Using STM ability for Adaptive Language Learning in Mobile Learning Environment

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Abstract: - Due to the rapid advancement in mobile communication & wireless technologies, many researchers and educators believed that these new technologies would have a great impact on the way of learning in the future. Mobile Learning (M-learning) can be implemented by effectively applying short-message services such as Short Message Service (SMS) and Multimedia Message Service (MMS) provided by mobile phone system, as Learning Content Delivery (LCD) methods, to deliver different types of Learning Content Representation (LCR). However, the most important issue is whether M-learning based on these LCD methods and LCR types can really achieve good Learning Outcomes (LOuts) and be accepted by mobile learners. Alavi and Leidner reported that most of the past studies mainly relied on the stimulus-response theory, which probed only the relation between IT (stimulus) and the LOuts (response) [2]. This over simplified the learning process of human beings. They also pointed out that the Psychological Learning Process (PLP) of learners is an important mediator which can not be neglected. Therefore, this research explores the restraint of Short-Term Memory (STM) ability, the most important part of PLP, on assessing LOuts of M-learning. Moreover, Baddeley thought that STM ability is composed of two subsystems capacities: Phonological Loop (PL) capacity and Visuo-Spatial Sketch Pad (VSSP) capacity [5]. Our study shows that if different LCR types can fit with learner's specific STM ability would provide higher LOuts in M-learning environment. Therefore, the most suitable way to help learners with lower PL and lower VSSP STM capacity is to provide them just basic learning materials. On the other hand, providing additional written annotations to learners with higher PL and lower VSSP STM capacity will help them learn better. Providing pictorial annotations will benefit learners with lower PL and higher VSSP STM capacity. Finally, for Learners with higher PL and higher VSSP STM capacity, the best way is to cater them with both written annotations and pictorial annotations in M-learning environment.

Key-Words: STM ability, Learning content delivery method, Learning content representation type, M-learning

1 Introduction

Mobile learning (M-learning) is the next generation of e-Learning and is based on mobile devices [53]. One advantage is the high availability of such devices: the market penetration of mobile phone in Austria is currently at a level of 81% and the numbers are still increasing [62]. It can be emphasized that the majority of the population have a mobile at hand most of the time. Thus, M-learning will be an important instrument for lifelong learning [27]. Two main strands of research seem to be emerging: first one is being promoted by suppliers of e-learning companies; they try to push M-learning into market based on experiences of e-learning and apply it for enterprise training [52][55]; another is being sponsored by educational organizations; they try to improve teaching, learning and management in academic education with the help of new technology [39][45][61]. Though the research on M-learning is a rather recent phenomenon, its development has been very fast as evident by looking at the current progress of research. One of the promising applications of M-learning has emerged from the application of Learning Content Delivery (LCD) methods (including the short-message technologies of mobile phone, namely SMS and MMS) to carry on language learning content in M-learning environment [8][13][37][59][60].

One of the earlier projects using mobile phones in vocabulary learning was developed by the researchers at Stanford Learning Lab [8]. They developed Spanish study programs utilizing both voice and email with mobile phones. Their results indicated that mobile phones were effective for quiz delivery if delivered in small chunks; they also indicated that automated voice vocabulary lessons and quizzes had great potential [59].

Thornton and Houser also developed several innovative projects using mobile phones to teach English at a Japanese university [59][60]. One of the projects focused on providing vocabulary instruction by SMS. Three times a day, they emailed short mini-lessons to students, sent in discrete chunks so as to be easily readable on the tiny screens. The results indicated that the students receiving SMS learned over twice the number of vocabulary words as the students using only Web based instruction, and that students receiving SMS improved their scores by nearly twice as much as students who had received their lessons on paper. Students' attitudes were also measured and it was found that the vast majority of students preferred the SMS instruction, wished to continue such lessons, and believed it to be a valuable teaching method. The authors theorized that their lessons had been effective due to their having been delivered as push media, which promotes frequent rehearsal and spaced study, and utilizes recycled vocabulary.

