negative) as a result of the introduction of the gaming stimuli. Davidson [23] stated that different emotions are discriminately lateralized in the frontal region of the brain. Several studies have specifically shown that positive and negative emotions can be reflected in high activities in the left and right prefrontal cortexes, respectively, at an alpha oscillations band ranging from 8 Hz to 13 Hz [23]. The EEG data were then collected from the channels located on the prefrontal cortical areas: F3, F4, AF3, AF4, F7, F8, FC5, and FC6. These locations represent the left and right hemispheres of the brain (the odd numbers indicate the left scalp and the even numbers indicate the right scalp). We log-transformed (i.e., neutral-logged) the average alpha oscillations density in μV^2 (UOM of power density) to normalize the distribution. Lindsley and Wicke [53] found that lower-density alpha oscillations reflect more activity because of the EEG data being inversely related to activity in the frontal cortex region for the alpha oscillation. Therefore, we used the following formula to compute the asymmetry values:

$$\begin{aligned} \textit{Asymmetry values} &= \log(\textit{left alpha oscillation density}) \\ &\quad - \log(\textit{right alpha oscillation density}). \end{aligned}$$

In the above formula, positive values indicate greater relative left alpha oscillations, which indicate negative emotions. The negatively asymmetrical values indicate positive emotions. The results of the pairwise *t*-test are shown in the first column of Table 4. The test indicates significant differences between the left and right hemispheres of the brain; specifically, the negative values indicate that the left frontal cortex is more active than the right frontal cortex during gameplay. Such an analysis aims to examine the emotional valence of participants after introducing an external stimulus (the game, regardless of game taxonomy). The results show that playing mobile games does influence brain activity. This evidence can also help locate the scalp region where the

Table 4. Pairwise *t*-Test for Brain Hemispheres on Alpha Oscillation (Smartphone)

	AF3–AF4	F7–F8	F3–F4	FC5–FC6
Mean difference (standard deviation)	–0.678 (0.909)***	–0.991 (0.726)***	–0.445 (0.615)***	–1.407 (0.661)***

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

signals are precise and intense. Two findings based on this set of observations were deduced.

First, playing software games induces positive emotions, as expected, rendering the left frontal cortex more active than the right frontal cortex. Second, brain activity in the left prefrontal cortex is more intense than in the right prefrontal cortex in our experimental context. This finding is in line with that of Gundel and Wilson [39], who found that an increase in left prefrontal theta oscillation density denotes an increase in cortical activities. In Step 2, we utilized the density of theta oscillations from the left side of the DLPFC to investigate whether gaming elements influence game engagement.

Step 2: Several researchers have found that the density of theta oscillations is positively related to the cortical activities in the left side of the DLPFC [47]. We approached the head of the Neuroscience Department of a leading hospital in Mainland China to acquire relevant comments on the assessment of user–game engagement by investigating cortical activities in the left side of the DLPFC. An important issue was highlighted: To reflect user–game engagement through cortical activities in the left side of the DLPFC, we had to ensure that the participants playing different games did not differ in terms of prior knowledge (or expertise). If individuals had prior knowledge or expertise, the density of their theta oscillations would be lower than the density of those who lacked such prior knowledge. We conducted a simple *t*-test to compare the (log-transformed) average density of theta oscillations of the AF3 channel and thus validated that no selection bias occurred among our participants. The results did not indicate a significant difference in terms of prior knowledge/expertise (mean difference = 0.521, standard deviation = 0.494). The choice of the AF3 channel was motivated by Klimesch et al. [48], who found that the theta wave rhythms are determined by the frontal midline areas.

Another important issue was also highlighted: we had to examine whether the density of theta oscillations is negatively related to the game engagement mentioned in previous studies (e.g., [13]). In resolving this issue, two steps were performed. First, the significant difference of density of theta oscillations between baseline (Stage 2) and treatment (Stage 3) needs to be proven. Second, such a different value is expected to correlate negatively with the game engagement obtained by postgame surveys. The first problem was solved in terms of a *t*-test that compared the average density of theta oscillations at Stages 2 and 3. The results show a significant difference.[4] Hence, we have sufficient evidence to believe that the density of theta oscillations is negatively

Table 5. Correlation Between *Diff* and Self-Reported Game Engagement (Mobile Games)

Game engagement	*Diff*				
Presence					
Gep1	–0.430**				
Gep2	–0.432**				
Absorption					
Gep3		–0.456**			
Gep8		–0.613**			
Gep9		–0.438**			
Gep14		–0.461**			
Flow					
Gep5			–0.426**		
Gep6			–0.557**		
Gep7			–0.578**		
Gep10			–0.302*		
Gep19			–0.532**		
Immerse					
Gep18				–0.477**	
Involvement					
Invol1					–0.530**
Invol3					–0.380*
Invol5					–0.410**
Invol6					–0.306*

** Correlation is significant at the 0.01 level (two-tailed); * correlation is significant at the 0.05 level (two-tailed).

correlated with game engagement. We then calculated the difference of the average densities of theta oscillations at Stages 2 and 3 as a new measure representing the change of densities of theta oscillations. This resulting value is referred to as *Diff*.[5] We had to investigate whether the density of theta oscillations is negatively related to game engagement to solve the second problem. We measured game engagement by adopting the items suggested in previous literature [17]. Then, the value of game engagement from the questionnaire was performed via Pearson's correlation with *Diff* in Table 5. Each dimension showed a significantly negative correlation between the computed differences *Diff,* which affirmed the findings of previous work. The items of the game engagement questionnaire are in the Appendix.

After completing the two steps described above, we chose the average theta oscillation density in the AF3 channel as the dependent variable to measure the fluctuations in cortical activity in the left side of the DLPFC. We performed log transformation (neutral log) to normalize the theta oscillation spectrum in μV^2 similar to what we did for the alpha oscillation spectrum.

We then compared the average theta oscillation densities in the AF3 channels of the participants playing different games on the smartphone. Although cortical activity fluctuated regularly throughout the execution of every task, both accumulated and average cortical activities increased throughout the duration of task performance. We thus computed the average logarithmic theta oscillation densities for the first 10 seconds and the last 10 seconds. These computations were used to derive the following formula to measure the variations in average theta oscillation density:

$$\begin{gathered}\textit{Variations in average theta oscillation density}\\ = \log(\textit{last 10 seconds theta oscillation density})\\ - \log(\textit{first 10 seconds theta oscillation density}).\end{gathered}$$

Analysis of variance (ANOVA) was found to be the most proper methodology to test our proposed hypotheses with the factorial design. However, the baseline data (the EEG data recorded at Stage 2) should be included as covariates to validate the hypotheses with the factorial design. Hence, instead of carrying out an ANOVA, we went a step further by conducting an analysis of covariates (ANCOVA) to test our hypotheses. We also included the emotional valence measured prior to the gaming session as another covariate in the ANCOVA.

