



Self-directed learning of core vocabulary in English by EFL learners: comparing the outcomes from paper and mobile application flashcards

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Abstract In light of the recent developments in mobile technologies and students' increased uses of these platforms for educational purposes, research on mobile-assisted learning is gaining increased attention. Within this line of inquiry, the current study explored vocabulary learning outcomes from paper and mobile application flashcards. The study used a repeated measures design, by exposing the participants (55 high-school students) to different learning conditions and testing their receptive knowledge of core vocabulary in English in three junctures of time over a year. The participants were asked to use digital or paper flashcards for vocabulary learning, and two standard measures of vocabulary knowledge in pre- and post-tests were used to compare vocabulary gains. The results revealed that both groups improved their vocabulary knowledge over time. Nevertheless, the participants in the experimental group who used mobile applications outperformed the control group (paper flashcards) in the post-tests, and the effect size of the observed differences was very large. The findings underscore the long-term impacts of mobile-assisted vocabulary learning, and the affordances provided by such platforms for learning a considerable number of words by EFL learners. The findings also promise implications for language learners/teachers and materials developers in English language teaching programmes.

Keywords Mobile-assisted vocabulary learning · Digital flashcards · Vocabulary · Mobile applications · Vocabulary learning strategies

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Introduction

Vocabulary is of central importance in learning foreign languages. Wallace (1982) has a very strong claim that "not being able to find the words you need to express yourself is the most frustrating experience in speaking another language" (p. 9). Wilkins (1972) also asserts that "without grammar very little can be conveyed, and without vocabulary nothing" (pp. 111–112). Hence, vocabulary knowledge has long been regarded to be the basis for learning new languages and an essential aspect to all uses of language (Morris & Cobb 2004). Nevertheless, vocabulary learning that occurs either incidentally or through deliberate attention and explicit teaching in the classrooms is a long-term process, which remained among the most challenging problems for most English as a Foreign Language (EFL) learners around the world (Nation, 2001 2013; Webb & Nation 2017). Previous research has revealed that in order to understand daily conversations, television programs and films in English, a vocabulary size of about 2000 to 3000 word families is needed (Nation, 2006 2013; Rodgers & Webb 2011; van Zeeland & Schmitt 2012; Webb & Rodgers, 2009a, 2009b). These vocabulary items provide 80 to 90 percent coverage in most text types, and it has been argued that learning this core (or essential) vocabulary should be prioritized in a well-balanced language learning course (Nation 2013; Webb & Nation 2017).

Over the past years, with significant developments in the corpus-based study of language to gain insights regarding its use in different domains (Dang 2019; Römer 2011; Szudarski 2018), a number of core vocabulary lists have been developed to inform English language teaching programs (Brezina & Gablasova 2015; Browne et al. 2013; Cobb & Laufer 2021). As developed based on a very large and well-balanced corpus with 273 million word (a subsection of the two billion word Cambridge English Corpus (CEC)), the New General Service List (NGSL) (Browne et al. 2013) is among the recently developed core vocabulary lists. Vocabulary items in the NGSL account for about 92.34% of the CEC, which show a considerable improvement over the old and widely employed core vocabulary lists such as the General Service List (GSL) (West 1953). In this regard, learning the NGSL is of significant importance for EFL learners, as they need this vocabulary in order to enhance their understanding and comprehension of the conversations and most texts in English. Considering the fact that after years of studying English, many such students may not even know the 2000 high frequent words (Webb & Chang 2012), finding new ways and more effective strategies for learning core vocabulary is a worthwhile undertaking that benefits language learners and instructional programs in various ways.

In recent years, developments in mobile technologies provided new opportunities for helping EFL students in improving their knowledge of different language skills through Mobile-Assisted Language Learning (MALL) (Anthony & Caterina 2019; Burston 2013; Z. Chen et al. 2020; Chwo et al. 2018; Demouy & Kukulska-Hulme 2010; Kukulska-Hulme 2009; Nazari & Xodabande 2020; Shadiev et al. 2017; Stephan & Philip, 2016; Xodabande 2017). In this regard, research in this area has examined different applications of mobile phones in language learning

and teaching, and a considerable proportion of these studies focused on the affordances of MALL for vocabulary learning (Burston 2013; Lin & Lin 2019; Mahdi 2017; Yang et al. 2021). Moreover, this body of research has investigated various perspectives such as sporadic, short-time attention paid to vocabulary learning due to its mobility and availability, personalization of learning through adjusting learning pace and level to the individual's language proficiency level, and contextualization of learning through Global Positioning System (GPS) (Z. Chen et al. 2020; Sung et al. 2015). The findings, however, have been inconclusive, ranging from viewing mobile phones as being beneficial to vocabulary learning to the contrary of being disadvantageous, or even not making any significant changes (Lin & Lin 2019).

