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Comprehending the influence of brain games mode over playfulness and playability metrics: a fused exploratory research of players' experience

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ABSTRACT

Undertaking cognitively stimulating activities over the course of life, such as playing brain games (*BGs*), is only possible if they continuously deliver a playful as well as playable experience. The understanding of how these subcomponents of experience (i.e. playfulness and playability) get influenced in both modes (single vs. two-player) of *BGs* was previously fuzzy. The objective of the presented research was to gain more insight into the preceding phenomenon. Various factors were recorded under both experience metrics (playfulness: engagement, enjoyment, and anxiety and playability: usability, adaptability, and non-invasiveness) during the presented research ($n = 117$) that incorporates the series of *BGs* play. Statistical analysis was performed on the recorded data that revealed significant correlations between as well as within the factors of both experience metrics. The presented research further implicated the quantitative findings in relation to the employed *BGs*' design and participants' social interaction. Thus, it is concluded that both modes of *BGs* dominate one another in terms of arousing the various factors of both experience metrics; however, neither mode delivers playfulness and playability in an absolute manner.

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Gamification; player experience; cognition; game designing; children

1. Introduction

The brain games (*BGs*) are immensely being considered for a long time as one of the most cost-effective, entertaining, and exciting cognitively stimulating activities (Dorval & Pepin, 1986; Drew & Waters, 1986; Dustman et al., 1992; Greenfield et al., 1996; Lowery & Knirk, 1982; McClurg & Chaille, 1987; Okagaki & Frensch, 1994; Subrahmanyam & Greenfield, 1994; Yuji, 1996). In the recent years, researchers also proposed numerous *BGs* that mainly offer single-player mode (Champion & McCallum, 2022; Douch et al., 2020; Kelly et al., 2020; Krouska et al., 2020; Mróz, 2021; Amin et al., 2022; Hamavar & Asl, 2021; Serrano-Barroso et al., 2021; Singh et al., 2020; Sara et al., 2022; Wu et al., 2022) and a very few that offer two-player mode (Aadeel et al., 2014; Vasiljevic et al., 2018); nonetheless, to attain their respective goals, keeping the players motivated to commence *BGs* activity on regular basis for a longer period of time has been a challenge (Aison et al., 2002;

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Eggermont et al., 2006; Garris et al., 2002; Ijsselsteijn et al., 2007; Melenhorst, 2002; O'Donovan et al., 2012; Pearce, 2008; Roschelle et al., 2000). It is evident in most of the scientific studies that a long-term commitment by the players can possibly be achieved if the associated game continuously delivers a playful as well as a playable experience (Alessandro & Franca, 2009; Eric et al., 2013; Guillaume et al., 2008; Jon-Chao et al., 2012; Jon-Chao et al., 2016; Vivian et al., 2006). Thus, it is important to identify the additional means that potentially assist to sustain both the subcomponents of experience (i.e. playfulness and playability). Therefore, like the various other substantially yet unexplored potential means, it is equally necessary to investigate the influence of both modes (single vs. two-player) of *BGs* over both the highlighted subcomponents.

This article presents empirical research that explores the influence of both modes (single vs. two-player) of *BGs* over both the experience metrics (playfulness: engagement, enjoyment, and anxiety, and playability: usability, adaptability, and non-invasiveness). It was essential to perform the presented investigation due to the following somewhat unaddressed questions.

(1) Based on the underlying factors of playfulness and playability metrics which mode of *BGs* delivers a better experience?
(2) How are the underlying factors of playfulness and playability metrics associated to influence the experience in each mode of *BGs*?
(3) How are the employed *BGs*' design and participants' social interaction influence the experience in each mode of *BGs*?

It is difficult to trace the challenges previous researchers faced in investigating the above-highlighted questions. As to the best of our knowledge, it is a first endeavor to extensively analyze the fusion of both experience metrics between both the modes of *BGs*. This conclusion is drawn from the literature review that was carried out to identify challenges, critical gaps, or overlooked extents of the research field that necessitate more investigation or analysis. A search string including primary (i.e. brain game), secondary (i.e. single-player or two-player or multiplayer), tertiary (i.e. playful, playable, or experience), and additional keywords (i.e. engagement, enjoyment, anxiety, usability, adaptability, or non-invasiveness) was selected to choose all the potential work for the literature review. The search process for this paper is based on digital libraries (i.e. ACM digital library, IEEE Xplore, Science Direct, Springer Link, and Wiley) (see Section 3). However, while addressing the above-highlighted questions, the presented research makes the following contributions.

(1) It identifies the dominating factors of playfulness and playability metrics between both the modes of *BGs* (see Section 5.1).
(2) It identifies significant correlations between as well as within the factors of both experience metrics in each mode of *BGs* (see Section 5.2).
(3) It further implicates the quantitative findings in relation to the employed *BGs*' design and participants' social interaction (see Section 5.3).

