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The impact of a virtual reality app on adolescent EFL learners' vocabulary learning

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ABSTRACT

VR technology allows learners to access simulated, immersive and interactive virtual environments to perform authentic learning activities. In particular, VR has emerged as a valuable tool for L2 learning. However, VR research has tended to pay more attention to desktop-based VR than to VR via mobile-rendered HMDs, leaving the potentials of VR through mobile-rendered HMDs yet to be investigated. Therefore, this study fills the gap by using a commercial VR app to examine the effect of VR via mobile-rendered HMDs on EFL learners' vocabulary learning. Forty-nine seventh graders in Taiwan were recruited from two intact classes and assigned to either an experimental (VR players) or control (video watchers) group. The VR players interacted with *Mondly* VR app using mobile-rendered HMDs and took part in conversations with virtual characters. The video watchers watched the walkthrough video signal of the VR player's app via a personal computer. Vocabulary tests, a perception questionnaire, and interviews were used to evaluate the participants' vocabulary learning. The results showed that the VR players' vocabulary learning and retention was significantly higher than the video watchers'. The majority of the VR players felt that VR-mediated vocabulary learning was motivating and beneficial. The VR app contextualized vocabulary learning by providing virtual environments with multimodal support and enhanced learner engagement through real-time interactivity and feedback. The video watchers' feedback revealed mixed feelings. Some felt that the walkthrough video facilitated vocabulary learning by providing word meaning and use in context. Others reported it lacked interactivity and their attention was easily distracted.

KEYWORDS
App; EFL vocabulary learning; mobile-rendered HMD; virtual reality

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1. Introduction

'Without grammar very little can be conveyed, without vocabulary nothing can be conveyed' (Wilkins, 1972, p. 111). According to Schmitt (2010), vocabulary learning is the primary basis for mastering a second language. To promote L2 vocabulary learning, recent advances in computer technology provide new pedagogical opportunities for superior learning experiences. Based on the concept of real-life simulations and interactivity, one of the most popular CALL applications is virtual reality (VR) technology. Researchers have claimed that desktop VR is a promising learning tool that facilitates L2 vocabulary acquisition by providing various simulated real life situations and contextual support (Chen, 2016; Lan, Fang, Legault, & Li, 2015; Madini & Alshaikhi, 2017). However, other researchers have not found that VR-mediated vocabulary learning leads to statistically significant improvements (Cheng, Yang, & Andersen, 2017).

Having said that, in most VR studies on L2 vocabulary learning have used desktop-based VR and the use of VR through mobile-rendered head-mounted displays (HMDs) for vocabulary learning remains in its infancy, with more research required to validate its usefulness. The purpose of the present study, therefore, was to investigate the impact of a VR app through mobile-rendered HMDs on adolescent EFL learners' vocabulary learning and their perceptions of VR-assisted vocabulary learning.

2. Literature review

The first section briefly introduces VR and reviews some recent research, focusing on findings suggesting potential applications of VR technology for language learning. The second section discusses the issue of VR-assisted vocabulary learning.

2.1. Desktop VR and language learning

VR is 'a highly interactive, computer-based, multimedia environment in which the user becomes a participant with the computer in a "virtually real" world' (Pantelidis,1993, p. 23). According to Parisi (2016, p. 1), 'VR is a medium with tremendous potential'. VR can provide L2 learners with realistically simulated environments for language learning (Lan, 2016; Lan, Lyu, & Chin, 2019), creates a strong sense of presence (Mikropoulos, 2006; Wang, Petrina, & Feng, 2017), allows space for exploration and interaction, and thus enhances learning (Chen, 2016; Wang, Lan, Tseng, Lin, & Gupta, 2019).

Regarding the use of desktop VR for language learning, motivation and self-efficacy are most frequently discussed. For example, Wehner, Gump, and Downey (2011) investigated the effects of *Second Life* on the motivation of English-speakers learning Spanish. Forty undergraduates participated in the 10-day study. They found that *Second Life* increased the participants' motivation. Santon (2017) used a self-efficacy scale and interviews to investigate 75 undergraduate students' self-efficacy and perceptions of virtual-world learning experiences. The results revealed that learners' self-efficacy increased due to the support, resources and immersiveness offered. Furthermore, researchers are also interested in examining language learners' anxiety regarding VR learning environments. For example, Melchor-Couto (2017) analyzed foreign language anxiety levels experienced by a group of participants who used the virtual-world *Second Life* to interact. It was found that compared to a control group who participated in similar interactions in a conventional classroom, the group's anxiety levels decreased. In summary, these studies indicate that desktop VR can promote motivation, foster self-efficacy and reduce the affective filter.

Other than affective reactions, some L2 research has demonstrated that desktop VR facilitates language learning by providing various simulated real life situations and contextual support. For example, Garrido-Iñigo and Rodriguez-Moreno (2015) examined the effects of the virtual environment *OpenSim*, which was used to teach French to 108 tourism students. A series of tests were conducted with all the participants to assess their language learning. They found the positive effects of VR on French acquisition and learners' motivation. Another example is Chen's (2016) study. He explored the impact of a desktop-based VR learning environment on EFL learners' linguistic development. The results revealed that VR technology provides an ideal environment for deep linguistic immersion and various situated learning experiences, which enhanced EFL learners' phonological, morphological, grammatical and syntactical knowledge.

In addition to the virtual space, some VR research into L2 learning has emphasized the importance of the real-time interactivity. For example, Peterson (2006) investigated EFL learners' interactions with avatars in a 3D virtual world. The participants were 24 Japanese college students. The findings showed that the avatars enhanced the participants' sense of telepresence, interaction management and application of communicative strategies. Furthermore, the interactive VR platform enables social interaction. In Lan, Kan, Sung, and Chang (2016) study, they examined the effects of different types of language tasks (i.e. information-gap and reasoning-gap) performed in *Second Life* on the Chinese as a Second Language learners' oral communicative accuracy. The results revealed that all the learners improved significantly in oral communication competence, especially with those performing the reasoning-gap task.