Moreover, among the various strategies employed for learning vocabulary in EFL contexts, the use of flashcards in their traditional and digital forms received significant attention (Nakata, 2011 2019), and due to the affordances provided for repetition and their scaffolding role for learning, they have been proved to be helpful (Kornell 2009; Kose & Mede 2018; Sage et al. 2019; Yüksel et al. 2020). In light of the recent developments in the functionality of mobile devices, digital flashcards in the form of mobile applications are becoming increasingly available for language learners. Nevertheless, most of the existing research in the field of mobile-assisted vocabulary learning has focused on using SMS/MMS technologies (Lin & Lin 2019). Although research investigating the use of various mobile applications for language and vocabulary learning is gaining increased attention, most studies were conducted in short-term interventions which makes it difficult to understand long-term impacts of mobile devices on language development (Lin & Lin 2019; Loewen et al. 2020). Furthermore, the use of digital flashcards designed as mobile applications for learning core vocabulary in English such as the NGSL remained even less explored. The current study aimed to fill part of this gap and investigated the long-term impacts of using a mobile phone flashcard application (i.e., Lexilize) and traditional paper flashcards on vocabulary learning of 55 EFL high-school students over a period of 12 months. The study adds to the growing body of literature on mobile-assisted vocabulary learning and sheds some light on the affordances provided by flashcard applications for developing vocabulary knowledge among EFL learners.

Review of the literature

A growing number of studies investigated various aspects of employing mobile applications for vocabulary learning. In this regard, the research investigated general efficiency of these apps compared with traditional paper-based materials (Wu 2014, 2015a, 2015b; Xodabande & Atai 2020), or focused on using GPS technology in mobile devices to take into account the peculiarities of the context for learning vocabulary (C.-M. Chen & Li 2010; Sandberg et al. 2011, 2014). This line of research either reported vocabulary learning mobile applications to be fruitful in terms of vocabulary retention, or found them to be arousing learners' interest in learning words through mobile devices (AbuSa'aleek 2014; Cho & Castañeda 2019; Lin & Lin 2019). Learners using context-aware mobile applications developed their

vocabulary knowledge and learned target words much more easily (Sandberg et al. 2014). Learning words through mobile applications also elevated language learners' self-regulation (Kondo et al. 2012) and self-awareness (Liu et al. 2008). Moreover, learners reported to be enjoying the experience of learning through mobile applications and found them facilitating in the course of vocabulary development (Cavus & Ibrahim 2009; C.-M. Chen & Chung 2008; Ono et al. 2015).

In a series of studies, Wu (2014, 2015a, 2015b) explored the effects of using mobile applications on teaching a considerable number of essential vocabulary to EFL students in China. Wu (2014) conducted a study with 50 Chinese ESL learners, divided equally into an experimental group and a control group. The researcher designed a mobile application for learning 852 English words over a semester by the experimental group, while the control group learned the same vocabulary using traditional materials. The use of the designed application for vocabulary learning resulted in higher levels of learning for the participants in the experimental group. Extending the number of the participants and the vocabulary items, Wu (2015a), in a pre- and post-test design study, used a similar application for learning 1274 English words among a population of 70 fourth-year college students. Similar to the previous study, the use of mobile application has been found to be facilitative in the development of vocabulary knowledge for Chinese university students. Wu (2015b) further extended the number of words to 3402 and the number of learners to 200. The smartphone application was used to facilitate students' self-directed learning of English vocabulary, comparing the results with those using the traditional paper format. Experimental group learners outperformed the participants in the control group with the average of 8.49% higher gains in their post-test. The overall results of these studies indicate that mobile applications can be regarded as beneficial for learning a large number of vocabulary items for EFL students and highlighted the role of self-directed learning in vocabulary development.

Basoglu and Akdemir (2010) also examined the undergraduate students' vocabulary gains in the Turkish context comparing paper flashcards with mobile flashcards. They found mobile flashcards beneficial to higher vocabulary gains and attributed it to the accessibility and portability of these devices. Nonetheless, another study by Burgess and Murray (2014) found that their psychology students were more inclined to use paper flashcards rather than digital ones. The reasons behind were suggested to be technical limitations of mobiles phones such as battery usage, the attractiveness of other applications, and general inclination of learners towards paper. In a more recent study, Sage et al. (2019) compared the effectiveness of paper, computer, and tablet flashcards over 108 undergraduate students at a Northwestern liberal arts college. The study used two formats of flashcards, ready made and self-created. The data were collected via a memory recall test, questionnaires on cognitive load, perceived control, satisfaction, and some other variables related to individual differences. The results of the study revealed that the tablet and paper flashcards were equally effective for the learners, but the computer flashcards were not as much helpful. Compared to paper and tablet flashcards, the students reported to be less in control of and satisfied with computer flashcards. Paper flashcards were reported to be the most satisfying format. As for cognitive load, all three formats appeared to be equivalent. Ready-made flashcards resulted in more recalls over self-created

flashcards, though they were reported to be requiring more effort. The results obtained from these studies highlight the importance of considering personal preferences of learners in using mobile devices and flashcards applications for learning vocabulary.