The preliminary assumption with ANCOVA is that no violation of a regression slope homogeneity assumption occurs. To test this assumption, we added the interaction terms of the covariates to the grouping variable in the ANCOVA model to determine whether the interaction terms are significant; if the terms are significant, the ANCOVA will be deemed as not applicable. The results, in which the p-values (F-values) of the Mood*Group and Baseline*Group were 0.359 (1.11) and 0.714 (0.458), respectively, indicated no violation of this assumption. Hence, we could perform the ANCOVA. The results of the ANCOVA tests on the various gaming groups using the smartphone showed a significant difference across game complexity ($F = 12.686$, $p = 0.001$) and familiarity ($F = 9.082$, $p = 0.005$). However, the interaction effect between the two dimensions was not significant ($F = 0.205$, $p = 0.654$). Furthermore, the covariates, namely, temporal mood ($F = 1.771$, $p = 0.191$) and baseline ($F = 0.003$, $p = 0.955$), did not show any significant differences across groups. Table 6 shows the detailed results of the hypothesis testing. Two findings were determined. First, low-complexity games utilize individuals' lower-density theta oscillations more as compared with high-complexity games. Low-density theta oscillations also inversely correlate with higher game engagement. Second, participants expend higher-density theta oscillations when faced with a lower level of game familiarity. Thus, game engagement appears to be low in games with low familiarity.

We employed similar methods to discuss the joint effects. We found that individuals exerted lower-density theta oscillations when playing games of greater familiarity and low complexity. Low-density theta oscillations were observed when individuals played low-complexity games. In games with higher complexity, higher game familiarity reduced the density of theta oscillations of users more than the low-familiarity games did. The estimated marginal means of the variations in average-density theta

Table 6. Comparisons of Variations of Average-Density Theta Oscillations Across Gaming Groups (Smartphone)

	Low-complexity versus high-complexity games		Low-familiarity versus high-familiarity games		
	Group 1 versus Group 2	Group 1 versus Group 3	Group 2 versus Group 4	Group 3 versus Group 4	Group 2 versus Group 3
Mean differences (standard deviation)	–1.990 (0.542)**		1.518 (0.577)**		
	–1.778 (0.819)**	–2.251 (0.770)**	–1.730 (0.633)**	–1.257 (0.569)**	–0.038 (0.590)

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

oscillations is shown in Figure 4.[6] Figure 5 shows the topographic EEG maps of the participants playing games on smartphones.

Discussion

Prior studies have been unable to provide conclusive findings on the type of gaming element or combination of gaming elements that can influence game engagement and the underlying neuropsychological mechanisms of this influence [63]. Game engagement can be presented by measuring the density of theta oscillations from the left side of the DLPFC. Less complex games arouse higher game engagement compared with more complex games. Furthermore, participants in the higher game familiarity groups displayed higher game engagement than those in the lower game familiarity groups. Thus, H1 and H2 are supported.

With regard to the low-complexity and high-familiarity games (Group 1), the lowest-density theta oscillations indicated the highest game engagement among the other groups. The high-complexity and low-familiarity games evoked the lowest game engagement (highest-density theta oscillations). Thus, H3 and H4 are supported. Significant differences were also found between Groups 1 and 2 as well as between Groups 2 and 4. Hence, H5 is supported. Significant differences were found between Groups 1 and 3 as well as between Groups 3 and 4. Thus, H6 is supported (as shown in Table 6). Aside from the support found for all of the hypotheses, we found no significant differences between Groups 2 and 3 (Group 2: low game familiarity and low game complexity; Group 3: high game familiarity and high game complexity) (as shown in Table 6). This result infers that the effect of game complexity and game familiarity on cortical activity in the left side of the DLPFC can indicate the existence of a symmetric compensation relationship. However, we cannot confirm the symmetric compensation relationship between game complexity and game familiarity without further examination. Thus, this inference warrants future research.

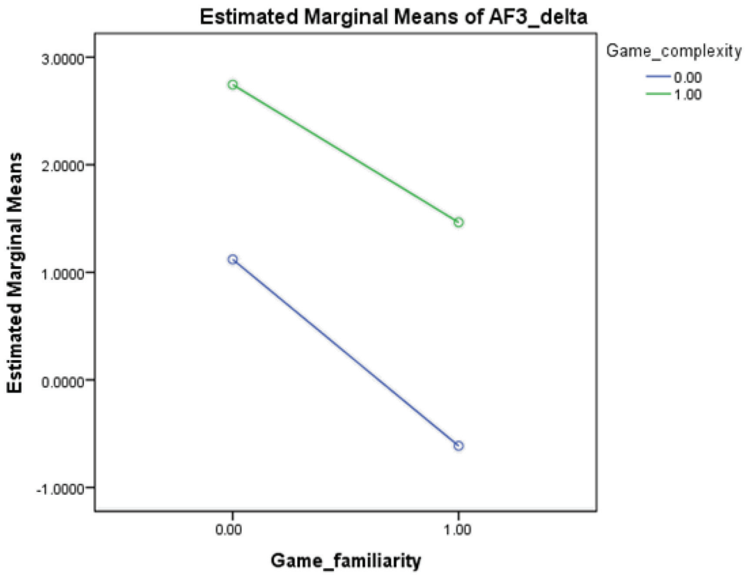

Figure 4. Estimated Marginal Means of the Variations in Average-Density Theta Oscillations (Mobile Game)

Note: Covariates appearing in the model are evaluated at the following values: baseline = 18.4940; mood = 4.57.

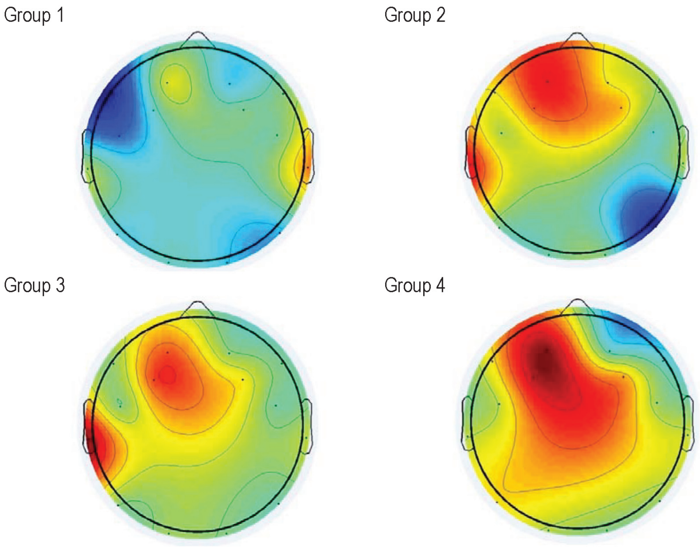

Figure 5. Topographic EEG Maps for Different Games Played Using the Smartphone

The results of the two types of quantitative studies (self-report survey and EEG study) verify the common thesis in human cognition research; that is, the neurophysiological research method can complement the traditional survey method and produce more precise and objective results [27]. To explain this phenomenon, we conducted the second investigation—the qualitative interviews—to triangulate further how gaming elements influence game engagement.

