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Effects of Design Factors of a Game-based English Vocabulary Learning App on Learning Performance, Sustained Attention, Emotional State, and Memory Retention

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【 Abstract 】

Numerous studies have confirmed that increasing vocabulary size is a critical part of learning English as a foreign language (EFL). The rapid development of mobile and game technologies has encouraged instructors to consider the potential of Mobile-Assisted Language Learning (MALL) with game. However, a mobile learning game that supports effective English vocabulary learning can only be designed after the effects of key design factors, including concentration, feedback, matching of the challenge to player skill, control, and immersion, on learning performance, have been examined. Therefore, this study assesses the effects of two different game-based English vocabulary learning apps with significantly different game design factors on learners' performance, sustained attention, relaxation, and vocabulary retention. Analytical results reveal that learners who used the game with weak game design factors exhibited significantly better vocabulary learning

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performance, retention, and relaxation and significantly lower sustained attention level than those who used the game with strong game design factors. This study also verifies that gender differences existed between the two game-based English vocabulary learning apps with different game design factors. Girls achieved significantly better English vocabulary learning and retention in the game app with weak game design factors. Additionally, based on an interview with several research participants, "matching of the challenge to player skill" and "feedback" were the most important game design factors in game-based English vocabulary learning apps.

Keywords

English vocabulary learning, Game-based learning, Mobile learning app, Game design factor, Learning performance, Sustained attention, Emotion

Introduction

For a long time, English has been considered to be the most important international language around the world and the most popular foreign language in non-English speaking countries. Nation (2001) indicated that the size of the vocabulary is the number of words that language learners know at a particular level of language proficiency. Rupley, Logan, and Nicholas (1999) suggested that having an extensive vocabulary greatly helps learners infer the meaning of English sentences. Therefore, vocabulary size plays a crucial role in English learning. However, Oxford (1990) claimed that language learners typically have difficulty in memorizing a large number of vocabularies because human memory capacity is limited.

Traditional vocabulary teaching methods, which include activities such as matching words to their definitions and filling words in the blank, are inadequate for efficiently enlarging the basic vocabulary of EFL learners. These traditional vocabulary teaching methods do not arouse students' interests; on the

contrary, jargon pedagogies may lead to resistance from English language learners, thus resulting in poor learning performance. Nunan (2003) showed that the grade of English has been lower in the Asia-Pacific countries, such as China, Korea, and Taiwan, where English is considered as a compulsory subject in schools. Accordingly, English teachers in Taiwan must urgently develop effective methods to improve students' English level, especially vocabulary acquisition, while fostering their interest in English learning. For example, Chen, Liu, and Huang (2019) applied a mixed methodology that combines quantitative and qualitative approaches to assess the effects of PHONE Words, a novel mobile English vocabulary learning app (application) designed with game-related functions (MEVLA-GF) and without game-related functions (MEVLA-NGF), on Taiwanese learners' perceptions and learning performance. Compared with MEVLA-NGF, their study confirmed that MEVLA-GF positively influenced learners' vocabulary acquisition and effectively assisted learners in retaining vocabulary. Also, Chen, Chen, and Yang (2019) developed an English vocabulary learning app with a self-regulated learning mechanism (EVLAPP-SRLM) to help Taiwanese learners improve their English vocabulary learning performance and motivation in a mobile learning context. Their study revealed that the learners using EVLAPP-SRLM to support English vocabulary learning exhibited significantly better learning performance and motivation than those of using the English vocabulary learning app without a self-regulated learning mechanism (EVLAPP-NSRLM).

Paribakht and Wesche (1997) proposed various EFL methods that could be used by teachers to improve students' vocabulary acquisition. Many studies (Burguillo, 2010; Dickey, 2011; Ebner & Holzinger, 2007) have found that digital games can improve students' learning performance and motivation. Adolescents are particularly fond of playing digital games. Numerous learning games that can run on portable devices for learners learning anytime and anywhere were designed. A survey in Taiwan found that 127 out of 137 students more preferred a mobile phone than a PC as the device for learning English (Lu, 2008). People can now use mobile devices to engage in many learning activities

anytime and anywhere. Consequently, properly designed mobile game apps may strengthen vocabulary acquisition for English learners, especially teenagers.

The attentiveness and emotion of learners essentially affect learning processes. Corno (1993) argued that attention improves the learning performance of learners with ordinary learning motivation or competitive intention. The learning performance of a learner who has low sustained attention will be reduced (Chen & Huang, 2014). Namely, students cannot acquire knowledge if their attention level is inadequate. Moreover, Horwitz, Horwitz, and Cope (1986) noted that many learners experience anxiety when learning foreign languages due to communication apprehension, test anxiety, and fear of negative evaluation. Arnold and Brown (1999) claimed that anxiety may most inhibit learning. It is associated with negative feelings, such as uneasiness, frustration, self-doubt, apprehension, and tension. Hence, how to reduce students' anxiety when learning a second language is an important research issue. Besides, when learners are bored, nervous, and stressed or lack of motivation, their negative emotion is raised, so their ability to learn is reduced. Therefore, learners' emotion also critically affects the quality of learning. Because attention and emotion are two important factors that affect learning performance, the effects of methods used for learning vocabulary influence attention and emotion on learning processes must be assessed.

Based on the flow theory (Csikszentmihalyi, 1990), Sweetser and Wyeth (2005) argued that concentration, feedback, challenge, skills, clear goals, immersion, and social factors are the most important considerations in designing a game. To design a skill training game that supports effective learning, Chen, Wang, and Hu (2018) claimed that exploring how key design factors, including concentration, feedback, challenge that matches with player skills, control, and immersion, affects learning performance and emotion is an essential research issue to the skill game design. Thus, their study chose two online English typing game sites that have significantly different game design factors to investigate the effects of game design factors on the emotion and learning performance of users. Their study confirmed that the online English

typing game site with significantly higher evaluation scores for the game design factors is superior to that with lower evaluation scores for the design factors in improving typing skills for males and involving negative emotion for females. The online English typing games are included in skill training games, whereas the game-based vocabulary learning apps used in this study are associated with cognitive type games. This study thus argued whether two game-based vocabulary learning apps of cognitive type games with significantly different design factors will also lead to different effects on vocabulary learning performance, sustained attention, emotion, and retention or not. As mentioned above, the first research question of this study is to examine whether two game-based vocabulary learning apps with significantly different design factors associated with concentration, feedback, matching of a challenge to player skill, control, and immersion have different effects on vocabulary learning performance, sustained attention, emotion, and retention. To answer these research questions regarding the game design factors of two game-based English vocabulary learning apps, the enjoyment of e-learning games (QEEG) questionnaire, which has satisfactory reliability and validity was used (Fu, Su, & Yu, 2009). A portable brainwave headset, which determines a person's sustained attention and relaxation level from EEG signals, was used to assess accurately the variations of sustained attention and relaxation of individual learners during learning processes.