Moreover, given the important role assigned to the intentional learning of foreign language vocabulary, a number of studies investigated the contribution of mobile applications in delivering target words to EFL learners following noticing rules (Leow 2019) and push mechanisms (Thornton & Houser 2005). In this regard, spaced repetition technique is embedded in some mobile flashcard applications which makes recycling learned items more systematic, and also sends reminding notifications to learners to review the learned words. For example, Kose and Mede (2018) used a mobile flash card application which was based on spaced repetition learning system and investigated its impacts on the vocabulary development and motivation of 38 students at a private university in Turkey. They also studied the perceptions of the teacher and learners taking part in this research on the integration of this mobile application into their classroom practices. The findings revealed higher levels of vocabulary development and motivation. Both learners and their teacher found this integration constructive and helpful. Similarly, Seibert Hanson and Brown (2020) investigated the impact of a mobile flashcard application (i.e., Anki) on language learning of 62 university students learning Spanish (beginner levels) over one semester. Having controlled for the baseline abilities and motivation, self-efficacy, and beliefs, the researchers developed pre-test and post-test including grammar and vocabulary items from the course book used in the classroom. On both pre- and post-tests, the learners were required to match Spanish words with their English translations, Spanish definitions, and pictures. The results of the study revealed a positive impact for the use mobile application on Spanish learning. Although their participants reported not to be very interested in using the applications, at the end of the semester, they reported higher levels of motivation and more effort-based incremental beliefs about learning.

In a quasi-experimental study of the influence of a similar flashcard application (i.e., Memrise) over a semester, Fathi et al. (2018) probed the effects of its use on the vocabulary learning and self-regulatory capacity in vocabulary acquisition among 59 Iranian learners divided into an experimental ($N=33$) and a control ($N=26$) group. The participants were getting ready for the Master-of-art (MA) degree university entrance exam. To learn vocabulary, the participants in the experimental group used the application while the control group learners followed traditional paper-based vocabulary learning strategies. Researchers developed multiple-choice pre- and post-tests on vocabulary, containing 60 items from the course book that the participants in both groups were expected to cover. To assess the learners' self-regulatory capacity in vocabulary learning, Self-regulating Capacity in Vocabulary Learning Scale (SRCVoc) was used. The learners in the experimental group developed their vocabulary knowledge and self-regulating capacity more than those in the control group. In another one-semester-long study in the context of Iran, Xodabande and Atai (2020) studied the impact of a mobile application on self-directed and autonomous learning of academic vocabulary among 38 university students divided into experimental ($N=20$) and

control ($N=18$) groups. This study adopted a pre-, post, and delayed post-test to investigate the effects of mobile-assisted vocabulary learning in the long run. The participants in the experimental group used a flashcard mobile application to learn vocabulary items, and those in the control group used traditional materials. Although the findings of the study showed improvements for both experimental and control group in terms of vocabulary knowledge, the impact on experimental group was significantly higher than that on the control group. The study highlighted the potential of mobile applications for self-directed learning of academic vocabulary and attributed the significant improvements in the participants' vocabulary knowledge to the inherent motivational potentials of introducing new technologies into language teaching (Stockwell 2013).