Investigation 2: Qualitative Research

An open-ended interview was designed to include two semistructured questions that will allow us to triangulate the participants' perceptions, cognition, and opinions on game engagement. The first question focused on the general feeling the participants experienced during gameplay on the smartphone. The second question was related to user–game engagement and self-assessed potential reasons for game engagement. The interview assigned approximately 10–15 minutes for discussion. The 44 participants from the quantitative studies participated in the interview study. After collecting the interview data, we recruited three independent assistants to transcribe the interview protocols. All of the transcribed scripts were double-checked by two skilled researchers. We then hired two coders to code the protocols [69], and protocol coding was conducted following the standard procedure [69]. The analysis of Cohen's kappa measurement indicated good intercoder agreement (kappa = 0.93, $p < 0.010$) [21].

Findings

We identified approximately 4,800 words (in Mandarin) in the answers of the participants. Each participant used 109 words on average to answer the interview questions. The detailed statistical results are found in Table 7.

Code 1-RW is the most dominant code in the first question, compared with codes 1-CZ and 1-SW (as shown in Table 7). This result indicates that when the participants play a software game, they are most concerned with the opportunity to utilize their cognitive capacities in playing the game and the perception of being able to play the game. For the second question, code 2-CZ is in the prominent position, followed by codes 2-PT, 2-KZ, and 2-SW (as shown in Table 7). These results indicate that the drivers of game engagement can be viewed from two perspectives: personal perception and cognitive-related gaming elements.

With regard to personal perception, three main perceptions were observed: sense of competition, sense of involvement, and sense of joy.[7] The expression of joy triangulated the findings of the EEG in terms of measuring and comparing the alpha oscillations band in the left and right prefrontal lobes of the brain cortexes. With regard to cognitive-related gaming elements, the participants certainly focused on game complexity and game familiarity in terms of user-game engagement (the percentage of codes 1-RW and 2-CZ supports this conclusion, as shown in Table 7). These findings corroborated the results from the quantitative studies in our research. Game complexity and game familiarity were the two prominent determinants found to influence user–game engagement when a participant plays software games.

In addition, we interpreted the codes in the four treatment groups. The participants in the high game complexity and low game familiarity treatment reported that the scenario

Table 7. Statistical Coding Results

	Code name	Meaning	Percentage
Interview question 1: What is your general feeling toward the software game?			
Word count: 1,933 words (in Chinese); Code count: 64 codes	1-CL	Game-playing logic	11
	1-WL	Negative feeling during gaming	5
	1-SJ	Perception of the passing of time	8
	1-RW	Self-assessment toward the difficulty of the game	30
	1-CZ	Self-assessment toward game control	19
	1-FY	Perception of the agility of processing information when gaming	13
	1-SW	Perception of the familiarity toward the scenarios in games	16
Interview question 2: Do you feel engaged during the game? If you do, would you figure out the reasons for the game engagement?			
Word count: 2,899 words (in Chinese); Code count: 99 codes	2-PT	Software game platform	20
	2-KZ	Trying out possibility for game control	21
	2-GC	Difficulty in controlling game	12
	2-CZ	Need to become familiar with the game	21
	2-GJ	Statement of perception when gaming	8
	2-SX	Willingness to put effort into gaming	18

built by the game provided a sense of virtual reality. The majority of participants worried about the high mental processing complexity involved and the gaming control that could potentially cost substantial cognitive capacity. They usually felt “unengaged” and perceived the game to be “difficult.” This observation corroborated the findings from Investigation 1, which demonstrated that high game complexity and low game familiarity result in an overwhelming burden with regard to cortical activity.

The participants in the high game complexity and high game familiarity treatment simply mentioned that the game required considerable mental effort to complete the necessary tasks. The participants made an issue of the considerable consumption of cognitive capacity, but made light of the gap in the game’s schemata familiarity (Figure 6). Hence, we can infer that a familiar scenario mitigates the cognitive effort in high game complexity conditions.

The participants in the low game complexity and high game familiarity treatment indicated no difficulty in playing the game. As reported, the game was highly operable and presented a familiar scenario. The participants were easily attracted to the storyline or context of the game and were generally unconcerned with the consumption

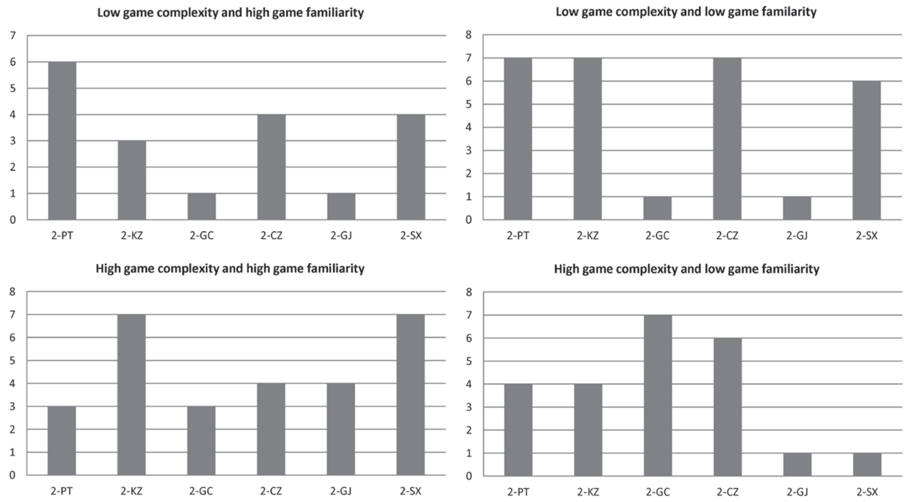

Figure 6. Histograms of Coding Results

Notes: 2-PT: software game platform; 2-KZ: trying out possibility for game control; 2-GC: difficulty in controlling the game; 2-CZ: need to become familiar with the game; 2-GJ: statement of perception when gaming; 2-SX: willingness to put in effort when gaming.

of cognitive capacity (Figure 6). Their gaming experiences were "interesting" and "fun." This observation was in accordance with the findings of Investigation 1.

The participants in the low game complexity and low game familiarity treatment reported that the novel atmosphere of the simple gaming mechanism did not overwhelm them. The most common obstacle was low game familiarity. The participants usually felt they were "not engaged" and "feel [felt] badly" during gameplay. Occasionally, they felt that they "do [did] not know how to play" in the process of conquering the target in a software game. Thus, we concluded that game engagement is disparately influenced by game familiarity in different game complexity settings. The distinctiveness was revealed by the EEG analysis.

Discussion

The results of Investigation 2 supported the findings in Investigation 1. Interestingly, most of the participants referred to their preference to play games on different software game platforms (see code 2-PT in Figure 6). For instance, screen size and resolution were mentioned most frequently when the participants were asked about the differences between mobile devices and conventional desktop computers. Although three participants complained that the small screen caused eyestrain, most of the participants agreed that a small screen with high resolution could enhance absorption during gameplay, especially for games with high operational complexity.