Overall, the literature reviewed emphasized that the unique affordances of VR as a learning tool stem from VR's ability to implement contexts and enable learners to visualize, manipulate and interact with information and objects, all of which facilitate language learning. However, several limitations revealed by previous studies exist. First, although VR is believed to be motivational and useful, the empirical evidence that supports this assumption is still limited (Lan et al., 2016). Second, qualitative methodological approaches have been dominant in the existing VR research on L2 learning, relying primarily on students' self-reporting subjective views on the advantages of VR for language learning. In addition, research has primarily focused on the motivational aspects of VR use. Finally, although an increasingly broad range of studies have used desktop VR to investigate L2 learning, so far few studies have examined the effectiveness of VR via mobile-rendered HMDs (Alfadil, 2017; Madini & Alshaikhi, 2017), the latest manifestation of the VR technology. This being the case, more research is required.

2.2. VR-assisted vocabulary learning

Regarding VR-mediated vocabulary learning, researchers have indicated that desktop VR positively affects vocabulary learning because it provides a learner-centered, immersive language learning platform which offers comprehensible input and meaningful interaction through context-based learning. For example, Lan et al. (2015) investigated how different learning contexts can impact the learning of Mandarin Chinese as a second language. Virtual and traditional learning environments were compared and examined from cognitive and linguistic perspectives. Thirty-one monolingual English speakers participated in a training study consisting of seven learning and testing sessions, followed by one additional session, a delayed post-test. The results showed that the learning trajectory of the participants in the virtual environment accelerated faster than that of those in the traditional learning environment. The multisensory stimuli of the virtual environment enabled learners to visualize, understand, and construct their own knowledge. Another example is Chen's (2016) study. He examined the effects of a desktop-based VR learning environment on EFL learners' vocabulary learning and cognitive development. He designed an online 3D desktop-based VR English learning platform for undergraduates. The participants completed six units in one semester and a vocabulary pretest and posttest were administered to evaluate their performance improvements. The findings revealed that VR provided EFL learners with contextual learning, its unique features positively affecting their vocabulary learning.

Furthermore, VR can provide multimedia learning materials involving audio, textual, and visual aids to enable learners to visualize, understand, and construct knowledge (Lan, 2016). For example, Liou (2012) studied the impact of VR mediation and the effects of pair work cooperation on vocabulary learning. The results showed that the participants learned vocabulary effectively through VR mediation. The greater the learner involvement is, the better vocabulary growth and retention is. Chen, Doong, and Hsu (2014) also conducted a study to investigate the effectiveness of VR on EFL learners' vocabulary learning. It was observed that their vocabulary competence had increased after the VR learning activities.

Although the aforementioned studies show the effectiveness of desktop VR-mediated vocabulary learning, Cheng et al. (2017) did not find statistically significant improvements based on VR-mediated instruction. They studied the effects of a VR game on Japanese vocabulary and culture learning. A 3D language learning game, *Crystallize*, was adapted for VR by integrating it with the Oculus Rift. Sixty-eight university students were randomly assigned to play either the VR or non-VR version of the game. The non-VR version was played on a normal computer screen. The other group played the game using the Oculus Rift HMD. A pretest and posttest of Japanese vocabulary was used to estimate the participants' language learning. A pre- and a post-game survey was administered to evaluate the participants' interest in Japanese culture. The results indicated that the VR players' sense of cultural involvement was significantly increased by the activity. However, there was no significant improvement in language learning. In response to this limited and inconclusive research, more studies are needed to investigate the efficacy of VR for EFL vocabulary learning.

The studies reviewed so far are all related to desktop VR. With the emergence of affordable head-mounted displays (HMDs), VR via mobile-rendered HMD is portable, offers high-resolution displays, creates strong feelings of presence, and delivers rich and fully immersive VR experiences. For example, in Madini and Alshaikhi's (2017) study, the researchers focused their attention on the impact of VR on English for specific purpose (ESP) vocabulary retention. Twenty postgraduates participated in the study and used cardboard glasses to watch VR videos. The results revealed that learners' vocabulary retention increased significantly. Hence, Madini and Alshaikhi concluded that VR videos help learners retain ESP vocabulary. Another example is Alfadil's (2017) study to explore the effects of VR using mobile-rendered HMDs on the ESL vocabulary acquisition of intermediate school students in Saudi Arabia. Sixty-four participants were divided randomly into experimental and control groups. The experimental group used the VR app *House of Languages* and Samsung Gear VR to acquire English vocabulary. The control group was taught using a traditional ESL vocabulary acquisition method. The findings revealed that the experimental group achieved higher scores in learning vocabulary than the control group and were left with a positive attitude toward VR applications for language learning.

Although Alfadil's (2017) study and Madini and Alshaikhi's (2017) study show the effectiveness of VR-mediated vocabulary learning via mobile-rendered HMDs, most VR studies (e.g. Chen, 2016; Chen et al., 2014; Cheng et al., 2017; Lan et al., 2015; Liou, 2012) on L2 vocabulary learning have used desktop-based VR. The use of VR through mobile-rendered HMDs in vocabulary learning remains in its infancy and studies analyzing the application, practices, and appropriateness of VR via mobile-rendered HMDs and its influence on EFL learners' vocabulary learning are relatively few. As such, more research is required to validate its usefulness. In addition, further empirical explorations are still needed to fully understand the processes pertaining to the use of VR through mobile-rendered HMDs in K-12 education. This being the case, the purpose of this study is to investigate the impact of a VR app used via mobile-rendered HMDs on adolescent EFL learners' vocabulary learning and their perception of VR-mediated vocabulary learning. The research questions addressed in this study are:

1. Does the VR app via HMDs significantly improve the adolescent EFL learners' vocabulary learning and retention?
2. Does the VR app via HMDs provide different benefits to the adolescent EFL learners' vocabulary learning? If so, what VR features contribute to the effectiveness of the vocabulary learning?
3. What are the adolescent EFL learners' perceptions of using the VR app for vocabulary learning?

3. Method

3.1. Research design

The study was conducted to investigate the impact of the *Mondly* VR app on EFL learners' vocabulary learning. It evaluated the effects of the virtual environment via the mobile HMDs. Two environments (virtual vs. non-virtual learning environments) were compared and examined from linguistic perspectives (see Lan et al. (2015) for a similar design for measuring the effects of context on vocabulary learning). Two versions of the foreign-language learning VR app *Mondly* were used. One was played on the HMD and the other was watched without VR on a regular computer screen.