The review of the existing literature showed that the use of mobile flashcards for vocabulary learning has been generally effective. However, in a recent meta-analysis of the research conducted on learning vocabulary through mobile devices, Lin and Lin (2019) pointed to the inconclusiveness of the research findings, and called for more scientific research studies to provide further evidence. Moreover, as mentioned earlier, learning vocabulary through mobile applications is a relatively under-researched area (Kose & Mede 2018; Lin & Lin 2019; Loewen et al. 2019, 2020; Xodabande & Atai 2020), and most of the empirical investigations conducted so far collected their data in short or very short spans of treatment times (Castañeda & Cho 2016; C.-M. Chen & Chung 2008; C.-M. Chen & Li 2010; Hwang & Chen 2013), which warrants further longitudinal research to better acknowledge and fully understand the impacts of mobile devices and associated technologies on vocabulary learning. Hence, there is a need for more long-term interventions in application-based mobile-assisted vocabulary learning to see if the learning outcomes are persistent over time. Additionally, there is a gap in the existing literature regarding the use of mobile devices for learning core vocabulary in English which is a significant learning goal for most EFL students. In this regard, the current study investigated the longitudinal impact of mobile flashcard application on learning core vocabulary in English over a period of 12 months. The short duration of the treatments in some of the earlier studies have unavoidably led to the employment of pre- and post-test designs, which are not expected to provide a complete picture of the long-term impacts of different treatments. In order to address this gap, this study used a repeated measures design (with pre-, post-, and delayed post-tests) to investigate learning outcomes. Finally, the review of the related literature indicated that the use of standardized vocabulary tests has been scarce in this line of research, and the studies used a variety of measures without reporting the validity and reliability of the tests (Lin & Lin 2019). In this regard, the current study used two standard measures of vocabulary knowledge, namely New General Service List Test (NGLST) (Stoeckel & Bennett, n.d.) and the updated Vocabulary Levels Test (Webb et al. 2017). By employing these tests, the current study investigated the contribution of mobile-assisted vocabulary learning on second-language knowledge development among EFL learners, which makes it possible to compare the results across different learning contexts. The following questions were addressed:

1. Which intervention (paper-based or mobile application flashcards) is more effective in enhancing the participants' receptive knowledge of the NGSL items across the three time periods?
2. Is there a change in the participants' knowledge of English vocabulary across the three time periods?

Method

Participants

The participants of the study were 55 high-school students (all males) selected based on convenience sampling procedures and their availability to the researchers from a high school in Tehran, Iran. The mean age of the participants was 17, and they were preparing to take the national university entrance exam to gain admission to higher education. Based on smartphone device ownership and also participants' preferences for using different materials for learning essential English vocabulary, they were divided into an experimental ($N=36$) and a control ($N=19$) group. The participants in the experimental group had Android or iPhone smartphone devices with appropriate screen size for installing and using the flashcard mobile application. An informed consent was obtained from the participants, and also their parents and school authorities were briefed on the aims of the study and its beneficial nature to the students English vocabulary knowledge development. Given the importance of vocabulary knowledge on English language testing module of national university entrance exam, although the participation in the research was voluntary, all the participants, parents, and school authorities had positive outlook towards the vocabulary learning intervention. We also ensured the involved parties that they can contact the researchers at any time during the research period if they have any concerns. The study adhered to further ethical considerations by ensuring the participants regarding the confidentiality of obtained data through various means.

Materials and instruments

The current study used the New General Service List (NGSL) (Browne et al. 2013) as the main resource for developing the participants' core vocabulary in English. NGSL contains 2818 items, and the list is available in alphabetical order or in three bands with frequency information. In order to learn the items in this vocabulary list, the participants in the control group were given a list of NGSL words and their translations in their first language (L1), and relevant flashcards printed on paper (an English word on the one side and L1 translation on the other side of the cards). They also received one-hour training on spaced repetition strategy (Kornell 2009; Roediger & Butler 2011) to maximize their learning. The participants in the experimental group installed Lexilize Flashcards application (*Lexilize Flashcards*, n.d.) on their mobile devices, and the same vocabulary items were loaded into the software using a Microsoft

Excel file. Lexilize Flashcards is a free application available for Android and iOS mobile devices, which makes vocabulary learning easier and motivating through incorporating various gaming features. These include (1) review words, (2) create pair, (3) select translation, (4) recall word, and (5) type word. The application works without internet connection, and it is also possible to have customized notifications as study reminders. Given the built in feature in the application for spaced repetition, participants in the experimental group did not receive related training but were instructed on downloading, installing, importing word lists, and using the application.

Moreover, two standard and validated measures of English vocabulary knowledge were used to investigate the outcomes from different learning conditions. In this regard, the study used New General Service List Test (NGLST) (Stoeckel & Bennett, n.d.), which is a test of written receptive knowledge of the New General Service List (NGSL) (Browne et al. 2013). The NGSLT contains 100 items which are grouped in five levels, each containing 20 multiple response questions types. According to test developers, the test is a reliable measure of NGSL that shows very high reliability (over 0.90). The updated Vocabulary Levels Test (Webb et al. 2017) was also employed which is a test of receptive vocabulary knowledge of English vocabulary developed based on BNC/COCA lists (Nation 2012). The test has two versions (A and B), and contains five sections that measures the knowledge of vocabulary at the 1000, 2000, 3000, 4000, and 5000 frequency levels using a multiple matching format.