To investigate the influence of the gaming platform, we conducted a robustness test by recruiting an additional 44 participants to play the same set of games on a desktop

Table 8. Pairwise *t*-Test for Hemispheres on the Alpha Oscillation (Desktop Computer)

	AF3–AF4	F7–F8	F3–F4	FC5–FC6
Mean difference (standard deviation)	–0.639 (1.120)***	–0.838 (0.750)***	–0.670 (1.600)***	–1.394 (0.786)***

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Table 9. Comparisons of Variations in Average-Density Theta Oscillations Across Gaming Groups (Desktop Computer)

	Low-complexity versus high-complexity games		Low-familiarity versus high-familiarity games		
	Group 1 versus Group 2	Group 1 versus Group 3	Group 2 versus Group 4	Group 3 versus Group 4	Group 2 versus Group 3
Means differences (standard deviation)	–1.134 (0.451)**		0.748 (0.469)		
	–1.416** (0.594)	–1.803** (0.677)	–0.466 (0.550)	–0.079 (0.639)	–0.387 (0.573)

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

computer. We report four significant findings. First, the negative correlation between game engagement and *Diff* was also identified in the desktop platform, as noted by the post–game playing survey results (Table 8). Furthermore, the average-density theta oscillations at the gaming session were significantly lower than those at the trial session (the mean difference and standard deviation were –0.847 and 0.627, respectively, with a *p*-value of 0.000). Second, the results of the pairwise comparisons of the brain hemispheres on alpha oscillations (Table 9) indicated significant differences between the left and right hemispheres, reflecting similar findings observed among the participants who used smartphones. Third, we conducted a simple *t*-test of the average-density theta oscillations in the AF3 channel to test for any systematic differences in prior knowledge. The results indicated no significant differences across participants (mean difference = 0.346; standard deviation = 0.504). Fourth, we compared the variations in average-density theta oscillations across the desktop gaming groups. The results are summarized in Table 10 and the visualization of the estimated marginal means is shown in Figure 7.

The results of the robustness test indicate that the outcomes derived from the mobile games were stable. The only exception was that no differences were found in the desktop gaming group across different levels of game familiarity for those on the high-complexity level.[8] One plausible reason for this is the screen resolution of the two devices, as reported in the qualitative investigation. Several studies have reported the

Table 10. Correlation Between *Diff* and Self-Reported Game Engagement (Desktop Games)

Game engagement	*Diff*				
Presence					
Gep1	–0.469**				
Gep2	–0.445**				
Absorption					
Gep3		–0.377**			
Gep8		–0.508**			
Gep9		–0.449**			
Gep14		–0.383**			
Flow					
Gep5			–0.565**		
Gep6			–0.565**		
Gep7			–0.579**		
Gep10			–0.464**		
Gep19			–0.298*		
Immerse					
Gep18				–0.352*	
Involvement					
Invol1					–0.277*
Invol3					–0.424**
Invol5					–0.384**
Invol6					–0.296*

** Correlation is significant at the 0.01 level (two-tailed); * correlation is significant at the 0.05 level (two-tailed).

positive relationship between screen size and attention to static content, such as text or images [64]. However, most current mobile devices undoubtedly have a higher resolution screen than most typical desktop computers, and a recent study stressed that screen resolution can also positively influence user adaptation [35]. To maximize screen resolution, only the most important features are selected for presentation [46]. Therefore, a small screen with a high resolution can better attract user attention in highly complex games.

General Discussion

Drawing on the theoretical foundation of engagement, we proposed and demonstrated that cognitive-related gaming elements, which are classified as game complexity and game familiarity, influence the density of theta oscillations from the left side of the DLPFC and game engagement.

In Investigation 1, we demonstrated that both game complexity and game familiarity have a significant effect on the density of theta oscillations from the left side of the

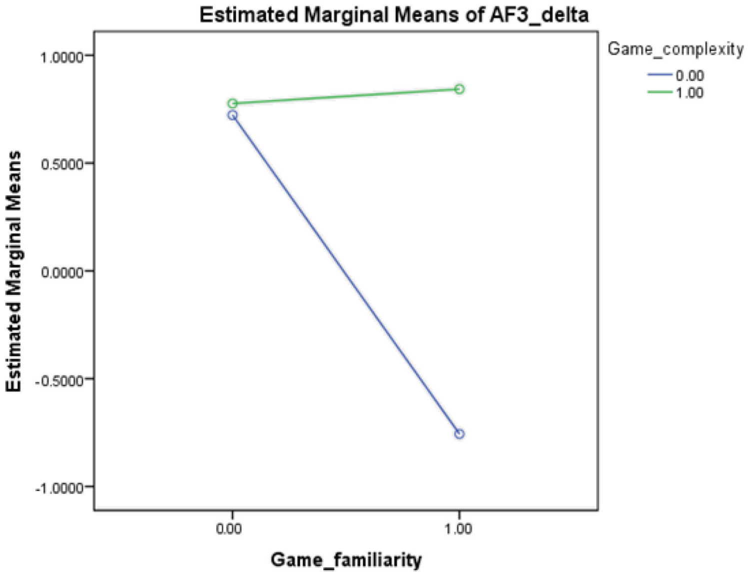

Figure 7. Estimated Marginal Means of the Variations in Average-Density Theta Oscillations (Desktop Game)

Note: Covariates appearing in the model are evaluated at the following values: Baseline = 19.3898, mood = 4.67.

DLPFC. These gaming elements also have a joint effect. Moreover, by investigating intrinsic neural correlations, cognitive stimuli (i.e., game elements), and outcome (i.e., the density of theta oscillations from the left side of the DLPFC, which is representative of game engagement), we demonstrated that the neurophysiological investigation method complements the traditional self-report survey method.

Investigation 2 focused on the triangulation of game engagement antecedents and the exploration of potential explanations regarding the influence of cognitive-related gaming elements. The results of our qualitative study provide sufficient support. Table 11 summarizes the intended contributions of our research.

Limitations

Prior to presenting the implications of this research, we should be aware of some caveats, which can serve as suggestions for future research. First, we collected data from 44 participants (i.e., participants from groups) in the quantitative investigations. The results of our study showed acceptable levels of statistical power (power = 0.973, with the effect size *f* = 0.365). The number of participants is considered acceptable for empirical studies involving the neurophysiological investigation method [61]. For the qualitative investigation, we obtained sufficient protocol data from the participants. In fact, our sample size for the verbal protocol analysis (i.e., 44 participants) is larger than in previous studies using verbal protocol analysis (e.g., [69]). We obtained sufficient

Table 11. The Intended Contributions of This Work

		Relevance	
Contributions	Current literature	Theory	Practice
Contributes to the conceptualization of gaming elements as important determinants of user–game engagement. The present paper directly argues that game design elements influence user–game engagement during gameplay.	Prior studies have focused on examining the high-abstract level of perceptual constructs as the determinants of game-playing motivation [49]. Hence, prior studies seldom touch on the game design issue [63].	√	
Contributes to the conceptualization of user–game engagement from the "process-oriented" and game design perspectives. Addresses the theoretical question of how to influence game engagement in consideration of the intrinsic game design perspective.	Prior research has rarely examined game engagement and game elements comprehensively and in an integrated manner. Previous studies have either focused on cognitive representatives of game engagement or neglected the importance of game elements [17].	√	
This research adds to the emergent field of exploration by understanding the neurophysiological effect of gaming elements on user–game engagement. The present paper presents a more detailed investigation of the relationship between gaming elements and user–game engagement during the game-playing process, compared with the prior literature.	Some data collection methods (e.g., self-report survey) may not be appropriate to use alone [41] and may lack excellent temporal resolution to measure cortical activity during the process of game playing [32].	√	
Contributes to the utilization of the multimethod research design in investigating the research question of game design and user–game engagement.	Prior research has seldom adopted the multimethod research methodology to investigate gaming research; rather, most studies are primarily single-method approaches, leading to incomplete insights and perception [68].	√	

(continues)

Contributions	Current literature	Relevance	
		Theory	Practice
Provides executable guidelines for designing high-level game engagement games through the manipulation of different types of game elements. Informs practitioners on how to specify game elements efficiently and successfully.	Prior research has rarely provided executable guidelines on game design based on its elements [26].		√

empirical data for the analysis and controlled the empirical research as rigorously as possible. Nonetheless, we suggest including more participants in future research.