Moreover, games traditionally have been considered a male-dominated area and boys always possess more confidence in playing computer games than girls (Cassell & Jenkins, 1998). Chen and Huang (2014) indicated that when differently gendered learners use technology-supported learning tools to assist learning, they may have different learning performances. In contrast, Chen, Chen, and Yang (2019) confirmed that using the proposed EVLAPP-SRLM to support English vocabulary learning significantly improves the learning performance and motivation of learners of both genders in comparison with EVLAPP-NSRLM. It is obvious that the gendered difference in the learning outcomes with the support of computer-assisted learning tools exists and is

valuable to be investigated. Therefore, the second research question of this study is whether gender differences exist among the effects on vocabulary learning performance, sustained attention, emotion, and retention for the two game-based vocabulary learning apps with significantly different design factors. The results of our research provide a valuable reference for game designers through revealing the game design factors that should be considered by the developers of game-based English vocabulary learning apps.

Literature Review

Vocabulary Acquisition and Memory

Having enough vocabulary size has long been regarded as a major prerequisite of language proficiency. Many studies (Elgort, 2013; Jensen, 2005; Nation, 2001) have emphasized the importance of vocabulary learning in language acquisition. Vocabulary has also been considered to be one of the key factors in the success of language learning (Jordan, 1997). In EFL, learning vocabulary items plays an essential role in all language skills, including listening, speaking, reading, and writing (Nation, 2001). Vocabulary can be defined as the words of a language or a lexical unit, including single items and phrases or chunks of several words that covey a particular meaning (Alfaki, 2015). That is, vocabulary not only addresses single lexical items—words with a specific meaning(s)—but also includes lexical phrases or chunks. Therefore, learning English vocabulary is not just about words; it also involves lexical phrases and knowledge of English vocabulary. Vocabulary size, also called vocabulary breadth, is the number of known words in a language (Laufer & Goldstein, 2004). Nation (2001) mentioned that vocabulary size is a key factor to improve the academic performance of students. Therefore, improving the ability of learners to enlarge their vocabulary size independently and strategically has been a major target of language instructors (Graves & Fink, 2007).

Most language learners have difficulty in memorizing English vocabulary (Oxford, 1990). As time goes by, many language learners forget words they have

learned as memory fades. Many studies thus have emphasized the importance of vocabulary retention (Dondi & Moretti, 2007; Jensen, 2005; Pimsleur, 1967). For example, Pimsleur (1967) suggested that acquired vocabulary cannot be retained for a long time if without an effective reviewing mechanism. However, retaining vocabulary in long-term memory is a challenge for EFL learners if they do not have opportunities to use these words in everyday life. Nation (2001) claimed that EFL learners are inclined to forget words easily if they do not use them frequently enough. Therefore, developing effective vocabulary learning schemes that can improve vocabulary learning and memory retention for EFL learners is an urgent issue.

Digital Game-Based Vocabulary Learning

In recent years, more and more people have tried to use digital games for various purposes beyond not leisure and entertainment. Game-based learning has been widely used in many areas of language education. Garris, Ahlers, and Driskell (2002) identified three major reasons why educators favor the use of game applications in teaching. First, educational philosophy has shifted from the traditional teacher-centered model to the learner-centered model. Learners nowadays are encouraged to participate more actively in their own learning. Second, the evidence shows that games improve users' learning and understanding of complex subjects. Finally, games motivate users to learn. Garris et al. (2002) pointed out that games can effectively enhance learning and understanding of complex subjects and motivate learners. Gee (2003) suggested that computer games are powerful educational tools that improve problem-solving, motivation, and social networks while supporting learning.

Hadfield (1999) divided language games into the categories of sorting, ordering, or arranging games; information gap games; guessing games; searching games; matching games; labeling games; exchanging games; board games, and role-playing games. Games have been frequently used to stimulate interest in reviewing vocabulary to improve acquisition (Huyen & Nga, 2003). Gairns and Redman (1986) used warm-up or end-of-class activities to practice

vocabulary and confirmed that vocabulary-related games help students memorize words. Competitive vocabulary games can be used to "recycle vocabulary," thus improving vocabulary learning (Sökmen, 1997). Vocabulary-related games have been employed to help students review words to improve retention (Chen et al., 2019). Chen et al. (2019) confirmed that sophomore students who learned English vocabulary using digital games on mobile devices had a more positive attitude toward vocabulary learning and significantly better performance than using mobile devices without digital games. Also, Uzun, Cetinavci, Korkmaz and Salihoglu (2013) found that learners who played digital games for learning outperformed others; had a more positive perception of vocabulary learning and greatly improved future vocabulary retention.

Game Design Factors and Flow Experience

Many studies (Choi & Kim, 2004; Dickey, 2005; Mulligan & Patrovsky, 2003) have revealed that game design factors are highly related to enjoyment, which has a strong influence on players' intention to play. Different levels of game design features may provide users with different gaming experiences. To determine whether game players had enjoyable experiences, Sweetser and Wyeth (2005) proposed a validated model, the GameFlow model, which can be used to evaluate and understand enjoyment in games. This GameFlow model considers 36 criteria and eight dimensions, which are concentration, challenge, skills, control, clear goals, feedback, immersion, and social interaction. Jegers (2007) developed a Pervasive GameFlow (PGF) model that was based on the GameFlow model. This PGF model has the same eight dimensions as the original GameFlow model, but with some new criteria to assess player enjoyment. Fu et al. (2009) developed a more rigorous scale, the EGameFlow model, for evaluating users' enjoyment of e-learning games, which was also based on the GameFlow model. They surveyed 166 university students in an online learning course and demonstrated that the EGameFlow model is an effective tool for evaluating the enjoyment of players in an e-learning game. Csikszentmihalyi (1990) proposed nine major game design factors, which were

challenge-skill balance, merging of action and awareness, clear goals, immediate feedback, concentration on the task at hand, a sense of control, loss of self-consciousness, time distortion, and autotelic experience. Choi and Kim (2004) divided the game design factors of Massively Multiplayer Online Role Playing Games (MMORPGs) into personal and social factors to examine users' gaming experience. They identified eight-game factors; the personal factors were challenge, fantasy, curiosity, control, and reward, whereas the social factors were game participants, audiences, and communities. Sweetser and Wyeth (2005) demonstrated a model with eight-game design factors - concentration, challenge, skills, control, clear goals, feedback, immersion, and social interaction – for evaluating whether players enjoyed in a game.

