Phonological Short-term Memory and L2 Reading Comprehension: A Case of Iranian EFL Learners

Mohammadtaghi Shahnazari,
Assistant Professor in Department of English
Faculty of Foreign Languages,
The University of Isfahan
Email: m.shahnazari@fgn.ui.ac.ir

Abstract

This study examined the role of phonological short-term memory (PSTM) in L2 reading comprehension at three proficiency levels. For this purpose, overall 140 EFL learners were employed at beginning, intermediate and advanced levels. They were all studying English as a foreign language in a private language school. All participants completed an English non-word recognition task, as a measure of PSTM. They also completed measures of reading proficiency, including a cloze test, a short- answer comprehension test, and a reading recall test. The data at three proficiency levels were collected and analyzed. The results of this study indicated that PSTM may employ a different type of cognitive resources and this is consistent at three different proficiency levels suggesting that proficiency level cannot play a role between PSTM and L2 reading comprehension.

Keywords: Phonological short-term memory; L2 reading; L2 proficiency, English non-word recognition task

1. Introduction

Phonological short term memory (PSTM) is specialized for temporary storage and processing of phonological features of language. It plays a role as a phonological store by holding phonological representations of auditory information for a brief period of time, and as an articulatory rehearsal system by enabling the reader to use inner speech to refresh the decaying representations in the phonological store (Baddeley, 2007; Ellis, 2001). A considerable body of evidence suggests that PSTM may be an essential cognitive mechanism underlying successful adult L2 vocabulary learning (e.g., Papagno, Valentine & Baddeley, 1991; Papagno &Valler, 1995), L2 oral fluency production (e.g., O'Brien, Segalowitz, Freed & Collentine, 2007) and early reading skills such as phonemic awareness (e.g., Baddeley & Logie, 1999; Spear-Swerling, 2007). However, while the results are consistent in establishing a relationship between PSTM and L2 vocabulary learning, there are divergent research findings on the role of PSTM in L2 reading. While some prior studies suggested a relationship between phonological short-term memory and L2 reading ability at early stages of L2 development (e.g., Service, 1992; Service & Kohonen, 1995), some other researchers did not find such a relationship (e.g., Harrington & Sawyer, 1992; Hummel, 2009; Kormos & Sáfár, 2008). These mixed research findings point to the need for further research on the relationship between PSTM and L2 reading. Thus, the present study was designed to use the same methodology at three proficiency levels to examine whether there is a relationship between PSTM and L2 reading comprehension. A further purpose of this study is see whether the relationship, if any, would vary at different proficiency levels.

2. Review of Literature

Phonological short-term memory is in charge of processing and retaining phonological information. It is often measured by presenting spoken lists of words (word span), digits (digit span) or non-words , and requiring participants to remember the lists of words and/or digits in the order in which they are presented. The maximum number of items that the individual can correctly recall is considered to be their phonological memory score. PSTM is a separate construct from working memory (e.g., Juffs & Harrington, 2011; Kormos & Sáfár, 2008) in that it manipulates processing of just phonological information. In other words,

phonological-short term memory controls the temporary storage and processing of verbal information (e.g., Baddeley, 2000, 2007; Baddeley & Hitch, 1974). Some research suggests that learning the sound structures of new words in L2 is mediated by this component (e.g., Gathercole & Baddeley, 1990; Gathercole, Service, Hitch, Adams & Martin, 1999; Masoura & Gathercole, 1999, Miyake & Freidman, 1998; Valler & Papango, 2002; Skehan, 1989). In contrast, Working memory is a limited capacity temporary storage system with a limited capacity pool of attentional resources(Baddeley, 1986, 2003, 2007; Baddeley & Hitch, 1974; Baddeley & Logie, 1999; Gathercole & Baddeley, 1993) for processing information while performing higher order cognitive tasks such as reasoning , learning and comprehension (e.g., Baddeley & Logie, 1999).

A good body of research suggests that PSTM may play an important role in L2 learning (e.g., Dufva & Voeten, 1999; French, 2006; Papagno, Valentine & Baddeley, 1991; Service & Kohonen, 1995). Most of these studies established an important role for PSTM in adult L2 vocabulary learning (e.g., Papagno, Valentine & Baddeley, 1991; Papagno & Valler, 1992, 1995) and L2 oral fluency (e.g., O'Brien, Segalowitz, Freed & Collentine, 2007). As Baddeley (2003) suggested, PSTM plays this role by maintaining the representation of new phoneme sequences, while at the same time, the articulatory rehearsal system (inner speech) facilitates encoding of these sequences.