Levy and Kennedy created a similar program for learners of Italian language in Australia, sending vocabulary words and idioms, definitions, and example sentences via SMS in a spaced and scheduled pattern of delivery, and requesting feedback in the form of quizzes and follow up questions [37].

Several other free and commercial language learning programs in M-learning environment have recently become available [13]: the BBC World Service's Learning English section offers English lessons via SMS in Francophone West Africa and China [24]; BBC Wales has similarly offered Welsh lessons since 2003; and an EU-funded initiative known simply as 'm-learning' provides English lessons directed towards non-English speaking young adults. The goal of such M-learning programs is to engage new kinds of learners (e.g., young, disabled) in a time and place of their preference [24].

According to Wagner, "…Mobile learning represents the next step in a long tradition of Technology-Mediated Learning"[63]. Therefore, it is very important to address the Technology Mediated Learning (TML) theory while exploring such M-learning programs [2]. TML is aimed to adopt Information Technology (IT) environment for learners to learn knowledge or to communicate with teachers and classmates. Based on the technological determinism, most researchers in TML field thought that whenever technology is available, people will be aware of it and apply it by following its standards so as to bring a better change for society [11]. Guided with this viewpoint, most studies concluded that as long as IT can be well provided, the Learning Outcomes (LOuts) of learners will increase accordingly [11]. Therefore, many research publications had emphasized the impact produced by IT itself, such as creating an effective learning environment by the use of IT, establishing more effective learning environment [54] using the excellent Information Communication Technology, or controlling the learning progress of learners with adaptive learning technology [9]. That is to say, the Technological Determinism solely considered that IT is the only issue in improving the LOuts.

In addition, some TML studies just focused on how IT functionalities can affect LOuts. For example, Rice pointed out that information technology should provide versatile communication functions to improve media richness so as to improve LOuts [49].

However, some TML researches have pointed out that LOuts are not only affected by IT functionalities, but they also depend on how people use IT to carry out teaching and learning [14]. Furthermore, some researchers also concluded that if the application process of IT for education can incorporate related learning theory and instructional strategy, the LOuts can be increased significantly [50].

Meanwhile, Alavi and Leidner also reported that most TML studies in the past mainly relied on the Stimulus-Response theory, which probed only the relation between IT (stimulus) and the LOuts (response) [2]. This oversimplified the representation of learning process of human beings. Alavi et al. further emphasized that the study of TML can not only be bound in IT and instruction, but the future studies should also take learners' characteristics into consideration while assessing LOuts of TML. They also pointed out that the Psychological Learning Process (PLP) of learners is an important mediator which cannot be neglected (Figure 1) [2]. Therefore, we consider reexamining the LOuts from the PLP point of view an interesting and important research topic.

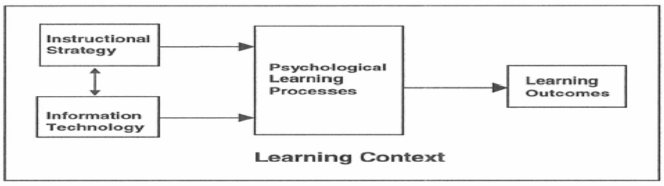


Figure 1 TML model [2]

2 Problem Formulation

The cognitive information processing viewpoint [35] explains the PLP that human beings absorb and apply knowledge via the internal psychological learning processes including sensory observation, attention, identification, transformation and memorization. Cognitive information processing theory states that when outer stimulation enters into the sensory system of humankind, individual perform a series of complicated processing procedures including noticing, coding, interpreting, organizing, storing and abstracting [38]. This operational procedure decides people's absorbability to such outer stimulation.