The remaining paper is organized as follows. Section 2 defines both experience metrics. Section 3 discusses the existing literature. Section 4 states the research methodology including complete detail about the game suite, research design, participants recruitment and experimental setting, data collection and analysis. Section 5 demonstrates the results. Section 6 provides conclusive remarks.

2. Definitional issues

The detailed research study of Nacke & Drachen, 2011 intended to describe playfulness and playability under the paradigm of user experience. However, in the existence of 250 previously published

research studies illuminating these two distinct multidimensional concepts, this research considered itself as groundwork. It is nearly impossible to cover all the correlated factors of playfulness and playability that help to describe experience in any scope of major or minor interest. For example, the term *playfulness* has been used to quantify the wide range of players' psychological conditions that comprise of their emotions (Hassenzahl & Tractinsky, 2006; Law et al., 2007), satisfaction (Sánchez et al., 2009), pleasure (Jordan, 1999), motivation (Kankainen, 2003), and fun (Garrett, 2003); whereas the term *playability* has also been employed numerous times to extensively assess the practicability of a game that incorporates its adaptability (Fernandez, 2008) and usability (Pagulayan et al., 2003; Pagulayan & Steury, 2004). Therefore, no definitional agreement so far exists about systematically encompassing both the experience metrics (Nacke & Drachen, 2011).

It is necessary to delineate a boundary of the presented research study by encompassing the diverse nature of both experience metrics. In this paper, the factors of enjoyment, engagement (immersion, flow, presence, and absorption), and anxiety are considered under the metric of playfulness and the factors of adaptability, usability, and non-invasiveness are considered under the metric of playability. The selection of the considered factors is made based on their noteworthy acknowledgment under the respective experience metric (Amir et al., 2019; Karen et al., 2018; Oliver & Stefan, 2017; Ralf et al., 2015; Sara & Timmy, 2017; Stefan & Maic, 2017; Stylianos & Eleni, 2018; Vincent & Stefan, 2018). The definition of each considered factor under the respective experience metric is quoted due to their noteworthy acknowledgment through citations (Brooke, 1996; Elisa et al., 2014; Gallagher & Prestwich, 2012; Hackbarth et al., 2003; Järvinen et al., 2002; Jeanne et al., 2009; Kickmeier-Rust et al., 2008; Kucklich, 2004; Seligman et al., 1984) as follows.

2.1. Playfulness

The term *playfulness* describes an individual's propensity to interact instinctively with video games by employing various playful modes of expression. Typically, it can be considered as an attitude that stimulates playability (Hackbarth et al., 2003). Three major factors that were considered under the metric of playfulness are described as follows.

2.1.1. Engagement

Engagement indicates a general involvement in the video game; however, it logically encompasses immersion, flow, presence, and absorption. These can be signified as continuously increasing engagement levels (Jeanne et al., 2009), which are explained as follows.

Immersion – The experience of a video game, where the player feels being a part of it, is termed as *immersion* (Wirth et al., 2007). Moreover, the immersion is also studied to measure the engagement in a gaming activity whilst preserving some consciousness of its surroundings (Banos et al., 2004; Singer & Witmer, 1999).

Presence – The perception of being virtually inside an environment is termed as *presence* (Mania & Chalmers, 2001; Mikropoulos & Strouboulis, 2004; Richard et al., 2006; Tamborini & Skalski, 2006). Soon after, another term *spatial presence* is also proposed to refer the perception of being integrated in a mediated environment (Wirth et al., 2007). Unlike the previous formulation, this characterization includes both media; the modern such as games and the conventional such as books.

Flow – The feeling that occurs when a player achieves a balance between its skill and the challenge of video game activity is termed as *flow* (Csikszentmihalyi & Csikszentmihalyi, 1988; Moneta & Csikszentmihalyi, 1996, 1999). Hence, the flow also indicates the feeling of being in control as well as experiencing time distortion.

Absorption – The total engagement in an ongoing gaming situation is termed as *absorption* (Irwin, 1999). In contrast to presence and immersion, being in this state stimulates a modified state of consciousness (i.e. like the flow). In this modified state there is a division among the thoughts, emotions, and the experience where the impact is not much accessible to consciousness (Glicksohn & Avnon, 1997).

2.1.2. Enjoyment

Enjoyment illustrates the positive emotion of a player in general. The description of enjoyment in a gaming activity was formerly vague (Sweetser & Wyeth, 2005) and not well discriminated from other theoretically related perspectives (Nacke & Drachen, 2011); however, lately, it is described as a combination of entertainment, (minimum) frustration, one's interest, challenge, and competence (Elisa et al., 2014).

2.1.3. Anxiety

Anxiety depicts one's worriedness, uneasiness and/or nervousness. It is also symbolized by an unpleasant state of inner turmoil, usually conveyed by nervous actions (Seligman et al., 1984). Likewise, the anxiety of the player implies an unpleasant emotion frequently occur due to the unforeseen gaming events.

2.2. Playability

The term *playability* implies the interaction quality between players and video games that enhances their interest during the gaming activity (Järvinen et al., 2002; Kucklich, 2004). Three major factors that were considered under the metric of playability are described as follows.