Two classes, comprising 49 seventh graders in total, were recruited. Students from both classes were randomly assigned to either the experimental (VR players) or control (video watchers) group. The VR players interacted with the VR app *Mondly*, using mobile-rendered HMDs. They navigated the virtual scenarios and interacted with the virtual characters via collaborative dialogs and received instant feedback. In contrast to this, the video watchers watched a prerecorded walkthrough video of the VR app on a standard personal computer (PC) screen. The walkthrough video was identical in content to the VR app but had a different presentation mode as it was viewed on a standard PC screen. The video watchers saw and heard the same virtual characters but could not interact with them. They could pause and replay the walkthrough video.

3.2. Participants

The participants were 49 seventh graders recruited from two intact classes, taught by the same English teacher, at a junior high school in Taiwan. There were 12 male and 12 female students in the experimental group ($N = 24$) and 15 male and 10 female students in the control group ($N = 25$). The participants were all native Chinese speakers; none of them had studied in an English-speaking country. They were aged 14–15 years and had undergone 7–8 years of formal English education. They were considered to have similar proficiency levels in English based on their teacher's judgment, the difficulty of their learning materials, and their English grades from the previous academic term, with most participants demonstrating an elementary level of English proficiency. None of them had previous experience of using VR apps for language learning.

3.3. Instruments

The instruments used in the study were the *Mondly* VR app, learning devices (i.e. Samsung Gear VR, a mobile phone and a PC), vocabulary tests, the VR vocabulary learning questionnaire and interviews.

3.3.1. Learning devices

The Samsung Gear VR and Samsung Galaxy Note 8 were employed as the learning devices for the VR players. The Gear VR is a mobile-rendered head-mounted device with lenses that divide the screen into two for the users' eyes. Lacking a built-in display, the headset was used with compatible Samsung Galaxy devices, such as Note 8, which acted as a processing center and image source. A PC was used for the video watchers.

3.3.2. Mondly VR app

Mondly is a foreign-language learning VR app produced by Ati Studios (http://www.mondlylanguages.com). The app was downloaded from the Oculus store (https://www.oculus.com/experiences/gear-vr/). It combines VR technology and automatic speech recognition (ASR). Only a few mobile-based VR apps (e.g. *House of Languages* and *Mondly*) have been developed specifically for language learning. *Mondly* was selected because it provides a learner-centered, immersive, and interactive language learning platform. The topic and contents were appropriate for the participants' age and proficiency level.

Mondly provided a high fidelity of representation and interactivity. The VR app replicates five real-life scenarios: Train, Taxi, Hotel: Reception, Hotel: Room and At the Restaurant. By wearing a VR headset, learners would have a stereoscopic view of the virtual environment and could zoom in to closely observe virtual objects (Figure 1).

Learners could converse with virtual characters and receive immediate feedback (Figure 2). During conversations, learners are prompted with responses to what the virtual characters say, and every answer learners give is transcribed on the screen. The app listens to the learners' words, analyzes the accuracy of their pronunciation, and gives positive feedback if they speak clearly and correctly. This is a green check mark which hovers over the transcription of what a learner has just said. For answers that are incorrect or unclear (Figure 3), the learners receive linguistic cues (e.g. Pardon me. Please repeat.) or kinesic signals (e.g. gesturing and staring).

Taken together, the representational fidelity (e.g. scene realism, smooth display of view changes and object motion and spatial audio) and interactivity (e.g. dialoging, controlling, navigating and searching) of *Mondly* might lead to high degree of immersion, making learners feel as if they are 'there' with the virtual characters.

3.3.3. Vocabulary tests

To gauge the participants' prior knowledge of the target words, a vocabulary pretest (Appendix A) was administered. The pretest comprised 25 target words from the intervention materials. These words were selected based on their difficulty and relevance to the learning materials, where misunderstanding these words would hinder comprehension. Furthermore, Nation's (2004) 14,000-word-family lists were

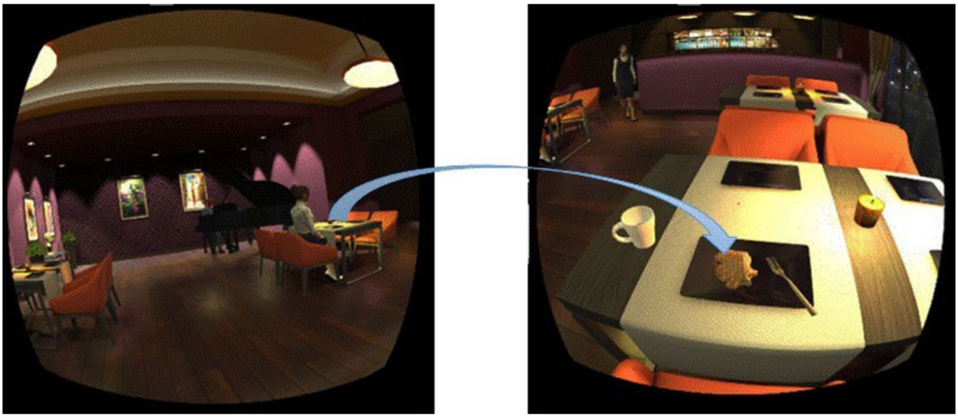

Figure 1. Screenshots of the virtual environment and objects.

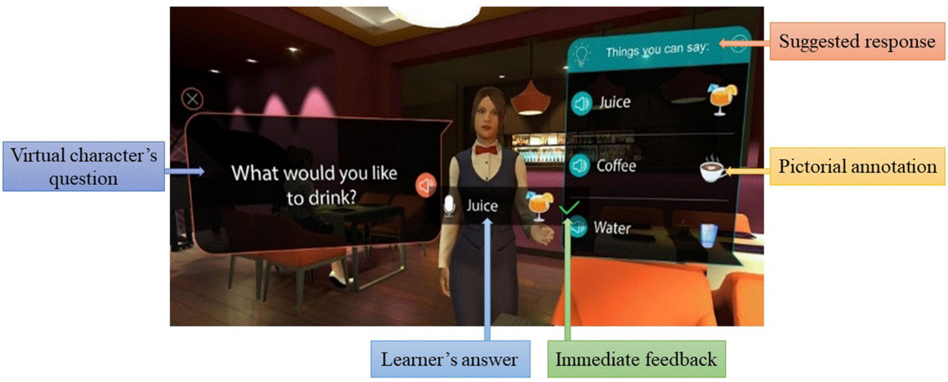

Figure 2. An example of the interaction with a virtual character.

used with RANGE software to indicate the 1000-word level at which each word occurred and its frequency in the VR app. For this, see Table 1.