The basic architecture of the cognitive information processing model is Multi-Store Model (MSM) [4]. This model consists of three types of memory: sensory memory, Short-Term Memory (STM), and Long-Term Memory (LTM). Atkinson and Shiffrin defined STM functionally as the gateway allowing information to be transferred to the LTM [4]. The research on STM shows that the speed of learning, the memorization of learned concepts, effectiveness of skill acquisition and many other learning abilities are all affected by the "STM capacity" [28][32]. In studies of first language, STM capacity has been shown to account for individual differences in text comprehension [19] and the ability to resolve syntactic ambiguity [31]. In both of these instances, individuals with higher STM capacity are superior at comprehending text and are able to maintain multiple interpretations of a text, resulting in better ambiguity resolution. In studies of L2 (second language) learning, [23][26] found that L2 reading skill is highly correlated with STM capacity. Abu-Rabia found significant correlations between STM capacity and L2 writing proficiency as measured by the test of written language [1]. Therefore, in reexamining the LOuts from PLP point of view in M-learning enviroment, the STM capacity is an important issue.

In the past, due to the lack of advanced measurement techniques, studies on STM done after Miller [42] could not reach a common ground. For example, Broadbent thought that STM capacity should be 4 to 6 chunks [7] but MacGregor concluded that it had only 4 chunks [40]; LeCompte even alleged that it even had only 3 chunks [34]. Usually, Miller's 7±2 chunks are widely adopted for measuring STM capacity in past years [42]. However, in recent years some scholars have started to study STM capacity based on Functional Magnetic Resonance Imaging (FMRI). For example, Fuster found in animal experiments that the prefrontal cortex is very important for visual and spatial information processing, especially in central fissure and its nearby area [22]. Many FMRI studies claimed that some special sub areas existed in the back side of prefrontal lobe and ventral, which serve spatial and non-spatial STM. FMRI study of Courtney showed that prefrontal fissure has special function on the spatial STM of human being [17]. The study of Fockert on visual selective attention also found that start of perceptual gyrus has relation with STM [20].

Therefore, Baddeley proposed Working Memory Model (WMM) where outer information was actually processed in two different parts when it entered into STM via sensory memory [5]. He described that WMM is a system, composed of one Central Executive (CE) and two subsystems, including Phonological Loop (PL) and Visuo-Spatial Sketch Pad (VSSP), that not only temporarily stores (just like the STM in MSM) but also operate on information at the same time.

So, examining the LOuts from MSM point of view in the past has been unsuitable. We reexamine the LOuts considering the role of STM ability in WMM. Since STM is composed of two subsystems, the definition of STM ability in our research is the integration of STM capacity of PL and VSSP. However, STM only can serve how to receive information successfully, but one important issue in learning is how to transfer information to LTM, leading to longer retention. A crucial perspective is Levels of Processing Theory (LPT) [10] that a memory trace can persist in LTM if it involves a deep level of processing. From perspective of LPT, using annotations as instructional strategies in vocabulary learning are very popular [15][18][29][47][48][58] and there are two major types of annotations (pictorial and written) [3]. For example, vocabulary learning strategies such as word annotations [15][58] and keyword annotations [18][48] require deeper processing of word meaning, and have been shown to enhance retention of target words. These different types of instructional strategies (Learning Content Representation, LCR) based on levels of processing emphasize that processing activities at the time of learning can have a major impact on subsequent learning [16].

Therefore, our research question is to explore how to fit different instructional strategies (LCR types) for presenting English vocabulary learning content with learners' different STM abilities in WMM, and examined the effect of LOuts. English Vocabulary Recognition and Recall (EVRR) tests are often used to examine students' English vocabulary knowledge [3][40]. Therefore, the LOuts in our study are scores of EVRR test.

3 Research Methodology

This paper examines LOuts from TML point of view in M-learning. Since every person has different STM ability for processing different LCR types delivered by different LCD methods, different LCR types matched with different LCD methods would therefore need different STM abilities to fit with. Therefore, this study herewith classifies learners into four groups according to their different STM abilities in M-learning environment, as shown in the four quadrants in Figure 2 - Quadrant 1: learners with higher STM capacity in both PL and VSSP, Quadrant 2: learners with lower STM capacity in PL and higher STM capacity in VSSP, Quadrant 3: learners with lower STM capacity in both PL and VSSP and Quadrant 4: learners with higher STM capacity in PL and lower STM capacity in VSSP.