2.2.1. Usability

Usability itself cannot be defined or quantified in an absolute manner; however, it is comprehensively described as an individual's appropriateness for the purpose (Brooke, 1996). According to ISO 9241-11, the usability measurement should involve the components of efficiency, effectiveness, and satisfaction. Similarly, these components must be measured in connection with its context for quantifying and assessing the usability of a video game.

2.2.2. Adaptability

The term *adaptability* usually refers to the ability of an individual to be adaptive in dynamic environments. Correspondingly, the adaptability of a game refers to the feature of being satisfactory for a diverse audience (Gallagher & Prestwich, 2012).

2.2.3. Non-invasiveness

Non − invasiveness is a term frequently used in health sciences to refer to some treatments given without cutting or putting anything into a patient's body (Topalo & Chele, 2012). Similarly, in video games, non-invasiveness implies a method that achieves its goal without any visible or tangible contact with the player (Kickmeier-Rust et al., 2008).

3. Literature review

3.1. Summary

Some of the video game-related research studies endeavored to describe the relationships among different subcomponents of experience (Alessandro & Franca, 2009; Eric et al., 2013; Guillaume et al., 2008; Jon-Chao et al., 2012; Jon-Chao et al., 2016; Vivian et al., 2006). Either engagement or anxiety, and sometimes both are the common factors that came under debate in each cited literature, either to comprehend their impact upon each other (Jon-Chao et al., 2012) or in relation to adaptability (Guillaume et al., 2008), usability (Alessandro & Franca, 2009), enjoyment (Vivian et al., 2006), flow (Jon-Chao et al., 2016) or presence (Eric et al., 2013). For example, Guillaume et al., 2008 proposed an emotion recognition method to sustain the engagement of the participants. They collected physiological observations and questionnaire-based feedback from 13 male and 7 female participants of age 27 (on average) during and after playing a *Tetris* game. Their conclusions indicate that the

engagement and the anxiety are the indicators for the adaptation. Likewise, Jon-Chao et al., 2012 developed an online puzzle game named *Chinese Idioms String Up Puzzle* to encourage the students to learn Chinese idioms. A survey was performed after the gaming activity to examine 122 participants (mean age: 13.09, 63 males and 59 females) in terms of their engagement, anxiety, and cognitive load. According to the survey, engagement was not significantly related to their anxiety. Vivian et al., 2006 also studied engagement but in-relation to the entertainment and the enjoyment in the massive multiplayer online role-playing games, where they determined a considerable link between engagement and enjoyment of the 40 participants (31 males and 9 females, aged between 14 and 27). Like Vivian et al., 2006; Alessandro & Franca, 2009 also employed eight massive multiplayer online games to study the design factors that may influence long-term user engagement; however, their study ($N = 47$) revealed that the engagement appears to have a low correlation with usability. Unlike Guillaume et al., 2008 and Jon-Chao et al., 2012, who investigated the significance of the correlation between anxiety and overall engagement, Eric et al., 2013 and Jon-Chao et al., 2016 explored subcomponents of the engagement (i.e. presence and flow, respectively) in association with anxiety. The study of Eric et al., 2013 comprised 18 participants (mean age: 44.11 (ranging from 24 to 72), 11 women and 7 men), that aimed to construct an interactive virtual environment (VE), revealed a considerable correlation between anxiety and the presence. Whereas the study of Jon-Chao et al., 2016, that explores internet cognitive failure (ICF) and its influence upon cognitive anxiety and flow while playing a puzzle game named Running Chinese Zodiac, concluded cognitive anxiety as inversely correlated to the flow experience. Junior high school students participated in this experiment including 74 males and 75 females of 14–15 years old.

3.2. Limitations and gaps

Implications of most of the above-cited literature (Alessandro & Franca, 2009; Guillaume et al., 2008; Jon-Chao et al., 2012 & Vivian et al., 2006) are somewhat like the presented research (see Section-5), yet we consider them unparalleled due to the following three reasons.

(1) It is widely known by the numerous pieces of evidence that the experience of the players varies in relation to their age (Ahmad et al., 2020, 2021, 2023; Faizan et al., 2016,) and game genre (Richard et al., 2006). Therefore, only the results of Jon-Chao et al., 2012, 2016 could have been comparable with the presented research (as they also employed serious games) if they would have incorporated children rather than teenagers in their research.
(2) It is imperative that the players undergo more than one video gameplay including their different modes to provide evidence of the findings from different game presentations and contexts. Many times, opting only a single game from a genre and limiting the play styles to only one mode could produce biased outcomes. Experimenting the association in more than one game and mode provides clear indications to lessen such bias (Ryan et al., 2006). Yet, none of the above-cited literature considered investigating the different modes of video game in their research, and only Alessandro & Franca, 2009 incorporated more than one video game of the targeted genre to overall understand the effective design factors for long-term user engagement. However, the findings of Alessandro & Franca, 2009 are still incomparable with the presented research as they did not mention the age group of targeted subjects as well as their targeted game genre does not match with the presented research.
(3) It is well-established that the correlation does not imply causation. The phenomenon is true since it is nearly impractical in a real-world situation to find the element(s) that has a causal connection with the other element, as there constantly exists the unknown factor(s) that affect(s) causality between the associated elements. The motivation behind the pervasive use of the correlation technique is not to find a causal relationship but to comprehend the impact of one element in relation to the other(s) while acknowledging the influence is not causal.