To examine how game design factors influence the flow experience of a game player, Kiili (2006) utilized a problem-solving game. The analytical results demonstrated that challenge- skill matching, clear goals, unambiguous feedback, a sense of control, and playability contributed to flow experiences. Kiili (2006) confirmed that flow experience is independent of gender, age, and gaming experience. According to Jegers's PGF model, the top three dimensions that affect whether a game is fun are concentration (games should require concentration and players should be able to concentrate), challenge (games should be sufficiently challenging and match with a player's skill level), and immersion (players should experience deep but effortless involvement). Although many studies have proposed validated models (GameFlow, Pervasive GameFlow, and EGameFlow), each of them can be used to evaluate game-related enjoyment, few research have studied how game design factors influence learning performance, attention, emotion, and memory, or whether learning performance, attention, emotion, retention and game design factors are mutually correlated. This study adds current knowledge about game-based English vocabulary learning apps, and identifies important factors for the designers of vocabulary learning games.

Research Methodology

Constructs of the Study

In this study, two game-based English vocabulary learning apps with significantly different game design factors were used to explore how game design factors influence learning performance, sustained attention, relaxation, and the retention of vocabulary by the participants. This study also examines whether gender differences existed in the learning performance, attention, relaxation, and the retention of vocabulary that was achieved using game-based English vocabulary learning apps with different game design factors. Therefore, the independent variable in this study is two games with significantly different game design factors; the dependent variables contain the vocabulary learning performance, sustained attention, relaxation, and vocabulary memory retention; the background variable is gender. Figure 1 shows the research architecture of this study. Both of the vocabulary game apps used the same official TOEIC words to support learners' vocabulary learning. Additionally, both experimental groups underwent the same vocabulary pretest, immediate posttest, and delayed posttest and all tests were based on the TOEIC vocabulary.

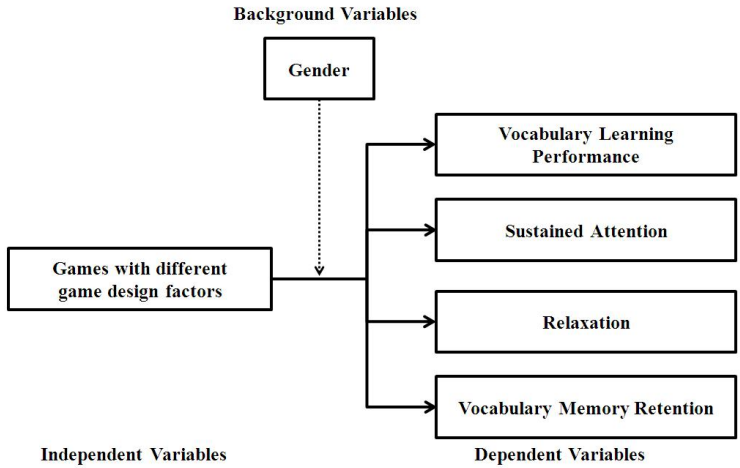

Figure 1 The Research Architecture of the Study

Research Design

A pilot study was carried out to confirm that the two selected game-based English vocabulary learning apps herein had significantly different game design factors on concentration, feedback, matching of the challenge to player skill, control, and immersion before the formal study was performed. A total of 36 Grade 12 students from a senior high school in Taiwan participated in the formal experiment. They were randomly divided into two experimental groups with a balanced distribution of gender and pretest scores based on the stratified random assignment by gender and pretest scores. The formal experiment lasted for four weeks and performed twice weekly. First, a pretest was conducted to determine whether the two experimental groups had the same English vocabulary level. Then, the researcher took ten minutes to explain the experimental procedure to all participants in detail. Both groups of learners then started to learn English vocabulary for ten minutes, before using their assigned vocabulary game app to assess the acquired vocabulary for 15 minutes. All of the learners wore a NeuroSky MindWave headset, which is an electroencephalography (*EEG*) device, to assess the sustained attention and relaxation of learners while they were playing the games. When the formal experiment was finished, the posttest was immediately performed to evaluate the learners' vocabulary learning performance and a semi-structured interview was conducted. A delayed posttest was carried out two weeks later to assess the learners' vocabulary retention.

Research Participants

A total of 36 Grade 12 students from a senior high school in Taiwan, comprising 18 males and 18 females, were recruited for the formal study. No research participant had had experiences with using game-based English vocabulary learning apps to enlarge their English vocabulary size before participating in the experiment, but all the research participants had had experiences with playing computer games for entertainment. All participants were assigned to either experimental group 1 to play the Star VOC game or

experimental group 2 to play the Tic-Tac-Toe game randomly based on pretest scores and gender distribution to ensure that the groups were the same in terms of pretest scores and gender distribution to reduce possible experimental interference by these variables. Table 1 shows the number of participants and gender distribution in both experimental groups in the formal study.

Table 1

Number of Participants and Gender Distribution of Two Experimental Ggroups in the Formal Study

Groups	Number of Participants	Gender	
		Male	Female
Experimental Group 1: Star VOC	18	9	9
Experimental Group 2: Tic-Tac-Toe	18	9	9
Total	36	18	18

To consider the research ethics of the designed experiment that involves recording attention and emotion states of the research subjects, written informed consent was obtained from the research subjects following a full explanation of the experiment. The informed consent letter contains the specific nature of the research, including that assessing EEG signals by the MindWave headsets developed by NeuroSky is safe as well as it would not result in any potential risks to the human body, the data that collected from them are only for the research, their name will never appear on any data collected and that instead we will provide a unique identification number on their data and that this information will remain secure such that only the principal investigator of this study will have access to it, the collected data that are no longer needed will be destroyed, and how participation will make a contribution to our study's goals.