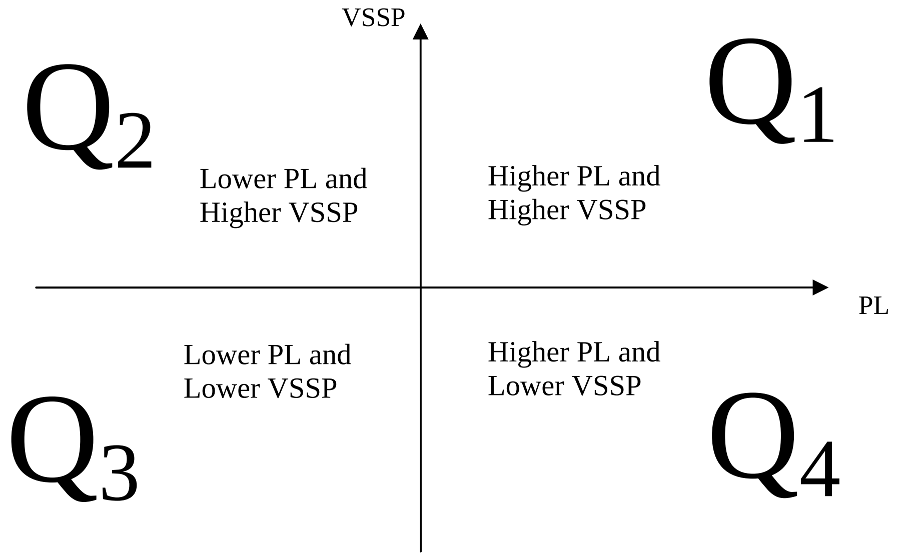


Figure 2 Four groups of learner classified by STM abilities

3.1 Research Design

There are several problems regarding the degree of strength with which the experimental outcome can really represent the reality. How are the subjects being selected and grouped? Is the selection biased? Would the practice effect affect their performance? Would the difficulty of learning content influence different groups of subjects? To solve these problems mentioned above, in the experiment a within-subject design is used so that every subject underwent all the four treatments with four different English vocabulary corpuses. This procedure balanced the individual difference among groups. Besides, a 4x4 Latin squares (LS-4) design is used to set the order of treatments and English vocabulary corpuses in a systematic way. This kind of design can balance the difficulty level of the English vocabulary corpuses and the proficiency level of the subjects. This LS-4 design is adopted from an experimental design textbook [33]. The within subject experiment design was used in this study over the between subject design because learners have different STM abilities and by having them each learn different LCR types that match with different LCD methods, they could have chances to access their preferred English learning content that fits with their STM ability. Table 1 illustrates the LS-4 design of our experiment.

Table 1 The LS-4 design

	T_1	T_2	T_3	T_4
P_1	A	B	C	D
P_2	B	D	A	C
P_3	C	A	D	B
P_4	D	C	B	A
..	..	..	..	..
P_n	..	..	..	..
Pn: People of the subjects Tn: Treatment of the English Vocabulary corpuses A: LCR type A, B: LCR type B, C: LCR type C, D: LCR type D				

3.2 Learning content

In order to evaluate the learning performance of students in vocabulary learning in M-learning, we assessed how many common English words a learner can remember before and after the experiment. We adopted the method proposed by Nation [43] to assess learner’s vocabulary learning. The Corpuses used in our experiment were sampled from the most common 2284 words suggested by Bauman [6].

For each learning vocabulary, four LCR types were used in our within subject experiment design: type A, providing an English word with its spelling, phonetic symbol, and Chinese translation (Baseline group); type B, providing the English word information like LCR type A plus written annotations such as an example sentence using that English vocabulary and Chinese translation (Written annotation case); type C, providing the English word information like LCR type A plus pictorial annotations such as a picture to represent the meaning of that English vocabulary (Pictorial annotation case); and type D, providing the English word information like LCR type A plus written annotations and pictorial annotations (Written annotation and Pictorial Annotations case), as shown in Figure 3.