Second, the length of gameplay was fixed (three minutes) for each participant in our experiment, which might have influenced the game engagement of some individuals. Nevertheless, the participants were not informed regarding when the gameplay would end during the experiment. This manipulation was used to ensure that the end of gameplay was within a single round of the game. For example, a single round of the rally racing game lasts about four minutes. When participants play for three minutes within the single round, game complexity is set by the game per se. In accordance with Colter and Shaw [22], we believe the time allotted for the software game experiment was sufficient to investigate game engagement within our research context. A trial session was conducted to minimize potential biases caused by the individuals. Certainly, a more precise selection of gameplay duration should be applied in future research.

Third, we varied each of the focal gaming elements by two levels (i.e., low and high; no more than two levels). In this study, we focused on theorizing the gaming elements as the important factors that influence game engagement. We also concentrated on investigating how the different combinations of gaming elements have various effects on user–game engagement. Thus, an investigation focused solely on the changes in game engagement in terms of variance in game complexity is beyond the focus of the present study. Nonetheless, future studies could examine whether the relationship between game complexity and user–game engagement is linear or nonlinear. To do so, scholars will need to operationalize game complexity as a continuous variable/fine-granularity discrete variable [2].

Theoretical Implications

Despite the aforementioned limitations, this study provides four key theoretical contributions. First, this paper contributes to the conceptualization of gaming elements as important determinants of user–game engagement. Prior studies have concentrated on examining the highly abstract level of perceptual constructs, such as psychological needs, norms, and utilitarian needs, as determinants of gameplay motivation [52]. Game design has rarely been examined [63]. With the new conceptualization, we directly argue that game design elements influence user–game engagement during gameplay [26].

Second, this paper contributes to the conceptualization of user–game engagement from the “process-oriented” and game design perspectives. We define user–game engagement as a concept that reflects the extent to which a game can immerse users in the game during gameplay. This theorization on user–game engagement is in line with recent research on game engagement, which argues that game engagement is shaped by the gameplay itself [44]. Prior studies have predominantly examined user–game engagement from the perspectives of motivation and users’ perception (e.g., [62]); however, these studies have failed to explain how intrinsic game design elements can be used to influence user–game engagement (e.g., [74]). The present paper addresses the theoretical dilemma of influencing game engagement from the intrinsic game design perspective, such as through gaming elements. Drawing on the theoretical foundation of engagement, our study augments prior studies by suggesting that a plausible reason for the mixed findings of prior studies may be the inadequate consideration of the gaming elements’ joint effect on the density of theta oscillations from the left side of the DLPFC during gameplay.

Third, we used EEG as the main neurophysiological investigation method to examine user–game engagement [32]. EEG ensures excellent temporal resolution to measure cortical activity during gameplay [32, 54]. Thus, we observed that cognitive-related gaming elements can be utilized well in different conditions and can jointly influence user–game engagement. For instance, we observed that low game complexity and high game familiarity significantly increase the level of user–game engagement. This significant change is measured by comparing the temporal variances of the density of theta oscillations from the left side of the DLPFC. These results can guide researchers in measuring user–game engagement as a “process-oriented” construct. More importantly, these results reflect a thorough investigation of the relationship between gaming elements and user–game engagement [44]. The present research adds to this emergent field of exploration by studying the neurophysiological effect of gaming elements on user–game engagement.

Finally, this study adopted both quantitative and qualitative research methodologies. We conducted the quantitative research (i.e., self-report survey and EEG study) to investigate the underlying mechanism of the effect of gaming elements on game engagement. The qualitative research (i.e., interviews) was carried out to acquire additional evidence and to triangulate the findings of the quantitative studies. A multilateral investigation into user–game engagement is more beneficial to the examination of unobtrusive cognitive activities in empirical studies. For example, results from interviews indicated that the software game platform could influence game engagement. Therefore, we performed a robustness test and proved that the type of game platform does not influence the relationship between gaming elements and user–game engagement. As argued by Johnson et al. [45], the multimethod research design generates research findings as comprehensively and completely as possible compared with the single-method research design. We considered the potential pitfalls of the multimethod research design and attempted to address them. Morse [58] argued that the main weakness of the multimethod research design is that it is often challenged by the rigor of each study and the saturability of data. The systematic process of research design and deployment ensured the rigor of the current study. With regard to the data saturability, we are confident that the qualitative and quantitative data were sufficiently rich for our analysis.

Practical Implications

The implications of our research provide valuable insights for practitioners. Game designers in the software game industry must have a clear vision of the specific effect of gaming elements on user–game engagement, and software game designers can formulate reasonable and executable strategies to utilize different types of gaming elements in enhancing game engagement with this knowledge. These implications are more salient in the mundane software game market, wherein several similar or imitative games simultaneously exist. For example, the games Fruit Ninja and Veggie Samurai share a similar game concept; that is, the use of a finger to control a knife and slice fruits (vegetables) to earn bonus points. The more fruits (vegetables) hit, the more bonus points earned. By applying our findings in this context, game designers can provide in-game features to either reduce game complexity (e.g., triple slicing, which means slicing once to cut three or more fruits or vegetables) or enhance game familiarity by providing more real-life background images or more types of fruits or vegetables if they want to establish better user–game engagement compared with their competitors.

For traditional nongaming companies, the results of this paper can provide a clear approach to the design of software games for business campaigns and actionable marketing proposals for sponsored software games. Traditional companies can use their brand name or trademark in the design of gaming features (e.g., a special button) to reduce game complexity. For example, when facing a monster that is difficult to defeat in a monster-hunting game, users can press a button with a specific trademark to acquire additional power to conquer the monster. The brand image becomes embedded in the minds of users, as this image is what "freed them from a difficult time." Consequently, the most carefully designed game can be appropriately leveraged to significantly enhance users' gameplay behavior and avoid the stickiness of the software game.