Research Tools

PHONE words app.

PHONE words, developed by Alice Education Studio, is an education-oriented mobile app that is rated 4.2 in the Play Store, which features four English vocabulary games, based on TOEIC vocabulary. Since the TOEIC vocabulary is quite similar to that in the General Scholastic Ability Test (GSAT), the app not only can be used as a research instrument, but also help the participants prepare the GSAT. Consequently, the PHONE words app was used as the research instrument in this study.

The five main functions of PHONE words are the word list, customized word list, pre-established learning path, traditional evaluation, and gamified evaluation. Users of the PHONE words app learn words in the list in alphabetical order. Detailed information about each word, including definition, pronunciation, and example sentences with audio clips, are presented after the word is clicked on. Learners can put words into a customized list for later review. Words in this customized list form the basis of the question pool in subsequent traditional evaluation or gamified evaluation.

The PHONE words app provides four vocabulary games - Tic-Tac-Toe, Tug-of-VOC, Black Sheep VOC, and Star-VOC. Experimental groups 1 and 2 played the Star VOC and Tic-Tac-Toe learning games, respectively. Star VOC is a mission-based game that derives from a famous movie, Star Trek. In the game, the user pilots a spaceship called “ALICE” to transport supplements to the final destination, Planet Alice. Along the journey, the player has to overcome plenty of obstacles such as dodging bullets and avoiding any kind of danger. At the beginning of the game, the player is given three lives and equipped with three bombs. The goal of this game is to choose the right answer to the specific vocabulary word between two options by approaching it, which will pop out randomly during the journey. Once the player gets the right answer, the power of the spaceship will be amplified; on the other hand, the player will lose a life once getting the wrong answer or being hit by the bullets. Figure 2 presents the

user interface of Star VOC in the PHONE Words app. The original Tic-Tac-Toe, also known as Noughts and Crosses was a paper-and-pencil game for two players. In the game, the learner is firstly given a multiple-choice question. If the learner answers correctly, he or she marks a space in a 3x3 grid first with an X or an O. The two learners who are playing the game are questioned alternately. The player who is the first to place three of the same mark in a row, column, or diagonal wins the game. Figure 3 shows the user interface for Tic-Tac-Toe in the PHONE Words app. Table 2 presents the features of these two games.

Figure 2 The User Interface of Star VOC of PHONE Words App

Figure 3 The User Interface of Tic-Tac-Toe of PHONE Words App

Table 2

Comparisons of Content Features of Two Game Apps in Five Game Design Factors

Game design factors	Star Voc	Tic-Tac-Toe
Concentration	Easier to trigger longer attention	Learners may get distracted sometimes

Table (Continued)

Game design factors	Star Voc	Tic-Tac-Toe
Feedback	Higher level of feedback In the game: Once a player gets right answer: more remaining chances, power up, extra bomb, scores adding up. End of the game: total scores, encouraging words	Lower level of feedback In the game: Once a player gets right answer: The player can get to pick the grid first End of the game: only the results
Challenge matches with player skills	The more questions that a player answers, the harder level of the game will be.	The questions, taken randomly, will not necessarily change the difficulty once getting the right answer.
Control	A higher level of control 1. Speed, replay, stop. 2. No mistakes are allowed or there won't be the next level coming up.	A lower level of control 1. Quit, replay. 2. The game will still go on if a player makes mistakes.
Immersion	A higher level of immersion Easier to get indulged completely in the game and not aware of the time passing	A lower level of immersion Easier to get bothered by the surroundings

To assess whether the vocabulary learning games differed significantly in five-game design factors - concentration, feedback, matching of the challenge to player skill, control, and immersion and whether the QEEG was satisfactorily reliable, a pilot study was performed before the formal study. All of the participants in the pilot study used both of the vocabulary learning games to experience the differences associated with the five considered game design factors. A total of 27 Grade 11 senior high school students were recruited for the pilot study, which was preceded by a ten-minute explanation of the

procedure and an introduction of the user interfaces of the two games. The participants in the pilot study were then asked to play each game for 15 minutes. After they had played the two vocabulary learning games, the participants were asked to fill out the QEEG. SPSS was then used to analyze the differences between the two games for the five-game design factors, based on independent-samples *t*-tests. Table 3 shows the results thereof, which confirm that these two vocabulary learning games differed significantly in the five considered game design factors, so that they could be used in the formal study.

Table 3

Summary of Dimensions Analysis in the Five Considered Game Design Factors for Both Vocabulary Learning Game Apps

Dimension	Game	N	Mean	Standard Deviation	*t*	Sig. (two-tailed)
Concentration	Star Voc	27	19.70	2.867	2.357	.024*
	Tic-Tac-Toe	27	17.20	3.778		
Feedback	Star Voc	27	14.45	2.625	2.649	.012*
	Tic-Tac-Toe	27	12.20	2.745		
Challenge matches player skills	Star Voc	27	12.95	2.818	2.536	.015*
	Tic-Tac-Toe	27	10.25	3.837		
Control	Star Voc	27	17.50	3.120	2.477	.018*
	Tic-Tac-Toe	27	14.90	3.507		
Immersion	Star Voc	27	11.10	3.160	2.202	.034*
	Tic-Tac-Toe	27	8.65	3.842		

* indicates p<.05; The highest mean scores of the five-game design dimensions are 30, 20, 20, 25, 20, respectively.

Vocabulary tests.

A pool glossary based on New TOEIC Official Test-Preparation Guide III was used to assess the participants' vocabulary learning performance regardless of vocabulary pretest, immediate posttest, or delayed posttest. The test questions involved an English-to-Chinese translation and a matching test.

Questionnaire about enjoyment of e-learning games (QEEG).