Research suggests that PSTM plays an important role in early reading skills such as phonemic awareness (e.g., Baddeley & Logie, 1999; Roth, Speece & cooper, 2002; Spear-Swerling, 2007). For example, in a longitudinal study that lasted for four years, Service (1992) examined the role of PSTM in English as a foreign language learning of 44 L1 Finnish primary school students. PSTM was measured through a pseudoword repetition task conducted in each year of the study. In each task, the participants were required to listen to two lists of pseudowords, an English-sounding list and a Finnish-sounding one, and repeat aloud the pseudowords they heard as quickly as possible. Service (1992) found a strong relationship between PSTM, as measured by the English-sounding pseudoword lists, at the start of the English instruction and the performance on tests of reading comprehension, listening and writing 2.5 years later.

Moreover, Dufva and Voeten (1999) examined the effects of PSTM and native language literacy acquisition on learning English as a foreign language in a longitudinal study. A total of 160 Finnish school children were asked to complete measures of native

language word recognition and listening comprehension in the first grade; word recognition, reading comprehension and PSTM in the second grade, and English skills in the third grade. Service's (1989) English pseudoword repetition task was used to measure the participants' PSTM. Using the structural equation modeling, Dufva and Voeten (1999) found that both PSTM and native language literacy (word recognition and comprehension skills) could have positive effects on learning English as a foreign language. These skills accounted for 58% of the variance in the beginning stage of English proficiency. Dufva and Voeten (1999) suggested that diagnosing at-risk children and providing them with training in word recognition in their L1 may help to develop their L2 proficiency.

Chun and Payne also (2004) examined the role of PSTM and working memory in the L2 German reading comprehension and vocabulary acquisition of 13 L1 English students in a second year German language course. A computer-delivered version of Daneman and Carpenter's (1980) L1 reading span test as well as a non-word repetition task were used to measure working memory and PSTM respectively. A German short story, including four sets of comprehension exercises followed by a recall protocol, was used as a measure of reading comprehension. The results indicated a strong relationship between PSTM as measured by word recognition and look-up behaviour, measured as the number of annotations which had been looked up and recorded while reading an L2 text. Learners with low phonological short-term memory capacity looked for an average of three times more words than participants with high phonological short-term memory ability. However, they did not give any significant research findings for working memory on any of the comprehension or vocabulary acquisition measures.

Hummel (2009) found no significant relationship between PSTM and L2 reading ability. He recruited 77 L1 French advanced ESL learners to complete a validated short form of the MLAT aptitude test, a non-word repetition task, and an L2 proficiency test including reading, vocabulary, and grammar sections. His results indicated a significant correlation between PSTM and L2 proficiency in general, and PSTM and the vocabulary and grammar sections of the L2 proficiency test in particular, but no statistically significant correlation between PSTM and L2 reading ability.

Moreover, Kormos and Sáfár (2008) found no significant correlation between PSTM and L2 proficiency. They investigated whether there is a relationship between PSTM and working memory capacity and performance in L2 language skills, with an L2 proficiency

test. They asked 121 secondary school students to complete a non-word repetition test, a Cambridge First Certificate Exam, and a backward digit span test after an intensive language training program. Their results indicated that there was no significant correlation between PSTM and L2 language skills(reading, listening, and speaking), but there was a significant correlation between working memory capacity, as measured by a backward digit span test and L2 language skills with the exception of writing. Kormos and Sáfár (2008) suggested that PSTM and working memory are distinct constructs, and play a different role in instructed second language acquisition.

Similar to the results for Kormos and Sáfár's (2008) study, Harrington and Sawyer (1992) found no significant correlation between PSTM as measured by a digit span and a word span test and L2 reading comprehension as measured by the grammar and reading sections of the TOEFL and a cloze passage. However, they found a significant, robust relationship between working memory as measured by an L2 reading span and both the TOEFL reading test and TOEFL grammar test.