Implications for IS Research

In addition to the implications discussed above, this study, as a NeuroIS work, contributes to existing NeuroIS research and serves as a stepping-stone for future work in this discipline [51]. After a comprehensive review of prior work (*MIS Quarterly* [27, 28, 32, 65], *Information Systems Research* [29], *Journal of Management Information Systems* [60], and International Conference on Information Systems proceedings [14, 30, 31, 43]), we identified two key determining contributions not covered in previous work. First, previous NeuroIS studies mainly performed trial-oriented rather than process-oriented observations; the participants were presented some visual stimuli and subsequently asked to make their decision immediately. For instance, Dimoka [27] empirically tested the correlation between brain areas and trust/distrust by presenting the participants with seller profiles. A similar strategy used in different scenarios, such as trust/distrust on product description across genders, was determined in other NeuroIS studies (e.g., [65]). Collectively, all of these works only captured a snapshot of neuropsychological activity rather than the entire process, which may not be applicable to the interpretation of overall usage or user experiences. Our study fills this gap by recording and interpreting the EEG data from the entire gaming process, which has not been shown before in IS research. We have sufficient reason to believe that this pioneering study can shift the knowledge of NeuroIS from a relatively static standpoint to a more dynamic and process-oriented perspective.

Second, previous NeuroIS studies were focused on confirm either existing theory [65] or findings that were obtained from traditional behavioral methodologies [27], but lacked power to interpret some emerging topics. However, the current study breaks the deadlock, and bridges the gap between NeuroIS studies and emerging research topics. In summary, our work contributes to existing IS research in two ways: (1) providing an example of process-oriented NeuroIS investigation and (2) bridging the gap between NeuroIS and an emerging research topic, namely, mobile gaming experiences.

Conclusion

Investigating the neural correlation between gaming elements and user–game engagement has the potential to strengthen our understanding of the initiation and continuance of game engagement. This study complements extant studies on game engagement by theoretically conceptualizing and empirically comparing the engagement measures from multilateral perspectives. In addition, it documents research focused on investigating the effect of two cognitive-related gaming elements on gameplay. This study has taken a modest step toward developing a theoretically sound understanding of the underlying neurophysiological mechanisms determining user–game engagement in the context of gameplay through two empirical investigations.

Acknowledgments: The work described in this paper was fully supported by two grants from the Research Grants Council of the Hong Kong Special Administrative Region, China (CityU 150511 and CityU 149810) and a grant from the NSFC/RGC Joint Research Scheme sponsored by the Research Grants Council of Hong Kong and the National Natural Science Foundation of China (CityU 115/10).

Notes

1. See www.pocketgamer.biz/r/PG.Biz/PG.biz+Mobile+Gaming+Mavens/feature.asp?c=40506/.

2. Because the institute explicitly requested us not to name the games because of concerns related to commercial interests, we are unable to provide detailed descriptions of the four identified games.

3. The EEG signals are collected and transferred from scalp surfaces to the devices via electrolyte solution. The quality or intensity of each channel is shown by four colors (green, yellow, red, and black indicate good, average, poor, and no signal, respectively) at the control panel. Hence, by monitoring the control panel, we could ensure that the signal was transferred in a valid and reliable manner throughout the entire gaming session.

4. The mean difference and standard deviation between Stages 3 and 2 are –0.787 and 0.718 respectively, with a p-value of 0.000.

5. *Diff* = (Average density of theta oscillations at Stage 3) – (Average density of theta oscillations at Stage 2).

6. We coded high game familiarity as 1 and low game familiarity as 0. High game complexity is coded as 1 and low game complexity is coded as 0.

7. Each participant may provide more than one perception.

8. No significant difference was found between different game familiarities ($F = 2.417$, $p = 0.127$); however, a partially significant difference was found between different game complexities ($F = 3.266$, $p = 0.077$). No interaction effect existed between game complexity and game familiarity ($F = 2.784$, $p = 0.102$).

References

1. Agarwal, R., and Karahanna, E. Time flies when you're having fun: Cognitive absorption and beliefs about information. *MIS Quarterly, 24,* 4 (2000), 665–694.

2. Aghion, P.; Bloom, N.; Blundell, R.; Griffith, R.; and Howitt, P. Competition and innovation: An inverted-U relationship. *Quarterly Journal of Economics, 120,* 2 (2005), 701–728.

3. Ahmad, K. Mobile game development and Asian market: Solid revenue prospects. Mind Commerce, 2011 (available at http://blog.mindcommerce.com/2011/12/06/mobile-gaming-market).

4. Andres, H.P., and Petersen, C. Presentation media, information complexity, and learning outcomes. *Journal of Educational Technology Systems, 30,* 3 (2002), 225–246.

5. Ang, C.S.; Zaphiris, P.; and Mahmood, S. A model of cognitive loads in massively multiplayer online role playing games. *Interacting with Computers, 19,* 2 (2007), 167–179.

6. Annetta, L.A.; Minogue, J.; Holmes, S.Y.; and Cheng, M.T. Investigating the impact of video games on high school students' engagement and learning about genetics. *Computer & Education, 53,* 1 (2009), 74–85.

7. Arakji, R.Y., and Lang, K.R. Digital consumer networks and producer–consumer collaboration: Innovation and product development in the video game industry. *Journal of Management Information Systems, 24,* 2 (Fall 2007), 195–219.

8. Arazy, O., and Gellatly, I.R. Corporate wikis: The effects of owners' motivation and behavior on group members' engagement. *Journal of Management Information Systems, 29,* 3 (Winter 2012–13), 87–116.

9. Astor, P.J.; Adam, M.T.P.; Jercic, P.; Schaaff, K.; and Weinhardt, C. Integrating biosignals into information systems: A NeuroIS tool for improving emotion regulation. *Journal of Management Information Systems, 30,* 3 (Winter 2013–14), 247–277.

10. Aymerich-Franch, L. Presence and emotions in playing a group game in a virtual environment: The influence of body participation. *Cyberpsychology, Behavior and Social Networking, 13,* 6 (2010), 649–654.

11. Baddeley, A.D. Working memory: Looking back and looking forward. *Nature Reviews, 4* (October 2003), 829–839.

12. Baumgartner, T.; Valko, L.; Esslen, M.; and Jancke, L. Neural correlate of spatial presence in an arousing and noninteractive virtual reality: An EEG and psychophysiology study. *CyberPsychology & Behavior, 9,* 1 (2006), 30–46.

13. Beeli, G.; Casutt, G.; Baumgartner, T.; and Jancke, L. Modulating presence and impulsiveness by external stimulation of the brain. *Behavioral and Brain Functions, 4,* 33 (2008), 1–7.

14. Benbasat, I.; Dimoka, A.; Pavlou, P.A.; and Qiu, L. Incorporating social presence in the design of the anthropomorphic interface of recommendation agents: Insights from an fMRI study. In M. Lacity, S. March, and F. Niederman (eds.), *Proceedings of the 31st International*

Conference on Information Systems. St. Louis: Association for Information Systems, 2010, pp. 228–250.

15. Berka, C.; Levendowski, D.J.; Lumicao, M.N.; Yau, A.; Davis, G.; Zivkovic, V.T.; Olmstead, R.E.; Tremoulet, P.D.; and Craven, P.L. EEG correlates of task engagement and mental workload in vigilance, learning, and memory tasks. *Aviation, Space, and Environmental Medicine, 78,* 1 (2007), 231–244.