Procedures

Prior to receiving any treatments, the participants' receptive vocabulary knowledge was tested using the NGSLT and version A of the updated VLT. This initial assessment of vocabulary learning needs revealed that the participants already knew around 50% of the items in NGSL. Accordingly, 1801 words in the second and third bands of the NGSL were selected as the target vocabulary items (the first 1000 words were skipped). This was followed by assigning the participants into the experimental and control groups and giving them different materials for learning core English vocabulary. In this regard, over a period of one year, the participants in the control group used paper-based flashcards, and those in the experimental group used the Lexilize Flashcards application. The participants studied the target words around 30 min per day, five days in the week based on the study plan given to them. The participants in the control group were asked to record a study log and report it to their teacher (and the researchers) on a weekly basis. The Learning statistics feature in Lexilize application was used to monitor the learning activities of the participants in the experimental group. For both learning conditions, parents' assistance was used to help the participants in following the assigned study plan. Finally, in order to assess the learning gains, receptive vocabulary knowledge of the participants was tested again in six-month intervals using the NGSLT and the different versions of the updated VLT.

Data analysis

The quantitative data were analyzed for both descriptive and inferential statistics using IBM SPSS software version 25. To this end, descriptive statistics including mean values and standard deviations were calculated for the scores obtained by the participants in pre- and post-tests. In order to see if the observed differences were statistically significant, a mixed between-within subjects analysis of variance (Palant 2016) was used. The between-subjects variable was group (experimental or control), and within-subject variable was time with three levels (i.e. pre-, and two post-tests). This analysis tests the main effects for each of the independent variables and investigates the interaction between the two variables.

Results

Table 1 shows the descriptive statistics for the two groups' performances on NGS LT and VLT in pre- and two post-tests. As for the pre-tests, the mean values for the scores on NGS LT were 46.56 ($SD=5.07$) and 49.16 ($SD=5.19$) for the experimental and control groups, respectively. The mean values for VLT (version A) were also 60.97 ($SD=6.1$) for the experimental group, and 58.79 ($SD=6.38$) for the control group. Regarding the post-tests, the mean values for the NGS LT were 63.61 ($SD=6.06$) and 54.32 ($SD=6.24$) for the experimental and control groups. The mean values for the scores obtained by these groups on VLT (version B) were also 72.6 ($SD=6.59$) and 67.68 ($SD=7.18$), respectively. Finally, with regard to

Table 1 Descriptive statistics

	Group	Mean	Std. Deviation	N
NGSLT (pre-test)	Experimental	46.56	5.073	36
	Control	49.16	5.188	19
	Total	47.45	5.217	55
NGSLT (1 st post-test)	Experimental	63.61	6.063	36
	Control	54.32	6.237	19
	Total	60.40	7.529	55
NGSLT (2 nd post-test)	Experimental	71.64	7.560	36
	Control	59.05	5.472	19
	Total	67.29	9.138	55
VLT (A) (pre-test)	Experimental	60.97	6.097	36
	Control	58.79	6.382	19
	Total	60.22	6.226	55
VLT (B) (1 st post-test)	Experimental	72.06	6.585	36
	Control	67.68	7.181	19
	Total	70.55	7.050	55
VLT (A) (2 nd post-test)	Experimental	81.69	6.849	36
	Control	73.26	4.629	19
	Total	78.78	7.343	55

the second post-tests, the experimental group had mean values of 71.64 ($SD=7.56$) for scores on NGSLT, and 81.69 ($SD=6.89$) for VLT (version A). The mean values on the same measures for the control group were 59.05 ($SD=5.47$) and 73.26 ($SD=4.63$), respectively.

The following chart (Fig. 1) is a visual representation of the mean scores for the NGSLT on pre-test and the subsequent post-tests, for the experimental and control groups. From the pre-test (time 1) to first post-test (time 2), both groups improved their scores on NGSLT; however, the chart shows that the participants in the experimental group (digital flashcards) benefited more from the intervention. From the first post-test to the second post-test (time 3), obtained scores on NGSLT followed a similar pattern for both groups, and all participants improved their vocabulary knowledge. Nonetheless, the users of mobile-based flashcard application attained better results on second post-test and learned more vocabulary items compared to the control group.

The following chart (Fig. 2) is a visual representation of the mean scores for the second measure of vocabulary knowledge used in the current study (i.e., VLT) across three testing times. Similar to the groups' performances on NGSLT, both groups improved their scores, however, those participants in the experimental group who used application-based materials benefited more from the intervention in the long term compared to the control group that used traditional materials. The findings from the updated VLT results showed that the interventions resulted in improving the participants' general vocabulary knowledge in English.