The QEEG with satisfactory reliability and validity (Fu *et al*., 2009) was used to assess the differences between the two vocabulary learning games for their design factors. The QEEG was designed using the GameFlow model (Sweetser & Wyeth, 2005), which measures users' enjoyment while playing games. The modified QEEG, with only some of the dimensions in the original QEEG (Fu *et al.*, 2009), is used herein, and some statements in the original QEEG were revised to make them more easily to be understood by senior high school students (Appendix). Therefore, the reliability of the modified QEEG had to be evaluated to ensure that users' enjoyment can be accurately measured. The modified QEEG involves 23 items with five dimensions, which are concentration (six items); feedback (four items); matching of the challenge to player skill (four items); control (five items) and immersion (four items). Responses to the questions were given using a five-point Likert-type scale, with 1 for "strongly disagree" and 5 for "strongly agree." The reliability of the QEEG was confirmed using Cronbach's Alpha. The results revealed that the modified QEEG had satisfactory reliability with a Cronbach's Alpha that is greater than 0.7 in five dimensions of game design factors (Cronbach's Alpha =0.82, 0.80, 0.80, 0.74, 0.70).

Assessment of sustained attention and relaxation of learners using NeuroSky's MindWave headset.

The brainwave device for assessing the sustained attention and relaxation of learners was produced by NeuroSky; it uses EEG technology to digitalize brainwave signals from the forehead, behind which the pre-frontal cortex gathers physiological states. The sustained attention and relaxation values, which were ranged from 0 to 100, denoted a learner's degree of focus and calmness. The validity and reliability of NeuroSky's MindWave headset have been confirmed (Chen & Huang, 2014), as determined from a correlation between Birdwatching scores, which is a visual attention-based cognitive

training program that was developed by Lumosity (Hardy, Drescher, Sarkar, Kellett, & Scanlon, 2011), and attention values assessed by NeuroSky's MindWave headset. The Birdwatching scores were strongly and positively correlated with the attention values assessed by NeuroSky's MindWave headset and the correlation coefficient was .73.

Semi-structured interview.

To obtain qualitative data that could not be obtained using the EEG headset or vocabulary tests, a semi-structured interview was performed at the end of the formal experiment. The interview guide, which contained topics and questions, was carefully designed in advance. During the interview, the interviewer followed the guide but was also allowed to extend the discussion in response to questions when he or she felt doing so would be helpful. A recorder was used to ensure that no important information from the interview would be missed. Valuable qualitative data were obtained from the semi-structured interviews with the interviewees for further analysis.

Experimental Results

The two vocabulary games that significantly differ on the five-game design factors were compared in terms of vocabulary learning performance, relaxation, sustained attention, and memory retention of the players. Additionally, semi-structured interviews were conducted.

Analysis of Vocabulary Learning Performance

Difference between vocabulary learning performances of two groups.

Table 4 shows the results of the independent-samples *t* pretest and posttest of the learning performance of both groups of learners who played game-based English vocabulary learning apps. The analytical results demonstrate that the pretest scores of the two groups did not significantly differ (t=-.729,

p=.471>.05), so the initial vocabulary levels of the learners in the two groups were not significantly different before the experiment was performed. However, the posttest scores of the two groups differed significantly (t=-2.079, p=.045<.05). The learners in experimental group 2, who played Tic-Tac-Toe, exhibited a significantly better vocabulary learning performance than those in experimental group 1, who played Star VOC.

Table 4

The Independent-Samples T-Test Results of the Pretest and Posttest Difference of Learning Performance for Both Group Learners Who Respectively Used Different Game-Based English Vocabulary Learning Apps

Tests	Number of Learners	Group	Mean	Standard Deviation	*t*	Sig. (two-tailed)
Pretest	18	Star Voc	48.88	23.57	-.729	.471
	18	Tic-Tac-Toe	54.55	23.09		
Posttest	18	Star Voc	54.27	22.55	-2.079	.045*
	18	Tic-Tac-Toe	68.16	17.16		

* indicates p<.05

Gender difference between vocabulary learning performances of two groups.

Table 5 shows the independent-samples *t*-test results concerning the learning performance of learners of different genders in the two groups. The girls who played the two game-based English vocabulary learning apps exhibited significantly different learning performances (t=-2.253, p=.039<.05), but the boys did not (t=-.667, p=.514>.05). The girls in experimental group 2, who played Tic-Tac-Toe, exhibited significantly better vocabulary learning performance than the girls in experimental group 1, who played Star VOC. Therefore, Tic-Tac-Toe effectively improved the learning performance of girls but did not significantly affect the learning performance of boys.

Table 5

The Independent-Samples T-Test Results of the Learning Performance of Learners With Different Genders Between Both Group Learners Who Respectively Used different Game-Based English Vocabulary Learning Apps

Gender	Group	Number of Learners	Mean	Std.	*t*	Sig. (two-tailed)
Boys	Star Voc	9	60.00	22.20	-.667	.514
	Tic-Tac-Toe	9	66.33	17.83		
Girls	Star Voc	9	48.55	22.68	-2.253	.039*
	Tic-Tac-Toe	9	70.00	17.32		

* indicates p<.05

Analysis of Relaxation Level

Difference between relaxation levels of two groups.

Table 6 shows the results concerning the relaxation levels of the two groups. Learners in experimental group 1, who played Star VOC had a significantly lower relaxation level than those in experimental group 2, who played Tic-Tac-Toe (t=-8.492, p=.000<.05).

Table 6

Results of Relaxation Level Between Two Groups

Dependent Variable	Number of Learners	Group	Mean	Std.	*t*	Sig. (two-tailed)
Relaxation Level	18	Star Voc	43.16	4.23	-8.492	.000***
	18	Tic-Tac-Toe	54.50	3.76		

*** indicates p<.001

Gender difference between relaxation levels of two groups.

Table 7 shows the results concerning the relaxation levels of the boys and girls in the two groups. Analytical results show that both boys and girls who played Tic-Tac-Toe had a significantly higher relaxation level than those who played Star VOC (t=-4.210, p=.001<.05; t=-10.394, p=.000<.05). Therefore, the players of Tic-Tac-Toe felt more relaxed than the players of Star VOC, regardless of gender.

Table 7

Results of Learners with Different Genders in Relaxation Level Between Two Groups

Gender	Group	Number of Learners	Mean	Std.	*t*	Sig. (two-tailed)
Boys	Star Voc	9	43.00	5.78	-4.210	.001**
	Tic-Tac-Toe	9	52.22	3.11		
Girls	Star Voc	9	42.22	2.99	-10.394	.000***
	Tic-Tac-Toe	9	56.77	2.94		

** indicates p<.01; *** indicates p<.001

Analysis of Sustained Attention Level

Difference between sustained attention levels of two groups.