Consequently, it is necessary to cover most of the factors (if all are impractical) to set up a comprehensive interpretation of the players' experience-related dependencies through correlation technique. Conversely, the literature did not emphasize on too many factors under their studies, which unlike the presented research does not provide a broader understanding of the domain.

Therefore, irrespective of the similarities between the inferences of most of the cited literature and the presented research study, the above emphasized three reasons collectively make this empirical research first-of-its-kind and incomparable with the outcomes of the existing literature.

4. Research methodology

4.1. Game suite

BrainStorm is a psychosocial game suite, exclusively designed for single or two-player activities (Faizan et al., 2017). A major reason behind the selection of this game suite over its competitors (e.g. Vasiljevic et al., 2018) is its uniquely designed game strategy (i.e. elucidated in the last paragraph of this section), which offers a cooperative yet competitive environment in two-player mode as well as clearly discriminates from its single-player mode. This game suite includes three *BGs* (shown in Figure 1): (i) *Picture Puzzle* (see Figure 1(a)), (ii) *Find the Difference* (see Figure 1(b)), and (iii) Letter and Number (see Figure 1(c)). These three *BGs* are designed to respectively target memory, vision, and analytical abilities. An overall flow of the employed *BGs* is described below.

4.1.1. Picture Puzzle

In *Picture Puzzle BG*, 15 images of renowned places and/or personalities are displayed one after another and each time the player must select their name correctly from the provided choices to earn 30 points (see Figure 1(a)). The underlying mechanism of this *BG* involves the player's attention to receive the data from their visual resource and pass it to the active memory. Active memory then proceeds and fetches its precise information from the declarative long-term memory, established previously in the memorization session. A clue cards based session, ranging from 5 to10 minutes, was organized for each participant, before the gaming activity, to memorize the names of renowned places and personalities that can be asked in *Picture Puzzle BG*; however, an insight was claimed by Ahmad et al., 2021 that on average only 10% of the places and personalities were already known to the participants.

4.1.2. Find the difference

In *Find the Difference BG*, three different pairs of similar images of renowned places are displayed one after another and each time the player must find exactly six differences between each pair of images to earn 30 points against each difference identification (see Figure 1(b)). The underlying mechanism

(a). *Picture Puzzle* **(b).** *Find the Difference* **(c).** *Letter and Number*

Figure 1. *BrainStorm* high fidelity prototype.

of this *BG* requires the player to hold visual information of the sample image for a few seconds in its active memory so it can be matched with a test image in order to identify differences between sample frame and test frame.

4.1.3. Letter and number

The *Letter and Number BG* has 10 incomplete series of numbers or letters that appear on the screen one after another and each time the player must figure out its sequence to complete the series by selecting the correct letter or number from the provided options in order to earn 30 points (see Figure 1(c)). The underlying mechanism of this *BG* requires the player to sequentially execute information visualization, articulation, analysis, and decision making based on their perception.

It is worth mentioning that the only additional feature that exists within the two-player mode of *BrainStorm* is to transfer a question (i.e. under two situations). The first situation is when a player, namely $player_1$, does not know the answer to its brand-new question and it seeks for assistance by explicitly transferring that question to its opponent, namely $player_2$. This transfer facility is only available once in every rank provided $player_1$ has attained third rank or the above. And if $player_2$ gives a correct answer of that transferred question, it earns 50 points and the $player_1$ obtains complimentary 30 points; whereas, in case of incorrect answer by $player_2$, both players lose 10 points. The second situation is when $player_1$ gives an incorrect answer to its brand-new question, and the question implicitly transfers to $player_2$ for a bonus attempt. If $player_2$ answers the transferred question correctly, it earns 40 points and $player_1$ obtains complimentary 20 points, whereas, in case of incorrect answer by $player_2$, there is no deduction in points of any player. Hence, each one has an opportunity to win additional points by supporting its opponent, which uniquely encourages the concept of cooperative gameplay in a competitive environment of *BrainStorm*. An explicit audiovisual intuition was embedded in the two-player mode of *BrainStorm* to notify each player about the arrival of the transferred question. This includes the addition of snowfall (i.e. whitish under the first situation and yellowish under the second situation) in the background theme of each *BG* along with the slight change in its background music, which is observed as clearly perceivable by EG_2.