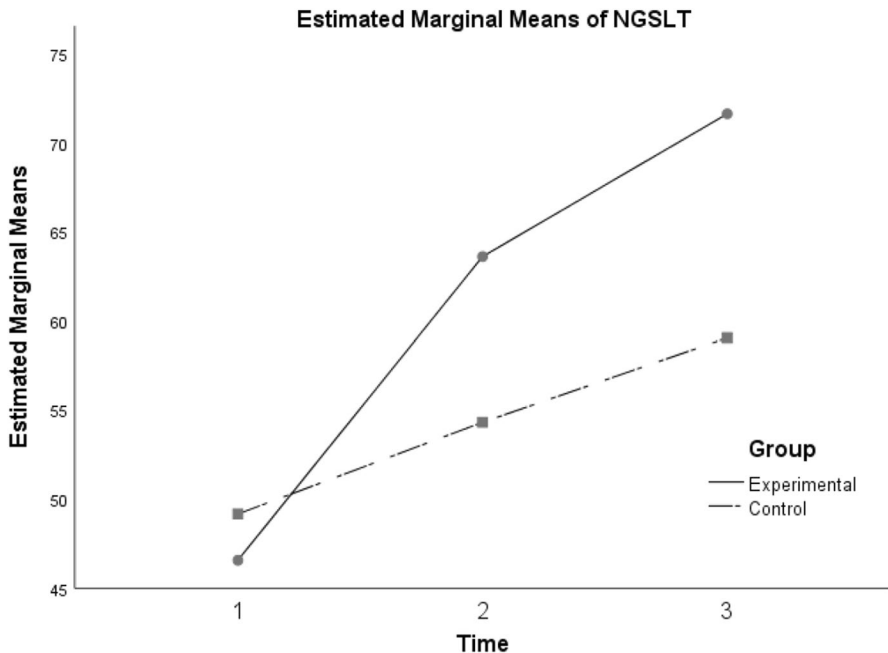


Fig. 1 Visual representation of the mean scores for the NGSLT

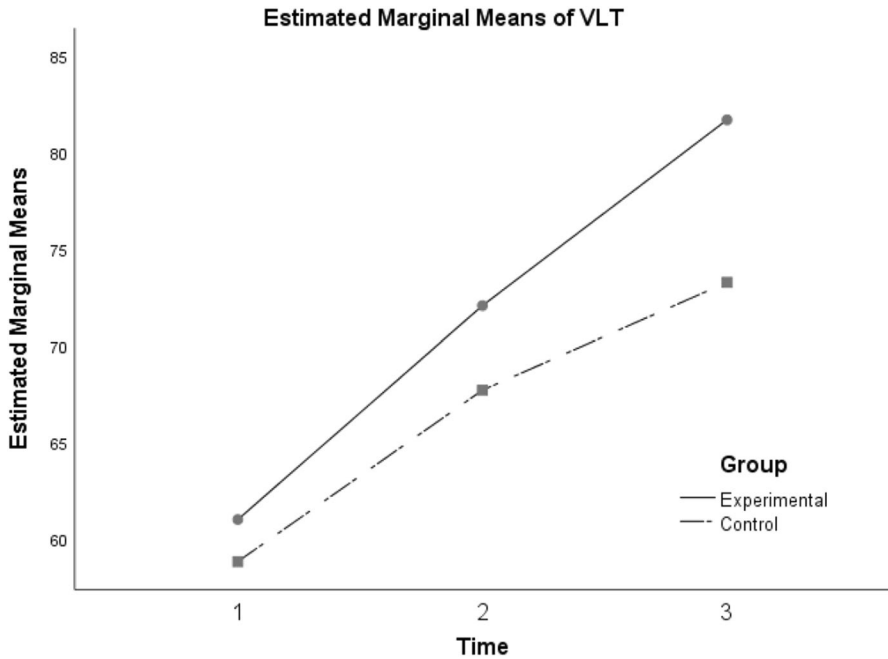


Fig. 2 Visual representation of the mean scores for the VLT

In order to further analyze the observed differences in vocabulary tests results among the groups, a mixed between-within subjects analysis of variance was performed. Before conducting this statistical test, the assumptions of homogeneity of variances (Levene's Test of Equality of Error Variances) and equality of covariance matrices (Box's Test of Equality of Covariance Matrices) were checked, and no violation was observed. The results of multivariate tests for within subjects variable (i.e. time) are shown in Table 2. The findings revealed a significant effect for time, Wilks' Lambda=0.22, $F(4, 210)=604$, $p=0.000$, $\eta_p^2=0.531$. There was also a significant interaction effect among the between-subjects variable (i.e., group) and within subjects variable (time), Wilks' Lambda=0.693, $F(4, 210)=10.55$, $p=0.000$, $\eta_p^2=0.167$. This interaction effect means that the impact of one variable is influenced by the level of the second variable. These findings also indicate that there was a significant difference among the scores obtained by the participants at three testing times. The result suggests a very large effect size for the observed differences (Cohen 1988).