The vocabulary pretest comprised two sections: a definition-supply test (word meaning) of 20 target words and 20 fillers, and five items for a cloze test (word use) using a dialog of about with less than 70 words. The fillers, high-frequency English words known to the participants, were used to avoid priming the subjects for the posttest. The participants had to mark the word forms they recognized and supply Chinese translations; otherwise, they had to check, *I don't know*. Only the target words are counted, with each correct answer awarded 1 point. Learning performance was gauged from the participants' test scores in the vocabulary posttests and the delayed posttests. The two tests were identical to the pretest except for the distractors, which they were arranged in a different order to prevent any rote effect. Each test took approximately 20 minutes to complete.

Zooming in and staring Gesturing

Figure 3. Screenshots of the virtual character's feedback.

Table 1. Analysis of the target words.

	Frequency				
Word list	1	2	3	4	5
1000	Change, carry, straight living, service, part-time	Bill, arrive	Check	Problem	Else
2000	Profession, shower sheet, map	Engineer, ticket			
3000	Concert	Translator	Elevator		
4000	Receipt, exit, vocation				
5000	Cocktail				
6000			Luggage		
Total word token	15	5	3	1	1

3.3.4. VR-mediated vocabulary learning questionnaire

A VR-mediated vocabulary learning (VRVL) questionnaire was developed to survey the VR players' perception of using the VR app for vocabulary learning. The questionnaire had six dimensions, with a total of 12 close-ended items: (1) simulation, (2) immersion, (3) interactivity, (4) presence, (5) experience and (6) motivation. These dimensions and their sources of references are listed in Table 2. The validity of the questionnaire was established through expert opinion. The participants were required to rate the items on a 5-point Likert scale, anchored by the end points *strongly disagree* (1) and *strongly agree* (5), with possible scores ranging from 12 to 60. Cronbach's α was used to assess the internal consistency of the survey.

3.3.5. Semi-structured interview

Semi-structured interviews were conducted with all the participants to collect in-depth data supporting the quantitative data. The VR players were asked open-ended questions on their experiences of using VR and their opinions on its value as a vocabulary-learning tool. The video

Table 2. Dimensions of measurements.

Dimensions	References
Simulation	Hew & Cheung, 2010; Lan, 2016; Lan et al., 2015
Immersion	Dalgarno & Lee, 2010; Sherman & Craig, 2003; Wang et al., 2017
Interactivity	Peterson, 2006, 2010; Lan et al., 2016; Wang et al., 2019
Presence	Dalgarno & Lee, 2010; Mikropoulos, 2006; Wang et al., 2017
Experience	Gee & Levine, 2009; Hew & Cheung, 2010; Chen, 2016
Motivation	Santon, 2017; Wehner et al., 2011

watchers were asked for their opinions on the use of video for vocabulary learning.

3.4. Procedure

After obtaining parental permission, a demographic questionnaire and a vocabulary pretest were conducted with all the participants 2 weeks before the intervention. Then, the VR players were introduced to the operation and functions of the *Mondly* VR app and Samsung Gear VR to ensure that they knew how to use the learning system. The learning activity was individually administered to the VR players. To accomplish the communicative tasks in *Mondly*, they had to navigate the virtual scenarios, interact with the virtual characters, and observe the objects, which took approximately 25–35 min. Regarding the video watchers, they also received the intervention individually. They watched the prerecorded walkthrough video without interacting with the virtual characters, which took approximately 15 minutes. Following the treatment, the participants were given a vocabulary posttest and an interview. Additionally, the VR players finished the VRVL questionnaires and were interviewed. A delayed vocabulary posttest was administered to the participants 1 week after the intervention. The experimental procedure of the present study is illustrated in Figure 4.

3.5. Data analysis

To determine any initial differences between the two classes regarding their prior knowledge of the target words, an independent-samples *t* test was calculated to compare the vocabulary pretest scores. To compare the vocabulary gain and retention of the experimental and control groups, an independent-samples *t* test was calculated again to measure the scores of the posttest and delayed posttest. A repeated-measures one-way ANOVA was further conducted, followed by Scheffe's post hoc tests, to examine the differences within each group over time. Descriptive statistics, including mean and standard deviations, were used to qualify the VR players' responses to the VRVL questionnaire. The results of the

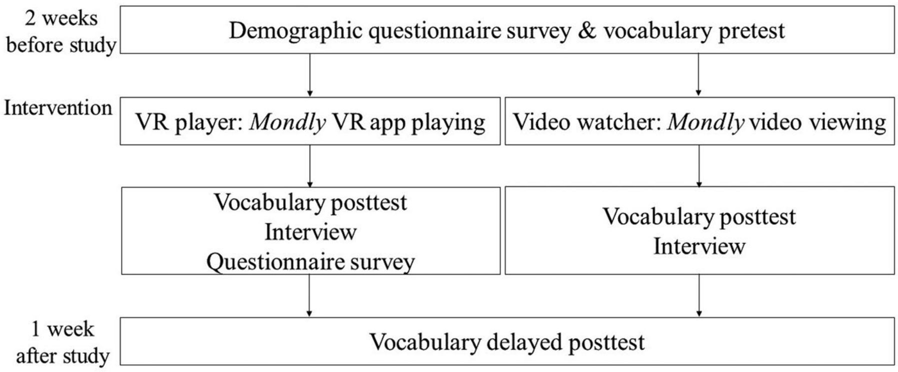

Figure 4. Experimental procedure of the study.

above quantitative analysis were substantiated by a qualitative analysis of the post-study interview data.

4. Results

This section presents the results of the vocabulary tests, the VR players' responses to the VRVL questionnaire, and the opinion survey.

4.1. Vocabulary tests

The first research question investigated the impact of the VR app on vocabulary learning and retention. An independent-samples *t* test was used to examine the difference in the mean scores of the vocabulary pre-test between the VR players and video watchers. Levene's test (F = 2.65, p = .11) did not achieve a level of significance so equal variances were assumed. As presented in Table 3, even though the video watchers had a higher mean score (M = 7.40, SD = 5.72) than the VR players (M = 7.08, SD = 4.53), the mean difference between the two groups (t = −.21, p = .83, η^2 =.00) was non-significant. Hence, previous knowledge of the target words between the two groups was similar.