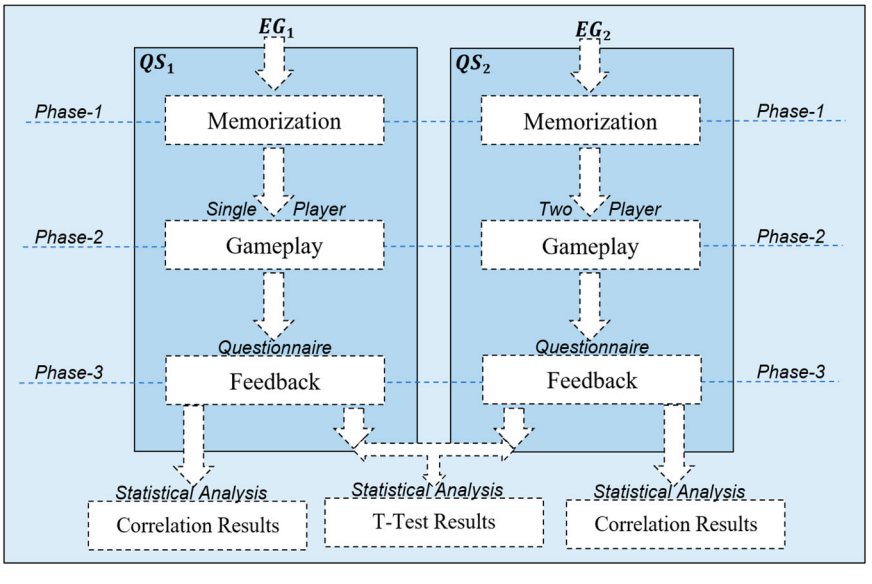

Figure 2. Steps of the research design.

4.2. Research design

This empirical research includes two independent quantitative studies (*QSs*: QS_1 and QS_2) (see Figure 2). Every *QS* is a threefold activity that was undertaken by the separate experimental groups (*EGs*:EG_1 and EG_2). In the initial phase of both *QSs*, each participant went through the memorization phase for *Picture Puzzle BG*. Later in the second phase of QS_1, each participant from the EG_1($n_1 = 59$) individually played all three *BGs* of *BrainStorm* game suite in a single-player gaming mode. Whereas in the second phase of QS_2, each participant from the EG_2 ($n_2 = 58$) played all three *BGs* of *BrainStorm* game suite against its competitor participant (i.e. also from EG_2) in a two-player gaming mode. Finally, in the third phase of both *QSs*, each participant provided questionnaire-based feedback against both experience metrics followed by the interview session.

4.3. Participants and psychologists recruitment into the experimental setting

For each *QS*, we invited volunteer children and their parent(s) from a neighboring community school. The recruitment process of children as the participants was carried out based on the criteria of their sufficient gaming experience (i.e. habitual of gameplay once a week or more). A reason behind the recruitment of children only with sufficient gaming experience was to avoid the learning curve and its consequences upon playfulness and playability during both *QSs*. An agreement about the data gathering was signed by the parent(s) of the children at the time of recruitment.

For each *QS*, we invited volunteer psychologists from neighboring hospitals. The recruitment process of psychologists was carried out based on the criteria of their sufficient experience (i.e. at least three years of professional practice history and basic familiarity with the gameplay). A reason behind the recruitment of psychologists only with sufficient experience was to collect an observation of the subject-matter experts during both *QSs*.

In the *QSs*, after welcoming the participants (65 male and 52 female Chinese children aged 9–10 years) and 8 psychologists in our department, we presented them the rationale of our current study and gave a basic guideline for the game activity. The *QSs* were performed in an indoor environment. Moreover, unlike the tablet, the 19.5 in. touch screens were utilized for the *BGs* play to allow each participant to interact with the *BGs* with better visibility. However, we fixed touch screens horizontally on the table to ease the participants like tablets (see Figure 3).

Figure 3. *BrainStorm* environmental setting.

4.4. Data collection

Feedback against both experience metrics were recorded from the participants right after the activity of *BGs* play in their respective *QS* upon a 5-point Likert scale questionnaire anchored by 1 (strongly disagree) and 5 (strongly agree). Every *QS*-intervention was 1 d for 8 h in which the computer-aided *BGs* multi-parallel activities were carried out under the observation of psychologists in quiet rooms. For each activity, one psychologist was appointed to observe. On average, each participant took 20 min to end their one-time gaming activity. Interactions among the competitor participants were observed during the activity of *BGs* play in QS_2. It is worth mentioning that most of the interactions were a casual exchange of thoughts, feelings, and updates about the ongoing gameplay (see Section 5). However, to prevent bias risk and the potential influence of any unknown variable in the *QSs*, the participants who had completed the activity were not allowed to interact with the participants who were waiting to start the activity. To independently as well as holistically understand the observations, a session was organized at the end of every *QS*-intervention with the group of invited psychologists, where they also interacted with each other about the observations of the participants.