As reviewed above, there were divergent research findings on the role of PSTM in second language reading comprehension. While some studies associated PSTM to second language reading ability (e.g., Dufva & Voeten, 1999; Service, 1992), some others found no relationship between PSTM and L2 reading ability (e.g., Hummel, 2009; Harrington & Sawyer, 1992; Kormos & Sáfár, 2008). These studies were also different in terms of the methodology and the proficiency level of the participants employed. These divergent research findings point to the need to examine the relationship between PSTM and L2 reading for each proficiency level. More specifically, prior studies used different methodologies to see if there was any relationship between PSTM and L2 reading ability. Moreover, all these studies focused on just one proficiency level, and none of them examined this potential relationship across proficiency levels. To make sure that the divergent research findings could not be due to the use of different methodologies and have a more accurate measure of the potential relationship between PSTM and L2 reading, the current study was designed to address the following questions:

1. Is there a relationship between PSTM and L2 reading ability?

2. If there is a relationship between PSTM and L2 reading ability, does it differ according to proficiency level?

2. Methodology

2.1. Participants

The participants were 140 EFL learners in a private language school. Their ages ranged from 16 to 35 years old. They were 57 males and 83 females and their prior language learning experiences differed from a period of six months to two years. Most of the participants were students. Prior to the study, all participants were given a consent form where all details of the research study had been elaborated. They had an opportunity to read through it and complete it in case they were willing to take part in the study.They were distributed into three groups of proficiency based on the New Interchange / Passages Proficiency Placement test (Lesley, Hansen, & Zukowski/ Faust, 2003). The participants whose proficiency scores were placed within a range of 1-30 were considered as the beginning participants, and the participants whose language proficiency scores were within a range of 31-49 and 50-70 were treated as the intermediate and advanced participants respectively. To compensate for their participation, the participants received 30 percent discount in their tuitions fees for their following semester.

2.2. Instruments

A battery of reading measures and a phonological short-term memory test of around 3-4 hours in duration were used. The phonological short-term memory test (PSTM) included a non-word recognition task. The reading measures included a cloze test, two short-answer reading comprehension passages and two L1 recall reading tests.

2.2.1. Non-Word Recognition Test

A non-word recognition task was used to measure phonological short term memory (e.g., Gathercole, Pickering, Hall & Peaker, 2001; Trofimovich, Ammar, & Gatbonton, 2007). In the non-word recognition task, the subjects listen to two consecutive sequences of pronounceable non-words and judge whether they are in the same or different order (e.g., Trofimovich et al., 2007). Non-words are used since they minimize the influence of vocabulary knowledge on phonological short-term memory and yield a relatively accurate estimate of it.

The non-words employed in this test (see Appendix) were adapted from Gathercole et al., (2001) by the researcher. The test consisted of 22 pairs of sequences of English non-words. The length of each sequence was gradually increased across the pairs within the range of 4 to 7 non-words. A range of four to seven sets of four to seven non-word sequences was given in this test. This test was conducted in a classroom context. The participants were asked to listen to each pair of sequences to determine whether the order of non-words in both sequences was the same or different by checking the boxes next to each choice in their answer sheet. To score the test, the total number of correct answers was determined. This represented an index for PSTM. The participants' phonological short-term memory scores ranged between 0 and 22 in this task.

This test was piloted on a total of 114 participants over four pilots, each time on a different group of participants. The first pilot included 52 participants at three proficiency levels. During the test session, the researcher noticed that some participants were taking notes while they were listening to the sets of English non-words. These participants later reported that the test instruction, which was given orally without any practice tests, had not been very clear to them. Since this could be a variable influencing the participants' performance, the second pilot study was conducted on another group of participants with a different design.

During the second pilot, the test was administered to a group of 44 participants in two separate sessions. Prior to the exam, the test instructions were given orally to the participants in a clear way. The instructions included two sets of four-English non-word length examples which were given to the participants to make sure that they had fully understood the test procedure. This was followed by a practice test including two four-English non-word length sets. The practice test was given orally with the same interval as the one in the main test by the researcher. Finally, the participants' questions were answered before the test started. After the test session, a few students reported that they had been confused by the oral explanation of the test instructions. They suggested that it would have been much better if they had been given the test instruction guide followed by an example in writing some time prior to the test.