Table 8 shows the results concerning the sustained levels of learners in the two groups based on an independent-samples *t*-test. The learners in experimental group 1, who played Star VOC, exhibited a significantly higher sustained attention level than those in experimental group 2, who played Tic-Tac-Toe (t=3.131, p=.004<.05).

Table 8

Results of Sustained Attention Level Between Two Groups

Dependent Variable	Number of Learners	Group	Mean	Std.	*t*	Sig. (two-tailed)
Sustained Attention Level	18	Star Voc	53.88	6.66	3.131	.004**
	18	Tic-Tac-Toe	47.22	6.09		

** indicates p<.01

Gender difference between sustained attention levels of two groups.

Table 9 shows the results concerning the sustained attention levels of learners of different genders in the two groups. Analytical results reveal that the sustained attention level of boys who played Star VOC was significantly higher than that of boys who played Tic-Tac-Toe (t=4.541, p=.000<.05), while no significant difference was found between the sustained attention levels of girls who played the two games (t=-.056, p=.956>.05).

Table 9

Results of Learners With Different Genders in Sustained Attention Level Between Two Groups

Gender	Group	Number of Learners	Mean	Std.	*t*	Sig. (two-tailed)
Boys	Star Voc	9	58.55	5.24	4.541	.000***
	Tic-Tac-Toe	9	45.11	7.16		
Girls	Star Voc	9	49.22	4.23	-.056	.956
	Tic-Tac-Toe	9	49.33	4.18		

*** indicates p<.001

Analysis of Vocabulary Memory Retention

Difference in vocabulary memory retention between two groups.

Table 10 shows the results of the delayed vocabulary posttests of the two groups. Analytical results reveal a significant difference between the two groups in the results of the delayed vocabulary posttest (t=-2.085, p=.045<.05). The mean score in the delayed vocabulary posttest of experimental group 2, who played Tic-Tac-Toe (M=64.55), was significantly higher than that of experimental group 1, who played Star VOC (M=50.22), indicating that learners who played Tic-Tac-Toe had better vocabulary retention than those who played Star VOC.

Table 10

Results of Delayed Vocabulary Retention Posttest Between Two Groups

Test	Number of Learners	Group	Mean	Std.	*t*	Sig. (two-tailed)
Delayed Vocabulary Posttest	18	Star Voc	50.22	23.09	-2.085	.045*
	18	Tic-Tac-Toe	64.55	17.82		

* indicates p<.05

Gender difference in vocabulary memory retention between two groups.

Table 11 presents the results concerning the vocabulary retention of learners of different genders in the two groups. Analytical results reveal a significant difference between the girls in the two groups for vocabulary retention (t=-2.241, p=.040<.05), but not significant between the boys in the two groups (t=-.692, p=.499>.05). The girls in experimental group 2, who played Tic-Tac-Toe, exhibited significantly better vocabulary retention than those in experimental group 1, who played Star VOC. Tic-Tac-Toe is thus

inferred to help girls retain vocabulary longer than Star VOC.

Table 11

Results of Vocabulary Memory Retention of Learners With Different Genders Between Two Groups

Gender	Group	Number of Learners	Mean	Std.	t	Sig. (two-tailed)
Boys	Star Voc	9	56.22	22.73	-.692	.499
	Tic-Tac-Toe	9	63.00	18.62		
Girls	Star Voc	9	44.22	23.15	-2.241	.040*
	Tic-Tac-Toe	9	66.11	17.95		

* indicates p<.05

Analyses of Correlations between Considered Dependent Variables and Game Design Factors

To determine whether significant correlations existed between the dependent variables and the game design factors, Pearson product-moment correlation coefficient analysis was performed to assess whether learning performance, sustained attention, relaxation, vocabulary retention, and game design factors were correlated with each other.

Correlations between game design factors and dependent variables for learners who played star voc to learn English vocabulary.

Table 12 shows the results of correlation analyses of game design factors and dependent variables for Star VOC. The results reveal that the game design factor “feedback” was positively correlated with sustained attention level (r=.456), whereas the game design factors “immersion” was negatively correlated with learning performance (r=-.422) and vocabulary retention (r=-.407), indicating that increased immersion of players of Star VOC reduced their learning performance and vocabulary retention.

Table 12

Summary Results of Correlation Analyses of Star Voc Among Different Game Design Factors and Dependent Variables

		Concentration	Feedback	Challenge	Control	Immersion	Attention	Meditation	Posttest	Retention
Concentration	Correlation	-								
	Sig. (two-tailed)									
Feedback	Correlation	.555*	-							
	Sig. (two-tailed)	.017								
Challenge	Correlation	.686**	.455*	-						
	Sig. (two-tailed)	.002	.048							
Control	Correlation	.733**	.736**	.512*	-					
	Sig. (two-tailed)	.001	.000	.030						
Immersion	Correlation	.630**	.533*	.877**	.569*	-				
	Sig. (two-tailed)	.005	.023	.000	.014					
Attention	Correlation	.287	**.456***	.164	.139	.293	-			
	Sig. (two-tailed)	.248	.048	.517	.583	.238				
Meditation	Correlation	-.291	-.318	-.207	-.154	-.236	-.167	-		
	Sig. (two-tailed)	.241	.198	.410	.542	.346	.509			
Posttest	Correlation	-.051	.038	-.336	-.075	**-.422***	.316	.153	-	
	Sig. (two-tailed)	.841	.880	.122	.767	.041	.201	.545		
Retention	Correlation	-.050	.025	-.326	-.087	**-.407***	.322	.180	.996***	-
	Sig. (two-tailed)	.843	.922	.125	.732	.044	.192	.476	.000	

* indicates p<.05; ** indicates p<.01; *** indicates p<.001

Correlations between game design factors and dependent variables for learners who played Tic-Tac-Toe to learn English vocabulary.

Table 13 shows the results of correlation analyses of game design factors and dependent variables for Tic-Tac-Toe. Game design factors of "concentration" and "control" were correlated with learning performance (r=.533, r=.480) and vocabulary memory retention (r=.548, r=.488) for learners who played Tic-Tac-Toe. Sustained attention level was also correlated with the game design factors "matching of the challenge to player skill" (r=.454) and "relaxation level" was positively correlated with learning performance (r=.578) and vocabulary retention (r=.568). Learners who exhibited a higher relaxation level also exhibited better learning performance and vocabulary retention.