16. Boyle, E.A.; Connolly, T.M.; Hainey, T.; and Boyle, J.M. Engagement in digital entertainment games: A systematic review. *Computers in Human Behavior, 28,* 3 (2012), 771–780.

17. Brockmyer, J.H.; Fox, C.M.; Curtiss, K.A.; McBroom, E.; Burkhart, K.M.; and Pidruzny, J.N. The development of the game engagement questionnaire: A measure of engagement in video game-playing. *Journal of Experimental Social Psychology, 45,* 4 (2009), 624–634.

18. Buschman, T.J., and Miller, E.K. Top-down versus bottom-up control of attention in the prefrontal and posterior parietal cortices. *Science, 315* (March 30, 2007), 1860–1862.

19. Chumbley, J., and Griffiths, M. Affect and the computer game player: The effect of gender, personality, and game reinforcement structure on affective responses to computer game-play. *CyberPsychology & Behavior, 9,* 3 (2006), 308–316.

20. Clarke, A.R.; Barry, R.J.; McCarthy, R.; and Selikowitz, M. EEG analysis in attention-deficit/hyperactivity disorder: A comparative study of two subtypes. *Psychiatry Research, 81,* 1 (1998), 19–29.

21. Cohen, J.B., and Reed, A., II. A multiple pathway anchoring and adjustment model of attitude generation and recruitment. *Journal of Consumer Research, 33,* 1 (2006), 1–15.

22. Colter, N., and Shaw, J. EEG coherence analysis and field dependence. *Biological Psychology, 15,* 3–4 (1982), 215–228.

23. Davidson, R.J. Cerebral asymmetry and emotion: Conceptual and methodological conundrums. *Cognition & Emotion, 7,* 1 (1993), 115–138.

24. Delorme, A., and Makeig, S. EEGLAB: An open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. *Journal of Neuroscience Methods, 134,* 1 (2004), 9–21.

25. Derakshan, N., and Eysenck, M.W. Anxiety, processing efficiency, and cognitive performance: New developments from attentional control theory. *European Psychologist, 14,* 2 (2009), 168–176.

26. Dickey, M.D. Engaging by design: How engagement strategies in popular computer and video games can inform instructional design. *Educational Technology, Research and Development, 53,* 2 (2005), 67–84.

27. Dimoka, A. What does the brain tell us about trust and distrust? Evidence from a functional neuroimaging study. *MIS Quarterly, 34,* 2 (2010), 373–396.

28. Dimoka, A. How to conduct a functional magnetic resonance (fMRI) study in social science research. *MIS Quarterly, 36,* 3 (2012), 811–840.

29. Dimoka, A.; Pavlou, P.A.; and Davis, F.D. Research commentary—NeuroIS: The potential of cognitive neuroscience for information systems research. *Information Systems Research, 22,* 4 (2011), 687–702.

30. Dimoka, A.; Bagozzi, R.P.; Banker, R.D.; Brynjolfsson, E.; and Davis, F.D. NeuroIS: Hype or hope? In J.F. Nunamaker and W.L. Currie (eds.), *Proceedings of the 30th International Conference on Information Systems.* Atlanta: Association for Information Systems, 2009, pp. 133–142.

31. Dimoka, A.; Benbasat, I.; Lim, K.; Straub, D.; and Walden, E. NeuroIS: Challenges and solutions. In M. Lacity, S. March, and F. Niederman (eds.), *Proceedings of the 31st International Conference on Information Systems.* Atlanta: Association for Information Systems, 2010, pp. 201–207.

32. Dimoka, A.; Banker, R.D.; Benbasat, I.; Davis, F.D.; Dennis, A.R.; Gefen, D.; Gupta, A.; Ischebeck, A.; Kenning, P.; Pavlou, P.A.; Müller-Putz, G.; Riedl, R.; vom Brocke, J.; and Weber, B. On the use of neurophysiological tools in IS research: Developing a research agenda for NeuroIS. *MIS Quarterly, 36,* 3 (2012), 679–702.

33. Fang, X.; Chan, S.; Brzezinski, J.; and Xu, S. Moderating effects of task type on wireless technology acceptance. *Journal of Management Information Systems, 22,* 3 (Winter 2005–6), 123–157.

34. Fidelman, M. Why 99.9% of all mobile games are not profitable: The six things mobile game developers must do to survive. SeekOmega, February 28, 2012 (available at www.seekomega.com/2012/02/why-99-9-of-all-mobile-games-are-not-profitable-the-6-things-mobile-game-developers-must-do-to-survive).

35. Findlater, L., and McGrenere, J. Impact of screen size and performance, awareness, and user satisfaction with adaptive graphical user interfaces. In M. Czerwinski and A. Lund (eds.), *Proceedings of the 26th Annual SIGCHI Conference on Human Factors in Computing Systems.* Atlanta: ACM Press, 2008, pp. 1247–1256.

36. Galin, D.; Johnstone, J.; and Herron, J. Effects of task difficulty on EEG measures of cerebral engagement. *Neuropsychologia, 16,* 4 (1978), 461–472.

37. Garris, R.; Ahlers, R.; and Driskell, J.E. Games, motivation, and learning: A research and practice model. *Simulation Gaming, 33,* 4 (2002), 441–467.

38. Gevins, A.; Smith, M.E.; McEvoy, L.; and Yu, D. High-resolution EEG mapping of cortical activation related to working memory: Effects of task difficulty, type of processing, and practice. *Cerebral Cortex, 7,* 4 (1997), 374–385.

39. Gundel, A., and Wilson, G.F. Topographical changes in the ongoing EEG related to the difficulty of mental tasks. *Brain Topography, 5,* 1 (1992), 17–25.

40. Hamari, J., and Lehdonvirta, V. Game design as marketing: How game mechanics create demand for virtual goods. *International Journal of Business Science and Applied Management, 5,* 1 (2010), 14–30.

41. Hoffman, B., and Nadelson, L. Motivational engagement and video gaming: A mixed methods study. *Educational Technology Research and Development, 58,* 3 (2010), 245–270.

42. Hong, W.; Thong, J.Y.; Chasalow, L.C.; and Dhillon, G. User acceptance of agile information systems: A model and empirical test. *Journal of Management Information Systems, 28,* 1 (Summer 2011), 235–272.

43. Hubert, M.; Linzmajer, M.; Riedl, R.; Kenning, P.; and Hubert, M. Introducing connectivity analysis to NeuroIS research. In J.F. George (ed.), *Proceedings of the 33rd International Conference on Information Systems.* Atlanta: Association for Information Systems, 2012, pp. 19–40.

44. Jennett, C.; Cox, A.L.; Dhoparee, P.C.S.; Epps, A.; Tijs, T.; and Walton, A. Measuring and defining the experience of immersion in games. *International Journal of Human–Computer Studies, 66,* 9 (2008), 641–661.

45. Johnson, R.B.; Onwuegbuzie, A.J.; and Turner, L.A. Toward a definition of mixed methods research. *Journal of Mixed Methods Research, 1,* 2 (2007), 112–133.

46. Jones, M.; Buchanan, G.; and Thimbleby, H. Improving Web search on small screen devices. *Interacting with Computers, 15,* 4 (2003), 479–495.