In response to these concerns, the test was administered to a group of 10 participants during the third pilot. These participants were at three proficiency levels and selected from the same language school as the main study. Here the participants were given a written test instruction guide 5 minutes before the test session. Then their questions were answered and a practice test including two sets of four English non-words was conducted prior to the test

session. Unlike the test session in which English non-words were played on a tape recorder, in the practice test, they were read aloud by the researcher. Similar to the procedure during the test session, the participants were required to determine whether the order of the English non-words was the same or different. Then the participants completed the test session. After the test session, some participants reported that they had been confused by the test instruction guide as it had been too detailed. They suggested that it might have been clearer if it was shorter and followed by a brief oral explanation.

To see whether this worked better or not, the test was administered to another group of participants during the fourth pilot. They included 8 participants, both males and females, at three proficiency levels. They were given a brief test instruction guide 5 minutes prior to the test session. Then an oral explanation followed by an example was given at the beginning of the test session. The participants were given an opportunity to ask questions, as well. Unlike the prior times, there were no questions here. After the participants had completed the test, similar to the times before, they were given a retrospective report to complete. They reported that they had had no problems with the test instruction guide or the test itself, except that the test had been memory demanding. This was consistent with the participants' reports during the prior three pilots.

The results of this study also indicated that the participants' scores were in a wide range. The Cronbach's Alpha for this measure was .706. This displayed a desirable internal consistency for this test. Furthermore, an item analysis was conducted on the test here to examine the contribution each item was making to the test. The results indicated that the discrimination index for the test items was in a satisfactory range of .43 to .97. Therefore, this measure, as indicated in the last pilot, was found as a reliable and good test of PSTM for the main study.

The test was administered to 140 participants at three proficiency levels in this study. The results of the main study were consistent with the ones in the pilot studies. The participants all reported that they had had no problems with the test, except that it had been demanding for them. The participants' scores showed a wide spread as well. Furthermore, the discrimination index for the test items was in a desirable range of .45-.87. This suggested that these test items could discriminate well between weak and strong participants. The internal reliability for this test (r= .683), as indicated by Cronbach's Alpha, was a bit lower

than that of the last pilot study (r= .706). This might have been due to test fatigue, likely as a result of using English non-words, as the participants had found this measure challenging.

2.2.2. Reading measures

Since all methods of measurement have some advantages and disadvantages, researchers believe that more than one test method should be used to measure a construct like reading comprehension (e.g., Cain & Oakhill, 2006; Alderson & Bannerjee, 2002; Koda, 2005; Leslie & Caldwell, 2009). To measure the participants' reading comprehension at each proficiency level, two L1 recall reading tests, two short-answer reading passages (Alderson, 2000), and a rational deletion format cloze test (Koda, 2005) were used. These methods of reading measures were chosen because they matched well with the aspect of reading (role of memory and limited pool of cognitive resources in reading process) this study was attempting to measure.

In the beginning, intermediate and advanced cloze tests, there were 40, 45 and 50 deleted content words respectively, and the participants were required to choose the best answer from among four choices. In short-answer reading test, the participants were required to read two passages at each proficiency level and answer to three types of literal, reorganization and inferential questions, three each (overall 9 questions for each reading test). In L1 recall test, the participants were required to write down what they had understood from an L2 text in their L1. This was because it could allow us to measure reading comprehension without allowing the participants' performance to be influenced by insufficiencies in their English writing ability, particularly at the beginning and intermediate levels, and obtain fuller accounts of their comprehension.

2.3. Data Collection Procedure

This study was carried out in two sessions. In the first session, all the participants were initially required to complete a 10-minute PSTM test and a 90-minute general proficiency placement test. In the second session, the participants were required to complete a set of reading measures, including a cloze test, two short answer tests and two L1 recall tests. The participants were required to complete the appropriate test versions for their proficiency level. They all completed these tests in the same order. They completed the cloze test, the

short-answer and the L1 recall tests in turn. Since these measures were different at three proficiency levels, they were conducted in three consecutive rounds. During the test sessions, the participants were given some food and drink to refresh them and prevent them from test fatigue.

2.4. Data Analysis

After the PSTM and reading measures were taken, each subject was given an ID code. Then each measure was scored by the researcher. The z-scores of all the measures were calculated using SPSS software. This was to weight all the tests equally. Correlations between the reading measures were earned. Significant correlations were found between the reading measures, cloze, short-answer test and L1 recall test at each proficiency level (e.g., r= .434, p < .01; r= .445, p < .01; r= .546, p < .01). A composite reading score was also created from the reading measure z-scores at each proficiency level so as to have a more stable index for the participants' L2 reading ability.