The independent-samples *t* test was calculated again to measure the scores of the posttest and delayed posttest. Levene's test for the posttest (F = .06, p = .81) and for the delayed posttest (F = .40, p = .53) did not achieve a level of significance, so equal variances were assumed. As detailed in Table 3, a significant difference was observed between the VR players (M = 16.71, SD = 6.86) and video watchers (M = 9.72, SD = 6.52) on the vocabulary posttest (t = 3.66, p = .00, η^2 = .22). The VR players outperformed the video watchers in vocabulary gains. Table 2 also shows that there were significant differences between the VR players (M = 14.58, SD = 7.13) and video watchers (M = 8.68, SD = 6.19) on

Table 3. Results of independent-samples *t* test for the participants' vocabulary tests.

Variable	Group	N	Mean	SD	*t*	*p*	η^2
Pretest	VR	24	7.08	4.53	−.21	.83	.00
	Video	25	7.40	5.72			
Posttest	VR	24	16.71	6.86	3.66***	.00	.22
	Video	25	9.72	6.52			
Delayed Posttest	VR	24	14.58	7.13	3.10***	.00	.17
	Video	25	8.68	6.19			

***$p < .001$.

the delayed posttest (t = 3.10, p = .00). The VR players demonstrated better vocabulary retention than the video watchers. VR appears to have helped learners store the target words in long-term memories.

A repeated measures ANOVA was next performed to examine the differences in the vocabulary pretest, posttest, and delayed posttest scores within each group. As listed in Table 4, a significant difference was found among the three tests for the VR players. Mauchly's W was .96 (X^2 = .87, p = .65). F (2, 46) = 58.31, p = .00, η^2 = .72, observed power = 1.00. The Scheffe's post hoc test was then used to examine the differences across the tests. The results demonstrated that there were significant differences between not only the posttest and pretest (p = .00) but also the pretest and delayed posttest (p = .00). However, no significant difference was found between the posttest and delayed posttest (p = .06). These results indicate that the attrition rate for the VR players was not too high (8.52%).

A significant difference among the vocabulary pretest, posttest, and delayed posttest was also observed for the video watchers (Table 5). Mauchly's W was .77 (X^2 = 6.07, p = .05). F (2, 48) = 4.58, p = .02, η^2 = .16. The Scheffe post hoc test was then used to examine differences across the tests. The results showed that there were significant differences between the posttest and pretest (p = .03). However, the means of the pretest and delayed posttest were not statistically different from each other (p = .48), and neither were the means of the posttest and delayed posttest (p = .22). The low scores of the video watchers on the posttest which immediately followed the procedure may to a certain extent explain the stability of the watchers' scores from the posttest to the delayed posttest.

According to these statistical results, the VR players outperformed the video watchers in vocabulary gains and retention. Specifically, the VR players performed better both on meaning-supply and cloze tests. As shown in Table 6, although no significant differences were found between the VR players' and the video watchers' definition-supply (t = .14, p = .89, η^2 = .00) and cloze (t = −1.07, p = .29, η^2 = .02) tests in the vocabulary pretest, the VR players (M = 14.21, SD = 5.78) achieved

Table 4. Results of repeated measures ANOVA for the VR players' vocabulary tests.

Source of variation	*SS*	*df*	*MS*	*F*	*p*	η^2	*Scheffe Post-hoc*
Between	1227.25	2	613.63	58.31***	.00	.72	Posttest > Pretest
Within							Delayed > Pretest
Subjects	2238.54	23	97.33				
Error	484.08	46	10.52				
Total	3949.87	70					

***$p < .001$.

Table 5. Results of repeated measures ANOVA for the video watchers' vocabulary tests.

Source of variation	*SS*	*df*	*MS*	*F*	*p*	η^2	*Scheffe Post-hoc*
Between	67.52	2	33.76	4.58*	.02	.16	Posttest > Pretest
Within							
Subjects	2368.67	24	98.69				
Error	353.81	48	7.37				
Total	2790.00	74					

*$p < .05$.

Table 6. Results of t-test analysis of the participants' word meaning and cloze tests.

		VR player		Video watcher				
		M	SD	M	SD	*t*	*p*	η^2
Pretest	Definition-supply	6.13	3.77	5.96	4.47	0.14	.89	.00
	Cloze	0.96	1.33	1.44	1.78	−1.07	.29	.02
Posttest	Definition-supply	14.21	5.78	7.48	5.27	4.26***	.00	.28
	Cloze	2.50	1.50	2.24	1.51	0.60	.55	.01
Delayed	Definition-supply	12.49	5.95	7.40	5.60	3.07***	.00	.17
	Cloze	2.13	1.51	1.28	0.94	2.34*	.03	.11

***$p < .001$.

significantly higher scores than the video watchers on the definition-supply test (M = 7.48, SD = 5.27) immediately after the intervention (t = 4.26, p =.00, η^2 = .28). On the cloze test, the VR players (M = 2.50; SD = 1.50) demonstrated better vocabulary knowledge than the video watchers (M = 2.24; SD = 1.51). However, the mean difference was non-significant between the two groups (t = 0.60, p = .55, η^2 = .01).

The VR players (M = 12.49, SD = 5.59) also retained word meanings significantly better than the video watchers (M = 7.40, SD = 5.6) in the definition-supply test (t = 3.07, p = .00, η^2 = .17) administered 1 week later. Similar results were also found for the cloze test (t = 2.34, p = .03, η^2 = .11). The VR players (M = 2.13, SD = 1.51) also performed better than the video watchers (M = 1.28, SD = .94).

Additionally, a repeated-measures ANOVA was performed to examine the differences in the mean scores regarding the definition-supply and cloze tests in the pretest, posttest, and delayed posttest within each group. On the definition-supply test, the VR players made the greatest progress immediately after the intervention and had retained nearly all the word meanings (F = 55.79, p = .00, η^2 = .71) 1 week later (Table 7). By contrast, the video watchers performed slightly better immediately

Table 7. Results of repeated measures ANOVA for the participants' definition-supply test.