	English Word	Written Annotation	Pictorial Annotation
Baseline group	**ash** 灰土 **n.** [æʃ]		
Written annotation case	**ash** 灰土 **n.** [æʃ]	**He wipes the ash on the table with a cloth.** 他拿桌布擦拭桌上的灰塵。	

Pictorial annotation case	**ash** 灰土 **n.** [æʃ]		
Written annotation and Pictorial Annotations case	**ash** 灰土 **n.** [æʃ]	**He wipes the ash on the table with a cloth.** 他拿桌布擦拭桌上的灰塵。	

Figure 3 Examples of the four LCR types presented on cell phone

3.3 Research Hypotheses

After reviewing the relevant research papers, we can now raise our research hypotheses as follows.

Hypothesis 1: The EVRR test scores of learners with higher PL and higher VSSP STM capacity (Quadrant 1) in both pictorial annotation and written annotation cases are significantly better than the baseline group.

Hypothesis 2: The EVRR test scores of learners with lower PL and higher VSSP STM capacity (Quadrant 2) in pictorial annotation case are significantly better than the baseline group.

Hypothesis 3: The EVRR test scores of learners with lower PL and lower VSSP STM capacity (Quadrant 3) in both pictorial annotation and written annotation cases are not significantly different.

Hypothesis 4: The EVRR test scores of learners with higher PL and lower VSSP STM capacity (Quadrant 4) in written annotation case are significantly better than the baseline group.

3.4 Experimental subjects

The subjects participated in our experiment were students of four classes selected from the two departments in two colleges (National Kaohsiung Normal University, NKNU and Far East College, FEC). Classes 1 and 2 were from the Industrial Technology Education Department of NKNU where total 71 students participated in this experiment. Classes 3 and 4 were from the Information Management Department of FEC with total 85 students.

Since we used 2x2 subject groups design, participants were divided into four different groups. For each group size to satisfy the minimum large sample size criterion (n 30), the minimum sample size in our experiment needs to be 120 (30×4=120). However, in order to have a more statistical power, we used 160 as our sample size. Because four of the subjects did not provide necessary background information, they were then excluded from the study. Thus, a total of 156 college students from NKNU and FEC participated in this experiment.

3.5 Experimental procedures

The experimental procedure consists of four different phases (Figure 4). First, participants met with the researcher at a computer classroom, where each person was asked to fill out a background questionnaire and then given a brief introduction to the experiment's objective and procedure. Second, participants seated in front of individual computers for the STM ability test using the STM ability test system (described in next section). Third, every subject was then assigned to view learning contents with random content assignment after they finished the STM ability test. Each participant individually read English words using their cellular phones which displayed in turn of the four different LCR types of English words sent out by the researcher. Participants spent approximately 50 minutes reading the 24 English words. Fourth, after viewing the learning content to learn the 24 English words, subjects were seated in computer classroom for the EVRR test to assess their learning outcomes of recognition and recall. EVRR tests are often used to examine students' English vocabulary knowledge [3]. EVRR usually involves multiple choice activities in recognition tests (Figure 4) whereby learners select or guess a correct response from the given alternatives. Such tests may strengthen any existing memory traces [40]. Recall test (Figure 5), on the other hand, demands the production of responses from memory. It is more difficult than recognition because learners must search for the correct answer within their mental representation of the newly experienced information [40].