Table 3 shows the results for the tests of between-subjects effects. The main effects comparing the two groups on both measures of vocabulary knowledge, namely NGSLT ($F(1, 53)=44.949$, $p=0.000$, $\eta_p^2=0.459$) and VLT ($F(1, 53)=25.117$, $p=0.000$, $\eta_p^2=0.322$) were both significant. This indicate significant differences in the scores obtained by the experimental and control groups on NGSLT and VLT measures. The effect size of the differences was also very large (Cohen 1988).

Table 2 Multivariate Tests of Within-Subjects Effects

Within-Subjects Effect		Value	F	Hypothesis df	Error df	Sig	Partial Eta Squared
TIME	Pillai's Trace	.784	34.206	4.000	212.000	.000	.392
	Wilks' Lambda	.220	59.504 ^a	4.000	210.000	.000	.531
	Hotelling's Trace	3.532	91.841	4.000	208.000	.000	.638
	Roy's Largest Root	3.527	186.927 ^b	2.000	106.000	.000	.779
TIME* Group	Pillai's Trace	.310	9.716	4.000	212.000	.000	.155
	Wilks' Lambda	.693	10.547 ^a	4.000	210.000	.000	.167
	Hotelling's Trace	.437	11.374	4.000	208.000	.000	.179
	Roy's Largest Root	.426	22.603 ^b	2.000	106.000	.000	.299

Design: Intercept + Group Within-Subjects Design: TIME. Tests are based on averaged variables

^aExact statistic

^bThe statistic is an upper bound on F that yields a lower bound on the significance level

Discussion

The first research question was concerned with the changes in the participants' vocabulary knowledge across three testing times. The findings (Table 2) showed that both interventions, namely the use of paper-based and mobile application flashcards resulted in significant developments in the students' vocabulary knowledge. In this regard, the current study provided empirical evidence for the effectiveness of mobile application flashcards in learning core vocabulary in English. These findings are congruent with the earlier studies that reported similar results (Fathi et al. 2018; Kose & Mede 2018; Seibert Hanson & Brown 2020; Xodabande & Atai 2020; Yüksel et al. 2020). Nonetheless, the findings are incongruent with the studies that reported no significant difference in the use of mobile-based and paper flashcards (Burgess & Murray 2014; Sage et al. 2019). One reason for the observed differences might be the motivational profile of the learners, as the participants in the current study were highly motivated to improve their English vocabulary, and motivation is among the most important factors that

Table 3 Tests of Between-Subjects Effects

Transformed Variable: Average							
Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig	Partial Eta Squared
Intercept	NGSLT	491,503.487	1	491,503.487	14,338.288	.000	.996
	VLT	712,090.910	1	712,090.910	19,213.347	.000	.997
Group	NGSLT	1540.820	1	1540.820	44.949	.000	.459
	VLT	930.910	1	930.910	25.117	.000	.322
Error	NGSLT	1816.792	53	34.279			
	VLT	1964.302	53	37.062			

impacts learning outcomes (Dörnyei 2009; Dörnyei & Ushioda 2010; Ushioda & Dörnyei 2012). Another reason relates to the characteristics of employed mobile devices and mobile applications. In this regard, unlike the participants in the Burgess and Murray (2014), the participants in the current study had access to much modern devices with larger screen sizes that provided a much better platform for vocabulary learning. The flashcard application used in this study also employed the gaming features that contributed to increased use of the digital flashcards for vocabulary learning. Moreover, the findings from the current study showed that flashcards applications were effective in helping the students to learn large number of words. This is also in line with previous studies that investigated the contribution of mobile applications for learning essential English vocabulary (Wu 2015a, 2015b). Given the importance of general service vocabulary in NGSL (Browne et al. 2013) for EFL students, the learning gains by the participants were highly valuable.