To gather feedback regarding the four aspects of engagement (i.e. immersion, flow, presence, and absorption), Game Engagement Questionnaire (*GEQ*) is employed (Jeanne et al., 2009). Feedback about the usability factor of *BGs* is recorded by exploiting the System Usability Scale (*SUS*) (Brooke, 1996). To collect feedback concerning the two aspects of emotions (i.e. anxiety and enjoyment), a compiled version of 11 the most frequently used questions in various past literature is borrowed from Elisa et al., 2014. Besides, to collect feedback about the adaptability and non-invasiveness against the hidden goal behind *BGs* play, the *ASCNQ* (Adaptability, Social interaction, Children's education and Non-invasiveness Questionnaire) is partially utilized (Faizan et al., 2017). The *ASCNQ* is a multi-dimensional construct, equally distributed for measuring its four components, hence it does not disturb the findings if the questionnaire gets partially used.

4.5. Data analysis

A statistical analysis is performed on the accumulated data to ascertain experience-related trends between as well as within the *QSs*. During the initial phase, a two-sample paired t-test is applied over the data of the same factors of experience metrics against both *QSs* to identify the impact of their difference. Besides the mean, standard deviation and standard error, Cohen's d-value is also calculated in this phase to measure its effect size (Cohen, 1992). The effect size is small if the value of $r_{Y\lambda}$ varies around 0.1, medium if it varies around 0.3, and large if it varies around 0.5; as claimed by Cohen, 1992. Whilst in the second phase, Pearson correlation (Cohen, 1988) is applied over the data of the factors of experience metrics for each *QS* to find their degree of correlation, where the "r" implies the direction as well as the effect size of the correlation. According to Cohen, 1988, 1992, the effect size is at a low level if the value of "r" varies between ±0.1 to ±0.3, medium if it fluctuates between ±0.3 to ±0.5, and large if it diverges between ±0.5 to ±1.0. Furthermore, the *p*-value is computed in this phase to show the impact of the findings (Cohen, 1988). It is well-established that the correlation does not imply causation, yet this method has been used by the immense range of literature that also includes a research study named *StudentLife* (Rui et al., 2014). It is almost impossible in a real-world situation to discover the element(s) that has a causal relationship with the other element, as there always exists unknown factor(s) that alter(s) the causality between the related elements. Hence, the motivation behind employing the correlation technique, is not to discover a causal relationship but to comprehend the influence of an element in relation to the other(s) while conceding the influence is not causal.

5. Results

5.1. Summary

Recorded trends of both experience metrics are shown in Figure 4. The demonstration relatively delineates playfulness (engagement, enjoyment, and anxiety) and playability (usability, adaptability, and non-invasiveness) in both *QSs*.

The result implies that in comparison with QS_1, both emotions (i.e. enjoyment and anxiety) relatively aroused more during QS_2 and their level of non-invasiveness against the hidden goal behind *BGs* play also significantly increased. As the participants enjoyed an activity of *BGs* play more in QS_2 ($\mu = 4.40$ and $\sigma = 0.55$) than in QS_1 ($\mu = 4.23$ and $\sigma = 0.62$), $t(116) = -4.926$, $d = 0.30$, $r_{\gamma\lambda} = 0.15$, $p = 0.05$; surprisingly, an emotion of anxiety throughout the *BGs* play also reported as higher in QS_2 ($\mu = 1.91$ *and* $\sigma = 0.31$) than in QS_1 ($\mu = 1.68$ and $\sigma = 0.48$), $t(116) = -3.193, d = 0.57, r_{\gamma\lambda} = 0.27$, $p = 0.05$. Similarly, the non-invasiveness reported as significantly higher in QS_2 ($\mu = 3.73$ and $\sigma = 0.64$) than in QS_1 ($\mu = 3.04$ and $\sigma = 0.58$), $t(116) = -6.207, d = 0.54, r_{\gamma\lambda} = 0.26$, $p = 0.05$. Conversely, the summarized results further implicate that in comparison with QS_2, the participants during QS_1 got more engage (QS_1: ($\mu = 3.32$ *and* $\sigma = 0.37$) and QS_2: ($\mu = 3.27$ and $\sigma = 0.32$)) ($t(116) = 2.725$, $d = 0.15$, $r_{\gamma\lambda} = 0.08$, $p = 0.05$) as well as adaptive (QS_1: ($\mu = 3.79$ and $\sigma = 0.41$) and QS_2: ($\mu = 3.61$ and $\sigma = 0.46$)) ($t(116) = 2.249$, $d = 0.41$, $r_{\gamma\lambda} = 0.20$, $p = 0.05$) with *BGs* play plus their level of usability (QS_1: ($\mu = 3.29$ and $\sigma = 0.34$) and QS_2: ($\mu = 3.20$ and $\sigma = 0.29$)) ($t(116) = 2.852$, $d = 0.30$, $r_{\gamma\lambda} = 0.15$, $p = 0.05$) for *BGs* also got enhance. It is worth mentioning that the overall engagement was computed by accumulating the outcomes of its four aspects (i.e. immersion, presence, flow, and absorption) as demonstrated in Table 1.