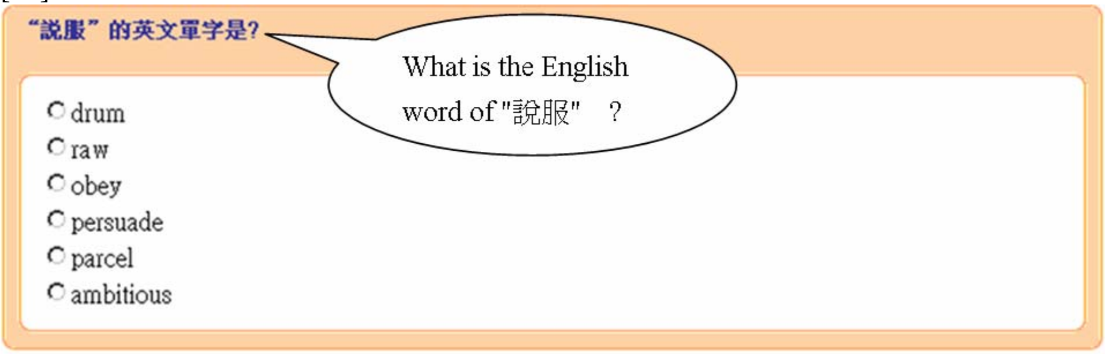


Figure 4 An example of recognition test in our study

Figure 5 An example of recall test in our study

In the experiment, participants spent approximately 15 minutes to complete the recall and recognition test. The average time set in all the research (Table 2) about L2 learning experiment is about 2 minutes. Therefore, we set 50 minutes for the learners in our experiment to learn the 24 English words).

Step 1 Step 2 Step 3 Step 4

Figure 4 Experimental steps

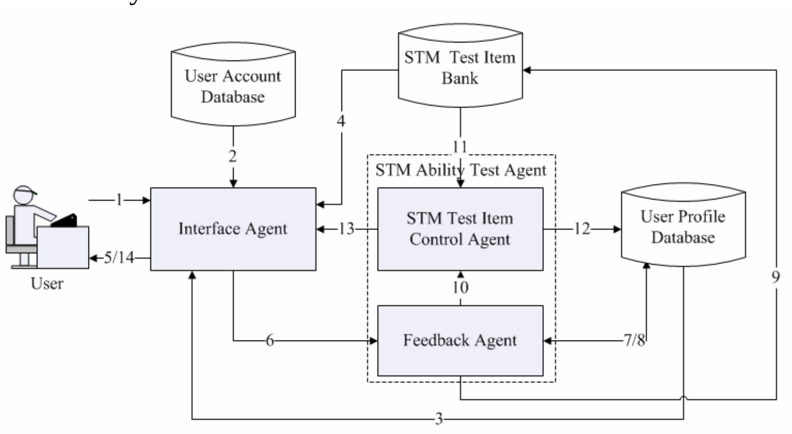
Table 2 The information of related research about L2 learning

Authors	Year	Subjects	Words	Minutes	Language1 -> 2
Svenconis & Kerst [56]	1995	48	24	22	English -> Spanish
Grace[24]	1998	181	48	no imitation	English -> French
Nagata[43]	1999	26	20	40	English -> Japanese

Labrie[35]	2000	66	23	no imitation (17.6)	English -> French
Al-Seghayer[3]	2001	30	21	30	Others -> English
Nikolova[45]	2002	62	20	90 (38.29)	English -> French
Finkbeiner & Nicol[20]	2003	47	32	45	English -> Dutch
Jones[29]	2004	80	25	14	English -> French

3.6 STM Ability Test System (STMATS)

We designed a STMATS based on two research articles [12][63] with some modifications to fit into our study. Figure 6 illustrates the proposed system architecture, which can be divided into two main parts, front-end and back-end, according to system operation procedures. The front-end part manages communication with users and records user behavior. Meanwhile, the back-end part analyzes users' ability and selects appropriate content to test users' STM ability. The interface agent belongs to the front-end part and it checks if user has responded a question and passes user's answer to feedback agent. It then displays the next test item to test user's STM ability.