Source of variation	*SS*	*df*	*MS*	*F*	*p*	η^2	Scheffe Post-hoc
VR players							
Between	868.11	2	434.06	55.79***	.00	.71	Post > Delayed test
Within	1908.54	69	75.20				Delayed > Pretest
Total	2776.65	71					
Video watchers							
Between	36.59	2	18.29	3.29*	.05	.12	Posttest > Pretest
Within	1825.53	48	76.07				
Total	1862.12	50					

*$p < .05$.

after viewing the video and had retained some of the word meanings 1 week later (F = 3.29, $p = .05$, $\eta^2 = .12$).

On the cloze test, the VR players performed significantly better immediately after the intervention. The decline was not too steep in the delayed posttest (F = 16.61, $p = .00$, $\eta^2 = .42$; Table 8). The video viewers also performed better immediately after viewing the video but had retained little 1 week later (F = 7.66, $p = .00$, $\eta^2 = .24$). According to these statistical results, a VR effect was noted in the VR players. They performed better in word meaning production and word use in context.

4.2. VRVL questionnaire results

The second research question concerned how the VR app facilitated EFL learners' vocabulary learning and retention. The estimated Cronbach's α coefficient of the VRVL questionnaire was 0.81, suggesting that the items have relatively high internal consistency. The average value of the replies to the items on the questionnaire was 4.22 (Table 9). This suggest that, in general, the majority of the VR players positively perceived the VR app for vocabulary learning, which boosted their motivation to learn. They appreciated the 3D real-life scenarios and multisensory stimuli (M = 3.97; SD = .92), which offered opportunities for word use in authentic contexts and thus made word meanings clearer and easier to remember (M = 4.31; SD = .67). Furthermore, being fully immersed in the virtual environment (M = 4.31; SD = .80), the VR players reported a strong sense of 'being there' with the virtual characters (M = 4.17; SD = .95). The interaction with virtual characters (M = 4.00; SD = .84) facilitated vocabulary learning. One noteworthy finding is that searching for required information (M = 4.51; SD = .70) in the virtual environment was most valued for vocabulary learning. According to these results, the answer to the second research question is that the unique features of the VR app: simulation, immersion, presence, interactivity, and experience positively affected the VR players' vocabulary learning.

Table 8. Results of repeated measures ANOVA for the participants' cloze test.

Source of variation	*SS*	*df*	*MS*	*F*	*p*	η^2	Scheffe Post-hoc
VR players							
Between	31.03	2	15.51	16.61***	.00	.42	Posttest > Pretest
Within	121.28	46	5.27				Delayed > Pretest
Total	152.31	48					
Video watcher							
Between	13.23	2	6.61	7.66***	.00	.24	Posttest > Pretest
Within	139.00	48	5.80				Posttest > Delayed
Total	152.23	50					

***$p < .001$.

Table 9. Results of the VRVL questionnaire.

Items	M	SD
Simulation		
I feel the virtual environment is realistic.	4.17	.95
The contextual and multisensory stimuli facilitate vocabulary learning.	3.97	.92
Immersion		
With the spatial audio and visual input, I feel fully involved in an authentic linguistic context.	4.31	.80
The immersive environment helps me fully concentrated on vocabulary learning.	4.03	.86
Interactivity		
Interacting with virtual objects and searching in the virtual environment are helpful for vocabulary learning.	4.51	.70
I learn English word meaning and use from the dialog with the virtual character.	4.00	.84
Presence		
The VR app *Mondly* creates a strong sense of presence, which helps me learn vocabulary effectively.	4.17	.95
I can examine 3D objects from multiple viewpoints, which helps me learn vocabulary.	4.11	.87
Experience		
I like to explore the virtual world.	4.23	.80
The VR app *Mondly* requires action, which offers opportunities for word use in actual situation and thus make meanings clearer and easier to remember.	4.31	.67
Motivation		
The VR app *Mondly* is very interesting.	4.37	.77
I feel emotionally involved when I use *Mondly* for English vocabulary learning.	4.43	.78

Table 10 lists the words that the VR players made significant progress on after the intervention. Two observations are worthy of note regarding the beneficial effects of *Mondly* VR app for vocabulary learning:

First, the VR app provided learners with opportunities to interact with objects, pictorial images, and environments, which are critical for understanding (Alfadil, 2017). For example, regarding the most improved vocabulary items, *engineer* ranked first, *cocktail* came second, followed by *bill*, *luggage*, *appointment*, and *profession*. The VR players could find pictorial images (i.e. for *engineer* and *cocktail*) and virtual objects (i.e. for *bill* and *luggage*) in the virtual environment. Notably, although the word *receipt* belongs to the 4000-word level which is far beyond the participants' proficiency level, most of them had no difficulty in learning its

Table 10. Analysis of the VR players' most improved vocabulary.

Ranking	Word	Correct answers		*Mondly* VR learning environment		
		Pretest N	Posttest N	Pictorial image	Virtual object	Interactivity
1	Engineer	10	21	√		√
2	Cocktail	6	16	√		√
3	Bill	10	17		√	√
	Profession	9	16			√
	Appointment	7	14			√
	Luggage	11	18		√	
4	Straight	10	16			√
	Change	9	15		√	√
5	Receipt	9	14		√	√
	Shower	15	20	√	√	
6	Carry	17	20			√
	Arrive	12	15			√
	Sheet	8	11	√		
	Exit	16	19		√	√
7	Check (in)	18	20			√
	Elevator	14	16		√	

Note: N refers to the number of correct answers.

meaning and use. The visual images (e.g. a stereoscopic view of the objects) and the freedom to explore their surroundings helped the VR players guess or infer the correct meanings.

Second, the VR app provided a high degree of interactivity, including dialoging, controlling, manipulating, searching, and navigating (Moreno & Mayer, 2007). Language was put into the context of dialog, experience, and action. Hence, the VR app offered opportunities for word use in actual situations and made the meanings of words such as *appointment* and *profession* clearer and easier to remember. Visual images, along with context-based interactions with virtual characters, helped the VR players learn word meanings and use. In addition to verbal interaction, kinesic signals (e.g. the virtual characters' facial expressions and body language), along with a sense of presence, benefited the learning of verb phrases such as *carry the luggage*, *check in*, and *go straight*.