5.2. Statistical insight

A statistical analysis is performed on the above-demonstrated data to understand the precise trends of correlation between as well as within both experience metrics for every *QS* (see Table 2). The stated results implicate that an induction of positive emotion(s) during *BGs* play influence(s) to build an optimistic perception regarding the usability of this game genre within a single-player mode (i.e. by offering (minimal) anxiety ($r = -0.32$, $p < 0.001$)) as well as two-player mode (i.e. by offering enjoyment ($r = 0.35$, $p < 0.001$) and (minimal) anxiety ($r = -0.57$, $p < 0.001$)) (see Table 2(a)). This positive emotion (i.e. enjoyment) induces by the

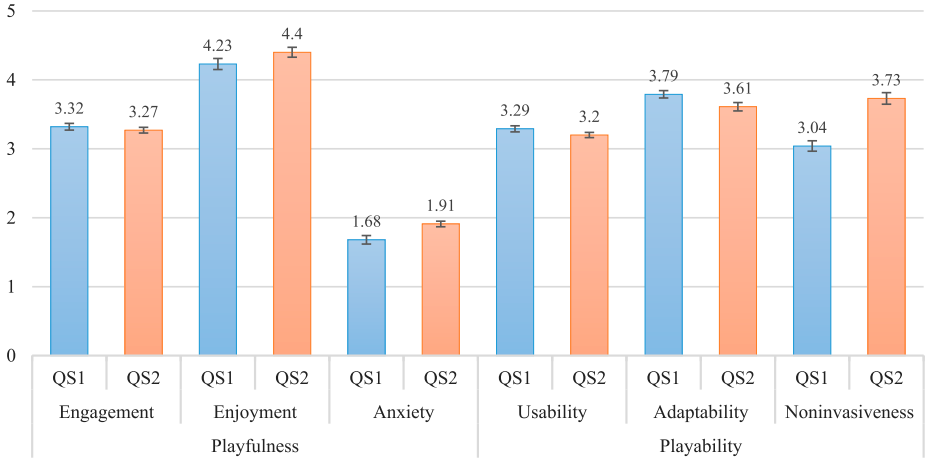

Figure 4. Experience result summary of both *QSs* with $\sigma_{\bar{x}}$.

Table 1. Four aspects result of engagement.

	Immersion		Presence		Flow		Absorption	
	μ	σ	μ	σ	μ	σ	μ	σ
QS_1	3.77	0.42	3.34	0.34	3.23	0.33	2.95	0.39
QS_2	3.56	0.34	3.30	0.25	3.23	0.48	2.99	0.22

degree of engagement *BGs* produce within single-player mode (i.e. in terms of presence ($r = 0.42$, $p < 0.001$), flow ($r = 0.47$, $p < 0.001$), and absorption ($r = 0.46$, $p < 0.001$)) as well as two-player mode (i.e. in terms of immersion ($r = 0.28$, $p = 0.04$), presence ($r = 0.37$, $p < 0.001$), flow ($r = 0.65$, $p < 0.001$), and absorption ($r = 0.20$, $p < 0.001$)); however, this positive emotion (i.e. enjoyment) gets a negative influence due to anxiety ($r = -0.30$, $p < 0.001$) only in single-player mode (two-player mode of *BGs* is surprisingly immune to this phenomenon) (see Table 2(b)). A state of being engaged in *BGs* play also influences to enhance adaptability (i.e. entirely, through being absorbed ($r = 0.38$, $p = 0.01$)) (see Table 2(c)) as well as non-invasiveness (i.e. partially, through being immersed ($r = 0.38$, $p = 0.058$)) within single-player mode; another aspect that influences to enhance non-invasiveness in a single-player mode is the induction of positive emotion (i.e. enjoyment ($r = 0.21$, $p < 0.001$)) during *BGs* play (see Table 2(d)). Conversely, in two-player mode, the enhancement of these factors (i.e. adaptability and non-invasiveness) influence through an induction of positive emotion during *BGs* play (i.e. respectively by offering enjoyment ($r = 0.51$, $p = 0.028$) as well as (minimal) anxiety ($r = -0.62$, $p < 0.001$) (see Table 2(c)), and (minimal) anxiety ($r = -0.53$, $p < 0.001$) (see Table 2(d)).

5.3. Design and interaction insight

Besides, the correlational influence between as well as within both experience metrics (see Table 2) that somewhat assists to dominate one gaming mode in a particular manner over the other (see Figure 4), it is also important to further implicate the quantitative findings in relation to the two-player *BGs*' design and participants' social interaction. The observation of QS_2 reported numerous active interactions between the opponent participants, which primarily includes an exchange of updates and support about the ongoing gaming situation. These interactions can be further

Table 2. Trends of correlation among both experience metrics.