Results of Semi-Structured Interview

The semi-structured interview, included five open questions, used to elucidate how game design factors influence learning performance, sustained attention, relaxation, and vocabulary retention. The interviews revealed that the learners of two groups who played the two games with different game design factors had different perceptions of their own attention and emotion. Players of Star VOC thought that the game design factors of "concentration" and "immersion" greatly affected their attention level, whereas "feedback", "matching of the challenge to player skill", and "control", affected their emotion, making them anxious. However, players of Tic-Tac-Toe thought that game design factors of "concentration" and "immersion" sometimes caused them to become distracted; they were calmer than the players of Star VOC.

Most of the interviewees indicated that the "concentration" factor had the greatest effect on their attention level and that this was followed by immersion. However, "matching the challenge to player skill" was considered to be the game design factor that most affected learning emotion. Players' emotions changed according to whether the game was too easy or too difficult for them.

Table 13

Summary Results of Correlation Analyses of Tic-Tac-Toe Among Different Game Design Factors and Dependent Variables

		Concentration	Feedback	Challenge	Control	Immersion	Attention	Meditation	Posttest	Retention
Concentration	Correlation	-								
	Sig. (two-tailed)									
Feedback	Correlation	.733**	-							
	Sig. (two-tailed)	.000								
Challenge	Correlation	.616**	.485*	-						
	Sig. (two-tailed)	.006	.041							
Control	Correlation	.620**	.405*	.630**	-					
	Sig. (two-tailed)	.006	.045	.005						
Immersion	Correlation	.599**	.527*	.773**	.530*	-				
	Sig. (two-tailed)	.009	.025	.000	.024					
Attention	Correlation	.202	-.056	**.454***	.282	.242	-			
	Sig. (two-tailed)	.421	.827	.046	.258	.333				
Meditation	Correlation	.328	.049	.205	.245	.205	.316	-		
	Sig. (two-tailed)	.184	.846	.415	.327	.414	.202			
Posttest	Correlation	**.533***	.211	.339	**.480***	.169	.117	**.578***	-	
	Sig. (two-tailed)	.023	.400	.168	.042	.502	.645	.012		
Retention	Correlation	**.548***	.236	.348	**.488***	.180	.108	**.568***	.999***	-
	Sig. (two-tailed)	.018	.346	.158	.046	.474	.671	.014	.000	

* indicates $p<.05$; ** indicates $p<.01$; *** indicates $p<.001$

The interviews revealed the perceptions of the learning performance of the players of the two games with different game design factors. Four of the five considered game design factors affected learning performance; “control” did not. “Concentration” affected attention level, which was related to learning performance; “feedback” provided learners with a sense of achievement, which improved vocabulary acquisition; “matching of the challenge to player skill” prevented anxiety, which would affect learning performance; “immersion” offered complete absorption, which was also related to learning performance.

The interviews revealed that the game design factors of “feedback” and “matching of the challenge to player skill” were regarded as the most important game design factors for a vocabulary game app. Most of the interviewees stated that feedback from the game made them willing to play the game for a longer time because it gave them confidence, which motivated them. The game design factor “matching of the challenge to player skill” favored learning by people with various levels of vocabulary knowledge.

The interviews revealed that some players of Star VOC may use it in the future, while others may not. However, most of the interviewees claimed that they enjoyed the game because of its exciting features, but they were not sure if the game would help them enlarge their vocabulary size. Learners who played Tic-Tac-Toe claimed that it would become boring if played for longer because the game was predictable and not challenging enough, but they would consider playing it in the future to enlarge their vocabulary size.

Discussion

This study combined quantitative and qualitative methods (i.e. mixed methods) to determine how two English vocabulary learning games with different game design factors influence vocabulary learning performance, sustained attention, relaxation, and retention. Quantitative data from vocabulary tests and an EEG device were analyzed to provide statistical results, while qualitative data from semi-structured interviews revealed participants’ perceptions of the two English vocabulary learning games used herein. The

analytical results reveal that learners who played Tic-Tac-Toe, which was the game with weaker game design factors, exhibited significantly better vocabulary learning performance and retention than those who played Star VOC with stronger game design factors. Interestingly, these findings are the opposite of the study associated with discussing how the game design factors affect the learning performance of skill training games, indicating that more exciting English typing games are more effective in training learners to type in English (Chen et al., 2018). In the semi-structured interviews of this study, learners who played Star VOC indicated that it was a fairly exciting game, but they tended to focus on the game-play, trying to get to the next level, rather than on its educational purpose of English vocabulary learning. Learners who played Tic-Tac-Toe claimed that the game helped them memorize vocabulary faster and longer. Accordingly, to summarize the research findings of the study of Chen et al. (2018), this study found that for cognitive learning tasks, such as English vocabulary acquisition, less exciting games are more effective, whereas for skill training tasks, such as English typing skills, more exciting games are more effective.

Gender differences are evident in the learning performance that is achieved by playing the two English vocabulary learning games herein. Tic-Tac-Toe, which has weaker game design factors, promotes better learning performance of girls than that of boys. The semi-structured interviews revealed that girls prefer Tic-Tac-Toe more than Star VOC. Hence, this study inferred that girls may prefer less exciting games. This finding is consistent with several previous studies, which found that girls prefer unhurried games, such as board games, quizzes, puzzles, and educational games, typically with colorful, slowly changing screens (Bonanno & Kommers, 2005; Gorriz & Medina, 2000; Lucas & Sherry, 2004).

In this study, learners who played Star VOC exhibited a higher sustained attention level than those who played Tic-Tac-Toe. Boys who played Star Voc had a higher sustained attention level than the girls. The semi-structured interviews revealed that learners who played Star VOC claimed that they paid

more attention to gaming features during game-play than to learning vocabulary. This fact may be logically inferred to be the reason why the players of Star VOC had a significantly higher sustained attention level than the players of Tic-Tac-Toe. Also, boys had positive perceptions of Star VOC probably because male learners prefer games with more exciting elements. These findings are consistent with those of Jansz (2005) and Connolly, Boyle, Stansfield and Hainey (2007), who found that males prefer action, adventure, sports and simulation games, which require dexterity and fast reactions.