4.3. Participants' interview

Analyses of the participants' interview data revealed noticeable attitudinal differences between the VR players and video watchers. Table 11 presents the results of the participants' responses to the interview questions. Regarding the VR players' motivation, most of them (83.33%) were motivated to learn vocabulary by a VR learning environment, which echoed the results of the perception questionnaire. The following are extracts from their interviews:

> 我喜歡VR，因爲很好玩，很酷，不死板，像電玩!虛擬世界很像真的，會讓我喜歡學單字。

Table 11. Summary of the participants' responses to the interview questions.

Category	VR player (*N* = 24)	Video watcher (*N* = 25)
Motivation		
Yes		
Immersion	15	0
Presence	14	0
Interactivity	12	0
Reduced anxiety, shyness, inhibition	12	4
Animation	11	8
No		
Lack of diversity (e.g. linear order)	2	8
A widely used language teaching medium	0	8
Test-like	0	5
Neutral	2	11
Perceived usefulness		
Yes		
Contextualized vocabulary learning	14	8
Multisensory input and learning support	14	8
Enhanced engagement	12	0
Avatar scaffolding through dialog	10	1
No		
Immediacy of interaction	2	2
Too much functionality: Distracted attention	4	8
Neutral	2	11
Perceived usability		
Easy to use	18	25
Mobility: Flexibility and convenience in learning	16	0
Technical problems: ASR system, VR interface	6	0

I like VR because it is interesting, cool, and not tedious. It is like playing computer games. The virtual world is realistic, which motivates me to learn English vocabulary.

我覺得很像真的看著一個人和她聊天，很好玩!讓我更投入虛擬世界裡!

I felt like I was looking at a person at eye-level. It was fun to talk with her! I was more involved in the virtual world.

Regarding the usefulness of VR-mediated vocabulary learning, eighteen (75%) of the VR players agreed that the VR app provided an immersive learning environment, which contextualized vocabulary learning, enhanced learner engagement, provided avatar scaffolding through dialog, and was thus beneficial for vocabulary learning. For example, one VR player stated,

我喜歡虛擬世界中的即時互動，過程中，我會停下來看一些東西，有些單字或句子可以重複好幾次，還有我和裡面的人的互動，讓我印象深刻，很容易記住。雖然我不是每個字都懂，但從情境和他的肢體動作，大該可以猜對意思。

I like real-time interaction in the virtual world. In the learning process, I would pause to see the objects, listening to the words or sentences repeatedly. My interaction with people in the virtual world gave me deeper impression of the learning content. I remembered words easier. Although I didn't know every word, the context and the virtual characters' body language helped me guess the meaning right.

However, four (16.67%) of the VR players had reservations about the value of the VR app. For example, one claimed that he had, on occasions, experienced difficulty in keeping up with the interactions due to the rapid messages and gaps in his linguistic knowledge. Two other VR players reported that the virtual world had too much functionality and the different stimuli distracted them. For instance, one player remarked,

> 我的英文不是很好。同時要聽懂，又要回答，又要看字，我也很好奇虛擬實境裡的東西，想看一下，但真的來不及。有些字，我不知道怎麼唸，我要重覆聽好幾次。雖然有提供字幕，我卻來不及讀完。

> I am not good at English. I had to listen, respond, and read the caption simultaneously. Also, I was curious about the objects in the virtual world. I would like to take a look at them. There's not enough time. I didn't know how to say some words. I had to listen to these words again and again. Although there was caption, I didn't have enough time to read it thoroughly.

Regarding the usability of VR through the mobile-rendered HMDs, most of the VR players (75.00%) perceived it as being easy to use and control. Nevertheless, not all the VR players found the technology easy to use, especially the ASR system (20.83%). Based on the above findings, the answer to the third research question is that VR-mediated vocabulary learning received positive feedback from the majority of the VR players.

As for the video watchers' opinion survey, the comments revealed mixed feelings. Eight of the video watchers (32%) indicated that dynamic presentations in the form of animation and films facilitated vocabulary learning. In addition, video provides words and language use in context, which facilitate vocabulary learning. By contrast, eight of the video watchers (32%) made unfavorable comments for the following three reasons: (1) video is a widely used language teaching medium in English classes, (2) the walkthrough video content proceeded in a linear manner without interaction and (3) walkthrough video viewing is like a listening test. Attention was another issue commonly mentioned. Some participants indicated that even though they were physically oriented to the video monitor, they did not attend to the images on the monitor. In this way, there is a danger that learners may view the video passively, which might result in their less effective learning. Regarding the technical aspect, all the video watchers perceived the video as being easy to use and control.

5. Discussion

Consistent with the research questions previously stated, the findings are discussed in this section. The first research question concerns the impact of the VR app on adolescent EFL learners' vocabulary learning and retention. The statistical results based on the posttest and delayed posttest showed that the VR players' vocabulary learning was significantly better than the video watchers'. This corroborates with Alfadil's (2017) study demonstrating the beneficial effects of VR via mobile-rendered HMDs on EFL vocabulary learning.

Regarding the VR players' performance over time, the results showed significant differences between not only the posttest and pretest but also the delayed posttest and pretest. The results indicated that the attrition rate for the VR players was not high after the experiment. With respect to the video watchers, the results revealed the mean difference between the pretest and posttest was significant. The means of the pretest and delayed posttest were not statistically different from each other, and neither were the means of the posttest and delayed posttest. The low scores of the video watchers on the posttest may explain some of the stability of the watchers' scores from the posttest to the delayed posttest.

Given the similar proficiency of the two groups, this disparity may be attributed to the impact of the VR app, which seemed to help the VR players retain the target vocabulary better than the video watchers. Although researchers have indicated that video enhances vocabulary learning because of the combination of verbal and visual elements (Perez, Peters, & Desmet, 2018; Wagner, 2010), in the present study, the effectiveness of the walkthrough video seemed limited. There are several possible reasons for the differences between the findings of this and previous studies. Notably, other studies have examined the efficacy of video, focusing on comparing visual and audio input. However, this study investigated the differences between VR and walkthrough video language learning. Compared with the VR players' input, the video watchers received less environment stimuli and opportunities for interaction.