More specifically, there were medium to high correlations between the basic reading measures at the beginning level. The high correlations were between the cloze and short-answer (r= .644, p < .01) as well as the short-answer and the L1 recall tests (r= .546, p < .01). There was a medium correlation between the cloze and the L1 recall tests (r= .428, p < .01). This suggests that the kind of cognitive and linguistic processes in the short-answer test tend to be more similar to that of the cloze and the L1 recall tests.

Correlations between the reading measures were obtained for the intermediate level. Similar to the results at the beginning level, there were significant correlations between these measures. This suggests that they all measure the similar construct. However, unlike the results at the beginning level, there were just medium correlations between the basic reading measures, specifically, between the cloze and the short answer tests (r= .445, p < .01), the cloze and the L1 recall tests (r= .303, p < .05), and the L1 recall and the short-answer tests (r= .434, p < .01).

At the advanced level, all the reading measures correlate with one another, with the exception of the L1 recall and cloze measure. The advanced level performance differs from the beginning and intermediate levels in this respect. This suggests that the kind of cognitive and linguistic processes required by the L1 recall test are different from those for the cloze

test at this level. Similar to the results at the intermediate level, there are just medium correlations between the basic reading measures here. More specifically, these correlations are between the cloze and short-answer tests (r = .431, p < 0.01) as well as the short answer and L1 recall tests (r= .399, p < .05). However, unlike the results for the beginning level, there is not a high correlation between the basic reading measures at the intermediate and advanced levels.

3. Results and Discussion

The participants' performance on PSTM test as an independent variable was analyzed distinctly for each proficiency group. The descriptive statistics of the participants' performance on this measure at each proficiency level are indicated in Table 1.

Table 1. Descriptive statistics for the phonological short-term memory measure at three proficiency levels

		N	Min	Max	Mean	S.D.
PSTM	Beg.	56	4	19	13.00	2.84
	Int.	43	7	20	12.23	2.89
	Adv.	41	6	19	13.36	2.82

*Note.*PSTM= Phonological Short Term Memory; Pro.= Processing; Beg.= Beginning; Int.= Intermediate; Adv.= Advanced

3.1. Correlation Results

To determine the strength of the relationship between L2 reading ability and PSTM, correlations were obtained between the measures of these variables at three proficiency levels. L2 reading ability was measured with a cloze test, two short-answer and two L1 recall tests at each proficiency level. A composite reading score was also created from the scores of the basic reading measures. PSTM, as discussed before, was measured through a non-word recognition task. The results for this analysis at each proficiency level are indicated in Table 2.

Table 2. Correlations between the PSTM and the Reading Measures for each Proficiency Level

Measure		Reading Composite	Cloze	Short Answer	L1 Recall
PSTM	Beginning	.063	.089	.001	.086
	Intermediate	.-018	-.063	.100	-.077
	Advanced	.081	.005	.213	-.035

Note. PSTM= Phonological Short Term Memory

As indicated in Table 2, there is no significant correlation between L2 reading ability and PSTM for each proficiency group.

This study examined the relationship between PSTM and L2 reading at three different proficiency levels. The findings of this study showed that there is not a significant relationship between PSTM and L2 reading comprehension. One possible explanation could be that PSTM which involves maintaining phonological information via rehearsal mechanisms (e.g., Baddeley, 1986, 2007; Baddeley & Hitch, 1974; Baddeley & Logie, 1999; Gathercole, Willis, Emslie & Baddeley, 1992) taps just the storage capacity of working memory. In contrast, reading comprehension, as a complex cognitive task, involves activating background knowledge, processing text knowledge and retaining their representations in working memory for further analysis, such as integrating idea units and making inferences (e.g., Cain & Oakhill, 2006; Hudson, 2007; Koda, 2005). Thus, reading comprehension, as a complex cognitive task, taps both components of working memory, processing and storage capacities. For this reason, PSTM and L2 reading measures may not employ the same kind of cognitive resources. These findings suggest that storage alone does not play a significant role in reading comprehension.