Several previous studies have found that emotions are significantly related to learning performance (Chen & Sun, 2012; Horwitz et al., 1986; Kort, Reilly, & Picard, 2001). In this study, relaxation level was significantly positively correlated with vocabulary learning performance and retention, especially for the players of Tic-Tac-Toe, which was the game with weaker game design factors. Thus, a higher relaxation level is inferred to be associated with better learning performance and retention. This result is consistent with previous studies (Goleman, 1995; Piaget, 1989), which have found that a peaceful state of mind is directly related to learning performance.

Finally, the semi-structured interviews provided valuable qualitative data that revealed learners' perceptions of vocabulary game design factors. Learners claimed that "matching of the challenge to player skill" and "feedback" are the two-game design factors that most importantly affect their learning performance and emotional states, while the study of Chen et al.(2018) suggested that the most important design factor in English typing games is "feedback." The research results of both studies provide valuable references for the game designers of developing cognitive and skill training games and further clarify what the most important factors in different kinds of serious games are.

Also, learning performance and relaxation were positively correlated herein. Therefore, if the level of vocabulary in the game is consistent with the learners' initial vocabulary level, then the learners are not likely to become anxious, thus favoring their learning. Additionally, learners claimed that Tic-Tac-Toe, which was the game with weaker game design factors, would become

boring if they had played it for a longer time because it was too easy or predictable, but they said they would use it in the future if they needed to enlarge their vocabulary size. Star VOC, which was the game with stronger game design factors, was enjoyed because of its exciting features, but players doubted that it would help enlarge their vocabulary size because they paid most of the attention to the game itself, rather than the learning of English vocabulary. According to cognitive load theory (Chandler & Sweller, 1991), the Tic-Tac-Toe game with weaker game design factors has extremely low extraneous cognitive load because the game was simple to learn as well as there were almost no rules. However, the weak design game also benefited from competition among players. In contrast, the Star VOC game with stronger game design factors required one to learn a strategy game that had inherently more rules and one played against oneself. The extraneous cognitive load required for the "strong design" imposes a level of extraneous cognitive load. In summary, entertainment and excitement are not major requirements of a cognitive learning game, such as an English vocabulary learning game. This study suggests that a successful English vocabulary game should strike a perfect balance between entertainment and educational purpose, focusing on ensuring that "matching of the challenge to player skill."

Despite its contributions, this study has several limitations. First, the number of participants was small at 36. The small sample size may challenge the representativeness of the research findings. Second, all of the participants were from a senior high school in Taiwan. Therefore, whether or not the results of the study can be transferred readily to other age groups requires further study. Third, the experimental period was lasted for 15 minutes per session, eight times a month. Accordingly, whether or not a longer experimental period would lead to different results needs to be further investigated. Fourth, this study focused only on two English vocabulary games with different design factors in the PHONE Words app. The results of the study cannot be transferred readily to other mobile vocabulary learning apps.

Conclusions and Recommendations

This study examined the learning performance, sustained attention, relaxation, and retention of players of two English vocabulary learning games with significantly different game design factors. Analytical results show significant differences and correlations among some considered variables. First, Tic-Tac-Toe was the more effective vocabulary learning game for English learners because it resulted in better vocabulary performance and retention than Star VOC did. Girls who played the vocabulary game with weaker game design factors (Tic-Tac-Toe) significantly outperformed those who played the vocabulary game with stronger game design factors (Star VOC) in both learning performance and vocabulary retention. However, learners who played the game with stronger game design factors (Star VOC) exhibited a significantly higher sustained attention level than those who played the game with the weaker game design factors (Tic-Tac-Toe). The players of Tic-Tac-Toe exhibited a significantly higher relaxation level than those of Star Voc. The boys had a higher sustained attention level than the girls when playing the vocabulary game with more exciting elements (Star VOC). The learners who were calmer and more relaxed while playing a vocabulary-related game (Tic-Tac-Toe) exhibited better vocabulary learning performance and retention. The girls were more relaxed than the boys when they played the vocabulary-related game with less exciting game elements (Tic-Tac-Toe). Finally, according to the interviews, the game design factors of "matching of the challenge to player skill" and "feedback" were regarded as the most important game design factors for a vocabulary-related game app, among five considered game design factors. The research findings of this study provide a valuable reference for serious game designers, revealing that the game design factors should be considered by the developers of serious games no matter the games are designed for, either English typing games or cognitive learning games.

This study suggested several future research directions. First, owing to time constraints, the experimental period in this study only lasted for four weeks, with two sessions a week for a total of eight sessions. However, much time is

required for learners to pick up, digest, and review vocabulary, hopefully committing it to long-term memory. Therefore, a study with a longer experimental duration should be performed. Second, the participants in this study were all students from Grade 12 of a senior high school. Therefore, future research could examine whether or not the considered game design factors would have different effects on the learning performance of learners of different ages or in different educational groups. Finally, this study explored only the effects of two game-based English vocabulary learning apps with different game design factors on vocabulary learning performance, sustained attention, relaxation, and retention. Accordingly, future research should consider the other games that support learning of other subjects to determine whether the results of this study can be generalized to those subjects.

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Appendix
Questionnaire for Enjoyment of E-Learning Games

Concentration
1. The game attracts my attention
2. The content provided by the game can arouse my concentration
3. Game activities are related to learning tasks
4. I have no distractions in the game mission
5. I can stay focused on the game
6. On tasks that I should focus on, I stay focused and not distracted
Challenge matches skills
1. I enjoy the game without feeling bored or anxious
2. The level of challenge of the game is moderate, not too difficult or too simple
3. As my level increases, the difficulty of the challenge gradually increases
4. The game can provide new challenges at the right pace
Feedback
1. In the game, I can get feedback for the parts I got right
2. I can get information about the score and level in the game
3. I can get immediate feedback on my behavior in the game
4. I can know about the new task immediately in the game
Control
1. I can control the menu of the game, such as start, pause, save, etc.
2. I feel that I can use the strategy of the game freely
3. I know the next step of the game
4. I can feel the control perception of the game
5. The game does not allow users to make mistakes that make it impossible to pass in the game
Immersion
1. When playing the game, I forget the existence of time
2. When playing the game, I become insensitive to the environment around me
3. When playing the game, I temporarily forget my daily worries
4. I can immerse in the game