The second research question investigated the relative effectiveness of the different interventions. In this regard, the findings revealed that the experimental group who used flashcard applications gained higher scores on vocabulary tests in the both follow-up post-tests (Figs. 1 and 2) and outperformed the participants in the control group who used paper-based flashcards (Table 3). The findings for the second research question are also in line with recent studies that compared learning outcomes from digital flashcards used on mobile devices and traditional materials (Fathi et al. 2018; Xodabande & Atai 2020; Yüksel et al. 2020). There might be some explanations for the observed differences in vocabulary knowledge gains attained by the participants. First, given that spaced repetition technique was employed in both learning conditions, the participants learned the target words in a systemic way, which contributed to significant learning outcomes for both paper- and application-based interventions. Second, from pre-test to the post-test, the experimental group that used mobile applications learned a considerable number of English words and performed much better on the post-test. In this regard, it seems that the use of flashcards in the form of mobile applications created a more motivating environment compared to the traditional paper-based flashcards (Fathi et al. 2018), which is mostly related to inherent motivational impacts that results from the introduction of new technologies for language teaching (Stockwell 2013). Moreover, previous research indicated that learners respond to MALL studies more positively if they find them relevant to daily and personal uses of technologies (Chwo et al. 2018). Third, in light of the growing functionality of mobile devices for language learning (Godwin-Jones 2017), the participants in the experimental group had easy access to the learning material, which facilitated learning at anytime and anyplace using mobile devices. Forth, the participants of the study were high-school students trying to enter higher education institutes through national university entrance examinations. Given the importance of English language module in the exam, they invested considerable time in working with the materials and were highly motivated to improve their vocabulary, which further contributed to their substantial learning gains.

The current study has some implications for EFL students, teachers, and materials developers in language teaching programs. First, the findings showed that the use of

flashcard applications resulted in better learning outcomes among the participants. In this regard, English language learners and teachers should pay special attention to this effective vocabulary learning strategy and incorporate mobile-assisted vocabulary learning in their courses. Second, it has been argued that second-language vocabulary learning is a continuous and long-term process that normally takes many years (Nation 2013; Webb & Chang 2012; Webb & Nation 2017). Nevertheless, as the participants of this study learned a considerable number (around 25%) of general service vocabulary over a year, it seems that the use of digital flashcards has a great potential to shortcut this process. Third, given the importance of core vocabulary for EFL learners, the time spent on learning these items contributes to bridging vocabulary learning gap reported for those learners (Hsu 2013; Ward 2009). Moreover, considering the prominence role of vocabulary knowledge in developing the other language skills including reading, listening, writing, and speaking (Nation 2001, 2013), focus on learning core vocabulary contributes to EFL learners' language proficiency development in general. Fourth, as vocabulary instruction receives insufficient attention in the classrooms, self-directed vocabulary learning via flashcards applications can compensate for this condition and facilitates setting and achieving vocabulary learning goals by language teachers and learners. This extension of the learning to beyond the classroom is important, given that formal instructional contexts are most of the time resistant to employ modern educational technologies that make the realization of various potentials of mobile devices in the language teaching classrooms difficult (Lai & Gu 2011).

Conclusion

In light of the recent developments in mobile-assisted language learning, the use of mobile applications and digital flashcards for vocabulary learning in gaining increased attention in language education. In this line of inquiry, a major research finding has been the relative effectiveness of mobile-based materials over the traditional resources for vocabulary development among EFL students. Nevertheless, the long-term impacts of using mobile devices and digital flashcard applications are less explored in the existing literature, and most studies examined the effectiveness of MALL interventions for vocabulary learning on very short periods (Burston 2013; Chwo et al. 2018; Lin & Lin 2019). In this context, the current study was a longitudinal study of mobile-assisted vocabulary learning over a year. Additionally, the study used standard and validated measures of English language vocabulary to compare the gains attained from using paper and digital flashcards. The findings revealed a significant main effect for time in the use of mobile devices for vocabulary learning and pointed the effectiveness of digital flashcards over traditional materials. Furthermore, the study focused on using a corpus-based core vocabulary list developed for EFL learners and aimed to bridge the vocabulary gap among EFL students (Hsu 2013; Webb & Chang 2012). The current study was also an attempt to link the findings from corpus-based study of language and materials development to address the vocabulary learning needs (Coxhead 2019).

The present study had a number of limitations that should be acknowledged. First, we used convenience sampling procedures in assigning the participants into different learning conditions. This makes the generalizability of the findings somehow difficult. Next, since the study lasted for a year, controlling for the participants' extra exposure to English language beyond the employed materials was not possible. In this regard, the easy access to English media via diverse platforms among language learners should also be taken into consideration in interpreting the findings, as some learning gains are inevitably caused by such exposure and contact with the target language (Xodabande 2018). Moreover, although vocabulary knowledge entails different components (Nation 2001, 2013), the current study focused only on written receptive knowledge of English words and did not examine how the use of different interventions result in developments in other aspects of vocabulary knowledge such as pronunciation, collocations, etc. Nonetheless, the current study provided empirical evidence for the effectiveness of mobile-assisted vocabulary learning in general, and digital flashcards applications in particular. As we see more developments in new educational technologies, further research is needed to shed light on the complexities involved in learning through such technologies.

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