The second research question concerns how the VR app promoted the VR players' vocabulary learning. In line with previous desktop-based studies (Chen, 2016; Lan, 2016; Lan et al., 2015), the virtual scenarios in *Mondly* contextualized vocabulary learning. Rich contextual information and multimodal stimulus support imagination and visualization, which helped the VR players guess or infer new word meanings and enhance retention. For example, the VR players made significant progress with the following words: *bill*, *receipt, luggage*, and *cocktail*. In addition, some VR players indicated that they often used the zoom-in function to observe objects from multiple viewpoints. Looking at the learned objects seemed to enhance their attentional control. According to Lan et al. (2015), using a focused gaze on target objects allow learners to focus their attention and consequently enhances learning.

A further significant type of assistance identified in the interview data involved the provision of authentic target language interactions with virtual characters and immediate feedback. This aided learners to effectively acquire new words and pragmatic competence in context, especially regarding those words with abstract concepts (e.g. *profession* and *appointment*). In addition to verbal interaction, the virtual characters' body language was beneficial for learning verb phrases such as *go straight* and *carry the luggage*. These findings are consistent with Wang et al. (2017) who found that context-based social interaction provided by VR fosters language proficiency. Another noteworthy finding was that the VR partners' exploration of the virtual world and the self-correction afforded by the avatars' scaffolding and feedback provided opportunities for repeated practice, which enhanced vocabulary learning and retention. In addition, an immersive environment provides a stronger sense of presence, which in turn motivates learners to process learning material more deeply (Dalgarno & Lee, 2010). Having a higher level of involvement, interaction, and attention on the learning content, the VR players outscored the video watchers in vocabulary gains and retention. Overall, the VR app put language into the context of dialog, experience, images, and action and offered opportunities for word use in actual situations. This made word meanings clearer and easier to remember (Gee & Levine, 2009). In addition to the VR effect, more time spent interacting with the learning materials in the virtual environment might also contribute to the VR players' better vocabulary learning.

However, some VR players appeared to have some reservations about the value of the VR app as a tool for vocabulary learning. They complained that the virtual environment had too much functionality, which caused a cognitive overloading problem (Moreno & Mayer, 2007). Another challenge arose from using the ASR system. Some players experienced glitches where they had to speak and then reiterate, which they found frustrating. The creators of *Mondly* could be advised to improve the ASR system and take individual differences (e.g. proficiency, learning styles and needs) into account.

6. Conclusion

The purpose of this study was to investigate the impact of the *Mondly* VR app on adolescent EFL learners' vocabulary learning and attitudes. The results demonstrate that the VR app positively facilitated EFL learners' vocabulary learning and retention regarding both word meaning and word use in context. Detailed analyses of the participants' perceptions further demonstrated that the VR-mediated vocabulary learning was enjoyable, motivating and beneficial. VR effectively facilitated vocabulary learning because it provided an immersive environment, comprehensible input and multimodal support, real-time interactivity, and immediate feedback. Furthermore, the VR players could experience authentic language and construct word knowledge through active interaction, participation and navigation. Such interaction and exploration in VR learning environments motivated the VR players to observe, search and evaluate their hypotheses, and thus enhance involvement, which facilitates vocabulary learning (Laufer & Hulstijn, 2001; Schmitt, 2010). By contrast, the video watchers received less environmental stimuli and fewer opportunities for interaction, which might have resulted in their less positive learning outcomes. From a pedagogical perspective, the study supports the inclusion of VR in EFL as it facilitates vocabulary learning and is motivating. It can serve as an additional tool for language learners to extend and consolidate their vocabulary knowledge.

Nevertheless, this study has some limitations. One limitation is concerned with the short intervention time. A related issue is the novelty effect. The novelty of the Gear VR technology is a unique experience for all VR players, which most likely heightened their interest in the content on the screens. Future study will need to investigate the impact of VR on EFL learning over the long term. Another limitation is the varying exposure time between the VR players and video watchers, which might in part affect the participants' vocabulary learning. The other limitations are the small sample size (the participants were roughly the same age and had similar proficiency profiles) and a limited selection of mobile VR apps. Thus, it is recommended that future studies be undertaken with larger, more diverse samples and incorporate a wider variety of VR app. Furthermore, future research could investigate the development and performance of other language skills, particularly productive skills such as speaking and pronunciation. This would provide a more comprehensive understanding of the role of VR via mobile-rendered HMDs in promoting EFL learners' overall language learning and, in turn, help practitioners make informed decisions on integrating VR into curricula.

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Appendix A

Vocabulary Pretest

Part I. Put a stick (√) in the word that you recognized and write down its Chinese meaning.

	English	Chinese
☐	1. Bill	______
☐	2. Carry	______
☐	3. Straight	______
☐	4. Arrive	______
☐	5. Check	______
☐	6. Problem	______
☐	7. Else	______
☐	8. Profession	______
☐	9. Ticket	______
☐	10. Engineer	______
☐	11. Appointment	______
☐	12. Elevator	______
☐	13. Receipt	______
☐	14. Change	______
☐	15. Luggage	______
☐	16. Map	______
☐	17. Shower	______
☐	18. Sheet	______
☐	19. Exit	______
☐	20. Cocktail	______
☐	21. Like	______
☐	22. One	______
☐	23. People	______
☐	24. Read	______
☐	25. Say	______
☐	27. See	______
☐	28. Some	______
☐	29. What	______
☐	30. You	______
☐	31. Help	______
☐	32. Much	______
☐	33. New	______
☐	34. Look	______
☐	35. Many	______
☐	36. Time	______
☐	37. Two	______
☐	38. Come	______
☐	39. Have	______
☐	40. Know	______

Part II. Read the dialog and complete the information by selecting the words in the box.

(1) On business	(2) Job	(3) Service	(4) Teacher	(5) Part-time
(6) Living	(7) Translator	(8) Full-time	(9) Life	(10) On vocation

(At a restaurant)

Waiter:	Hi!
Jenny:	Hello!
Waiter:	What is your name?
Jenny:	Jenny, Chen.
Waiter:	Nice to meet you. Are you here __________?
Jenny:	Yes, I hope to relax a little.
Waiter:	What do you do for a __________?
Jenny:	I am a __________. I am good at both English and Japanese.
Waiter:	Do you work all week?
Jenny:	I work __________. Only some of the week.
Waiter:	Do you like it here?
Jenny:	Yes, your __________ is excellent.
Waiter:	Thank you very much.