47. Klimesch, W. EEG alpha and theta oscillations reflect cognitive and memory performance: A review and analysis. *Brain Research Reviews, 29,* 2–3 (1999), 169–195.

48. Klimesch, W.; Schack, B.; and Sauseng, P. The functional significance of theta and upper alpha oscillations. *Experimental Psychology, 52,* 2 (2005), 99–108.

49. Lee, M.-S.; Ko, Y.-H.; Song, H.-S.; Kwon, K.-H.; Lee, H.-S.; and Nam, M. Characteristics of Internet use in relation to game genre in Korean adolescents. *CyberPsychology & Behavior, 10,* 2 (2007), 278–285.

50. Lewis, B., and Porter, L. In-game advertising effects: Examining player perceptions of advertising schema congruity in a massively multiplayer online role-playing game. *Journal of Interactive Advertising, 10,* 2 (2010), 46–60.

51. Liang, T.-P. Cognitive neuroscience in information systems research. *Pacific Asia Journal of the Association for Information Systems, 4,* 1 (2012), 1–3.

52. Lin, Y.-L., and Lin, H.-W. A study on the goal value for massively multiplayer online role-playing games players. *Computers in Human Behavior, 27,* 6 (2011), 2153–2160.

53. Lindsley, D.B., and Wicke, J. The electroencephalogram: Autonomous electrical activity in man and animals. *Bioelectric Recording Techniques, 1,* Part B (1974), 3–83.

54. Mathalon, D.H.; Whitfield, S.L.; and Ford, J.M. Anatomy of an error: ERP and fMRI. *Biological Psychology, 64,* 1–2 (2003), 119–141.

55. McMahan, A. Immersion, engagement, and presence: A method for analyzing 3-D video games. In M.J.P. Wolf and B. Perron (eds.), *The Video Game, Theory Reader.* New York: Routledge, Taylor & Francis Group, 2003, pp. 67–86.

56. Mikulka, P.J.; Scerbo, M.W.; and Freeman, F.G. Effects of a biocybernetic system on vigilance performance. *Human Factors, 44,* 4 (2002), 654–664.

57. Moon, J.; Hossain, M.D.; Sanders, G.L.; Garrity, E.J.; and Jo, S. Player commitment to massively multiplayer online role-playing games (MMORPGS): An integrated model. *International Journal of Electronic Commerce, 17,* 4 (Summer 2013), 7–38.

58. Morse, J.M. Principles of mixed methods and multimethod research design. In A. Tashakkori and C. Teddlie (eds.), *Handbook of Mixed Methods in Social & Behavioral Research.* Thousands Oaks, CA: Sage, 2003, pp. 189–208.

59. Nacke, L.E.; Grimshaw, M.N.; and Lindley, C.A. More than a feeling: Measurement of sonic user experience and psychophysiology in a first-person shooter game. *Interacting with Computers, 22,* 5 (2009), 336–342.

60. Nunamaker, J.F.; Derrick, D.C.; Elkins, A.C.; Burgoon, J.K.; and Patton, M.W. Embodied conversational agent-based kiosk for automated interviewing. *Journal of Management Information Systems, 28,* 1 (Summer 2011), 17–48.

61. Ohme, R.; Reykowska, D.; Wiener, D.; and Choromanska, A. Analysis of neurophysiological reactions to advertising stimuli by means of EEG and galvanic skin response measures. *Journal of Neuroscience, Psychology, and Economics, 2,* 1 (2009), 21–31.

62. Olson, C.K. Children's motivations for video game play in the context of normal development. *Review of General Psychology, 14,* 2 (2010), 180–187.

63. Przybylski, A.K.; Rigby, C.S.; and Ryan, R.M. A motivational model of video game engagement. *Review of General Psychology, 14,* 2 (2010), 154–166.

64. Reeves, B.; Lang, A.; Kim, E.Y.; and Tatar, D. The effects of screen size and message content on attention and arousal. *Media Psychology, 1,* 1 (1999), 49–67.

65. Riedl, R.; Hubert, M.; and Kenning, P. Are there neural gender differences in online trust? An fMRI study on the perceived trustworthiness of eBay offers. *MIS Quarterly, 34,* 2 (2010), 397–428.

66. Sanchez, J.L.G.; Zea, N.P.; and Gutierrez, F.L. From usability to playability: Introduction to player-centered video game development process. In M. Kurosu (ed.), *Proceedings of Human Centered Design.* San Diego: Springer, 2009, pp. 65–74.

67. Sauseng, P., and Klimesch, W. What does phase information of oscillatory brain activity tell us about cognitive process? *Neuroscience and Biobehavioral Reviews, 32,* 5 (2008), 1001–1013.

68. Smith, S.P.; Johnston, R.B.; and Howard, S. Vicarious experience in retail e-commerce: An inductive taxonomy of product evaluation support features. *Information Systems and e-Business Management, 3,* 1 (2005), 21–46.

69. Someren, M.W. van; Barnard, Y.F.; and Sandberg, J.A.C. *The Think Aloud Method: A Practical Guide to Modelling Cognitive Processes.* London: Academic Press, 1994.

70. Spilich, G.J.; Vesonder, G.T.; Chiesi, H.L.; and Voss, J.F. Text processing of domain-related information for individuals with high and low domain knowledge. *Journal of Verbal Learning and Verbal Behavior, 18,* 3 (1979), 275–290.

71. Tan, E.S.-H. Entertainment is emotion: The functional architecture of the entertainment experience. *Media Psychology, 11,* 1 (2008), 28–51.

72. Thomas, D.C., and Meglino, B.M. Causal attribution in an intercultural interaction: The effect of stimulus presentation mode. *Journal of Cross-Cultural Psychology, 28,* 5 (1997), 554–568.

73. Webster, J., and Ahuja, J.S. Enhancing the design of Web navigation systems: The influence of user disorientation on engagement and performance. *MIS Quarterly, 30,* 3 (2006), 661–678.

74. Weibel, D.; Wissmath, B.; Habegger, S.; Steiner, Y.; and Groner, R. Playing online games against computer vs. human-controlled opponents: Effects on presence, flow, and enjoyment. *Computers in Human Behavior, 24,* 5 (2008), 2274–2291.

Appendix: Items for User–Game Engagement

Gep1	When playing game, I lose track of time.
Gep2	When playing game, things seem to happen automatically.
Gep3	When playing game, I feel different.
Gep5	When playing game, the game feels real.
Gep6	When playing game, if someone talks to me, I don't hear him or her.
Gep7	When playing game, I get wound up.
Gep8	When playing game, time seems to kind of stand still or stop.
Gep9	When playing game, I feel spaced out.
Gep10	When playing game, I don't answer when someone talks to me.
Gep14	When playing game, I lose track of where I am.
Gep18	When playing game, I really get into the game.
Gep19	When playing game, I feel like I just can't stop playing.
Invol1	In general, I have a strong interest in playing this game.
Invol3	Playing this game matters a lot to me.
Invol5	I definitely have a "wanting" for playing this game.
Invol6	I am involved in playing this game.

Source: Adapted from Brockmyer et al. [17].