[Note: the numbers indicate the system operation procedure]

Figure 6 The STMATS architecture

The STM ability test agent can be divided into two separated agents, namely the feedback agent and the STM test item control agent. The feedback agent aims to collect user feedback information, update user's STM ability, and adjust the difficulty parameters of STM test items. Moreover, STM test item control agent aims to select appropriate STM test items for user from the STM test item bank. Based on the system architecture, the detail operations of the system are described as follows:

1. Collect user personal information via the interface agent.
2. Identify user status based on personal information via the user account database.
3. Load user's initial STM ability based on the user profile database (if user is a new user, then the system assigns his/her STM ability with a moderate level).
4. Select appropriate STM test items from the STM test item bank based on user's STM ability.
5. Display STM test items to users and wait for user's feedback response (after user browse the STM test item, he/she is asked to recall it).
6. Collect user's feedback responses using the feedback agent.
7. Re-evaluate user's STM ability based on his/her feedback responses on the selected STM test item.
8. Store user's new STM ability into the user profile database.
9. Modify the difficulty parameters of STM test items in the STM test item bank. In order to avoid hostile test, this step only apply in the pretest stage.
10. Send user's re-evaluated STM ability to the STM test item control agent for STM test item selection.
11. Select new STM test items from the STM test item bank based on user's STM ability.

12. Record the ID of selected STM test item to avoid making duplicate selection.
13. Display selected STM test items in the content display-area via the interface agent.
14. User performs further testing processes based on the STM test items.
15. Repeat Steps 4 to 15 until the user completes the exams.

4 Results and Discussion

Table 3 shows the results of analysis with respect to the four research hypotheses. From this table, we can see that hypothesis 1, hypothesis 2 and hypothesis 3 are accepted through statistic analysis, and hypothesis 4 is partially accepted.

Table 3 Results of analysis with respect to the four research hypotheses

	Recognition Score	Recall Score	Average Score
Hypothesis 1 : (Require B >A, C >A)	B > A (p=0.000) B < D (p=0.000) C > A (p=0.000) C < D (p=0.003) D > A (p=0.000) D > B (p=0.000) D > C (p=0.003)	B > A (p=0.006) B < D (p=0.016) C > A (p=0.011) D > A (p=0.001) D > B (p=0.016)	B > A (p=0.000) B < D (p=0.000) C > A (p=0.000) C < D (p=0.005) D > A (p=0.000) D > B (p=0.000) D > C (p=0.005)
	Accepted	Accepted	Accepted
	Recognition Score	Recall Score	Average Score
Hypothesis 2 : (Require C >A)	C > A (p=0.000) C > B (p=0.016) D > A (p=0.000)	C > A (p=0.027) C > D (p=0.018) D < C (p=0.018)	C > A (p=0.000) C > B (p=0.012) C > D (p=0.027) D > A (p=0.002) D < C (p=0.027)
	Accepted	Accepted	Accepted
	Recognition Score	Recall Score	Average Score
Hypothesis 3 : (Require A=B=C)	No significant difference	Not significant difference	Not significant difference
	Accepted	Accepted	Accepted
	Recognition Score	Recall Score	Average Score
Hypothesis 4 : (Require B >A)	B > A (p=0.000) B > C (p=0.005) D > A (p=0.000) D > C (p=0.005)	Not significant difference	B > A (p=0.000) D > A (p=0.000)
	Accepted	Rejected	Accepted

A: To provide vocabulary information for learners and No any annotations
B: To provide vocabulary information for learners and written annotations
C: To provide vocabulary information for learners and pictorial annotations
D: To provide vocabulary information for learners and word plus pictorial annotations

The result of Hypothesis 1 in Table 3 shows that LCR type A is worse than B (p=0.000) and C (p=0.000) in recognition scores, and LCR type A is also worse than B (p=0.006) and C (p=0.011) in recall scores. And LCR type A is also worse than B (p=0.000) and C (p=0.000) in average scores. Therefore, we can conclude that the hypothesis 1 proposed in this research is accepted.

The result of Hypothesis 2 in Table 3 shows that the LCR type C in recognition scores is better than A (p=0.000). Moreover, in the recall test, LCR type C is better than A (p=0.000). In averages scores, the LCR type C is better than A (p=0.000). Therefore, we can conclude that hypothesis 2 is accepted.