	QS_1			QS_2	
	r	p-value		r	p-value
(a). Correlation between the usability and the other targeted experience					
Enjoyment	–	–	Enjoyment	0.35	<0.001
Anxiety	−0.32	< 0.001	Anxiety	−0.57	<0.001
(b). Correlation between the enjoyment and the other targeted experience					
Immersion	–	–	Immersion	0.28	0.04
Presence	0.42	< 0.001	Presence	0.37	<0.001
Flow	0.47	< 0.001	Flow	0.65	<0.001
Absorption	0.46	< 0.001	Absorption	0.2	<0.001
Anxiety	−0.3	< 0.001	Anxiety	–	–
(c). Correlation between the adaptability and the other targeted experience					
Absorption	0.38	0.01	Absorption	–	–
Enjoyment	–	–	Enjoyment	0.51	0.028
Anxiety	–	–	Anxiety	−0.62	<0.001
(d). Correlation between the non-invasiveness and the other targeted experience					
Immersion	0.38	0.058	Immersion	–	–
Enjoyment	0.21	< 0.001	Enjoyment	–	–
Anxiety	–	–	Anxiety	−0.53	<0.001

Table 3. Statements of the participants in post-gameplay interview session during QS_2

P_7: Points deduction policy was nagging.	P_{12}: That funny interaction with my opponent about the transferred questions, it was so amusing!	P_2: I forgot about the data collection soon as I started interacting with my opponent.
P_{19}: Yes … I am sure! My performance would have been better without the points deduction policy.	P_{25}: The points policy was unique, I loved supporting my opponent during the competition. Can you imagine!	P_{17}: I did not realize about the data collection since I was so engaged in gaming activity.
P_{22}: Points deduction policy was simply unjust.	P_{41}: The interaction kept me energetic to compete.	P_{29}: Points deduction policy kept my attention occupied; I did not think about the data collection at all.
P_{36} How can one point well under that points deduction policy? It is impossible!	P_{48}: The whole gaming competition was fun.	P_{31}: I did not bother about the data collection; I was just enjoying the gaming session.
P_{53} It felt harsh sometimes to impose to attempt someone else's question and get your own points deducted if the answer is incorrect.	P_{57}: An exciting part of the gaming competition was the interaction with my opponent, indeed!	P_{46}: I forgot about the data collection since I was more concerned about my performance
(a). About mild anxiety	(b). About immense enjoyment	(c). About non-invasiveness

apportioned into three broader groups based on type of questions (i.e. brand-new, and explicitly or implicitly transferred) a participant received. It is observed that the participants seemed to be more concerned while attempting either the brand-new questions or the ones that are explicitly transferred by their opponent for assistance; however, they were more relaxed while answering the implicitly transferred bonus questions. A post-gameplay interview session was conducted with EG_2 to further understand the rationale behind the observation in relation to the quantitative findings and the employed *BGs*' interfaces. The statements of few of the participants indicated (see Table 3(a)) that the brand-new questions and the ones that were explicitly transferred by the opponent caused mild anxiety at some point in time due to the points deduction policy of *BrainStorm*; however, the statements of most of the participants indicated (see Table 3(b)) that they immensely enjoyed in most parts of the gaming session due to the overall competitive points policy of *BrainStorm* as well as the active interaction with their opponent. Besides, it also revealed during the interview session (see Table 3(c)) that this immense enjoyment as well as mild anxiety, and especially the highlighted phenomena behind them fully grasped participants' attention that significantly assisted in non-invasive data collection.

6. Conclusion

Insight about the potential factors that influence playfulness and playability within the different modes of *BGs* was previously fuzzy. In this regard, based on the available literature and currently faced challenges we highlighted several questions (see Section-1) that were previously unaddressed, and attempted to find their answers within the scope of limited yet crucial experience metrics (see Section-5). First and foremost, it is essential to acknowledge that neither mode of *BGs* delivers an appropriate experience in an absolute manner as neither of them outperformed for all the factors of both experience metrics (see Figure 4). If the objective is to achieve relatively higher engagement, usability, and adaptability then the single-player mode of *BGs* is the more appropriate choice; whereas on the contrary, if the aim is to make *BGs* play more enjoyable, then the two-player mode is the more suitable option. Despite this, it is essential to understand the emotional condition of the audience before offering them the two-player mode of *BGs* because along with the higher enjoyment rate it also arouses the emotion of anxiety. Nonetheless, if the goal is to achieve a higher level of non-invasiveness about the hidden goal behind *BGs* play, then the two-player mode is the more appropriate choice.

From a quantitative point of view, the presented research delineates a boundary by encompassing the diverse nature of both experience metrics. The factors of enjoyment, engagement (immersion, flow, presence, and absorption), and anxiety are considered under the metric of playfulness and the factors of adaptability, usability, and non-invasiveness are considered under the metric of playability. It is intended to expand the presented research in future by considering more factors in both experience metrics.

From a qualitative point of view, participants' social interaction and post-gameplay interview sessions were considered to understand the quantitative findings in relation to the employed *BGs*' interfaces. It is intended to expand the presented research in future by recording electroencephalogram (EEG) data in parallel with players' facial expressions and gameplay screen analytics to identify the specific features in the games in this suite that contribute to the results to propose design guidelines for the game developers.

From a dependency point of view, the presented research employed three *BGs* of *BrainStorm* game suite; however, to what extent are these results applicable to the considered game modes of the game genre in general is worth investigating in future.

Ethical approval

All the performed procedures in the presented studies concerning human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was taken from the parent(s) of all individual participants included in this research study.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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