The result of Hypothesis 3 in Table 3 shows that there is no significant difference among these three scores, it means these scores of LCR type A, B, C and D are equal. Therefore, we can conclude that the hypothesis 3 proposed in this study is accepted.

The result of Hypothesis 4 in Table 3 shows that the LCR type B is better than A (p=0.000) and C (p=0.005). However, B is only better than A (p=0.000) in average scores. Therefore, we can conclude that hypothesis 4 is only partially accepted.

4.1 Interpretation for Quadrant 1 learners

Table 3 shows that for learners with higher PL and higher VSSP STM capacity, the EVRR test score of LCR type B, C and D are better than LCR type A. Therefore, the most beneficial way to help Quadrant 1 learners is to provide them with more written annotations, pictorial annotations or both in M-learning environment.

4.2 Interpretation for Quadrant 2 learners

Quadrant 2 learners have higher capacity of PL STM than VSSP STM. Consequently, they have better skills to learn contents in nonverbal form than in verbal form [23][26]. Table 3 also shows that these learners' EVRR test score of LCR type C are better than LCR type A. Therefore, from this perspective and from statistical analysis, it is evident that the most suitable method to help Quadrant 2 learners in M-learning environment is to provide them with more pictorial annotations (LCR type C).

4.3 Interpretation for Quadrant 3 learners

Statistical analysis in Table 3 shows that for learners with lower PL and lower VSSP STM capacity, there are no significant differences in learning outcomes (EVRR test scores) among the four LCR types matching with the two LCD methods in M-learning environment. This result shows that use of more annotations will be of no use for these learners.

The possible explanation for this phenomenon is that these learners do not have large capacity of verbal and nonverbal STM. Therefore, according to cognitive load theory [56], if instructors provide learners with too many written or pictorial annotations, it will only cause higher cognitive load in their STM, leading to irritation and lack of concentration. In such situation, the learners would possibly ignore or skip that information. The most suitable arrangement to help Quadrant 3 learners is to use simple LCR type and just showing them the main parts of content that they need to learn (LCR type A) in M-learning environment.

4.4 Interpretation for Quadrant 4 learners

According to the research of [23][26], learners with a large capacity of verbal STM have great skills of verbal material learning. Therefore, providing them with learning material in verbal forms is better than providing it in nonverbal form. In our experiment design, the LCR type B and D are all provided with written annotations, and these learners should get higher scores than learners in LCR type A and C. However, Table 3 shows that for learners with higher PL and lower VSSP STM capacity, the EVRR test score of LCR type B are better than A except in recall test. Therefore, we can conclude that hypothesis 4 is only partially accepted. The EVRR test scores are only significant at recognition score, but they are not significant at recall test score. Consequently, care is needed before claiming that "providing Quadrant 4 learners with more written annotations is a suitable method for helping them in their study in M-learning environment".

5 Conclusions

This study addressed the issue of instructional strategies (LCR types), information technologies (LCD methods) and learners' characteristics (STM abilities) in M-learning. It explored the matching of using different LCR types for presenting English vocabulary learning content and different LCD methods to fit with learners' different STM abilities, and examined the effect of different fits using EVRR scores. From statistical analysis, we found that the matching of different LCR types and different LCD methods to fit with learners' different STM abilities would result in different EVRR scores. This implies that a fitting issue exists between matching of different LCR types with different LCD methods and learners' different STM abilities. Therefore, the most suitable way to help learners with lower PL and lower VSSP STM capacity is to provide them just basic learning materials. On the other hand, providing additional written annotations to learners with higher PL and lower VSSP STM capacity will help them learn better. Providing pictorial annotations will benefit learners with lower PL and higher VSSP STM capacity. Finally, for Learners with higher PL and higher VSSP STM capacity, the best way is to cater them with both written annotations and pictorial annotations in M-learning environment.

Acknowledgments

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