The results of this study are consistent with prior results in L1 (e.g., Daneman & Carpenter, 1980) and L2 studies (e.g., Harrington & Sawyer, 1992; Hummel, 2009; Kormos & Sáfár, 2008) which specifically investigated whether there was a relationship between PSTM (as well as working memory capacity) and reading comprehension. For example, Daneman and Carpenter (1980) investigated the role of individual difference in working memory capacity and PSTM in L1 reading comprehension. The results in their study

indicated that the variability in L1 reading ability could be explained by the working memory capacity, but not by the PSTM, as measured by a word or digit span test. Similarly, Harrington and Sawyer (1992) examined the relationship between PSTM and working memory capacity on the one hand and L2 reading comprehension on the other. The results of their study indicated that working memory capacity, rather than PSTM, could explain individual differences in L2 reading comprehension. Further support comes from Hummel's (2009) and Kormos and Sáfár's (2008) studies where they found no significant correlation between PSTM and L2 reading ability.

In contrast to the results of this study and prior studies discussed above, Chun and Payne (2004) found evidence of a relationship between PSTM and L2 reading ability. The findings of their study displayed that there was a high negative correlation between PSTM and look-up behaviour while reading an L2 text. They argued that participants with low PSTM looked up L2 words more than participants with high PSTM, implying the participants with higher PSTM had a better command of L2 vocabularies, and consequently a better L2 reading ability. Chun and Payne suggested that the participants with low PSTM capacity used other factors (e.g., features of the software application) to compensate for memory limitations while reading an L2 text. This supports the idea that with multiple abilities in working memory, individuals make up for weaknesses in some areas by using other strong points (e.g., Mackey, Philp, Egi, Fujii & Tatsumi, 2002). While this study did show a connection between PSTM and a specific reading strategy, it should be noted that Chun and Payne did not find a direct link between PSTM and reading comprehension.

Overall, the current study fits with prior L2 studies which found no significant relationship between PSTM and L2 reading. However, it should be noted that vocabulary research suggests that there is a relationship between PSTM and L1 reading (e.g., de Jong & de Jong, 1996; Engle, Carullo & Collins, 1991; Gathercole, Willis, Emslie & Baddeley, 1991, 1992) and L2 reading (e.g., Masuora & Gathercole, 2005; Papagno, Valentine &Baddeley, 1991; Service, 1992; Service & Craik, 1993; Service & Kohonen, 1995), particularly at lower proficiency levels, mediated by L1 and L2 vocabulary development respectively, which in turn impacts on L2 reading ability. For example, Service and Kohonen (1995) explored the relationship between PSTM and L2 reading comprehension as evidence of a relationship between PSTM and L2 vocabulary learning. This relationship may be established through the processes where readers convert letters into sounds while reading a text, and store them temporarily in PSTM (or verbal short-term memory) until the last letter is translated. Then

they blend the full sequence of sounds into a word. This explanation is consistent with the Baddeley's (2006) study in which he asserts there is a relationship between PSTM and reading ability "possibly in a number of ways, ranging from learning letter-sound correspondences, through sound blending, possibly up to the level of text comprehension (p., 13)." Phonological awareness or sensitivity is also argued to play an important role in reading ability, even more than that of PSTM (e.g., de Jong & Olson, 2004). Phonological sensitivity is strongly related to PSTM, and defined as "the ability to detect and manipulate the sound units of one's oral language" (de Jong, 2006, p., 37).

However, at the higher proficiency levels, the role of PSTM diminishes, and as Masoura and Gathercole (2005) argued, may be replaced with "other factors which impose increasingly significant constraints on the ease of vocabulary expansion (p., 423)." One of these factors, they added, could be existing long-term phonological knowledge which mediates L2 vocabulary leaning once participants' familiarity with the language increases, reducing the role previously played by PSTM. This argument is consistent with Cheung's (1996) study, in which he found a relationship between PSTM and L2 vocabulary learning with lower proficiency EFL learners, but not with those at higher proficiency levels. Further support comes from Hummel's (2009) findings that PSTM could explain individual differences in L2 proficiency among ESL learners at lower levels of proficiency, but not among those at higher levels.

Thus, if this is the case, one anticipates a relationship between PSTM and L2 reading comprehension. However, as the results of the current study and those of prior studies indicated, there should be at least two conditions available to explore this relationship: (1) lower proficiency participants, and (2) a measure or measures of L2 vocabulary because the relationship between PSTM and reading seems to be mediated by vocabulary learning. Similar to Kormos and Sáfár's (2008) study, the current study included lower proficiency participants, but no L2 vocabulary measures, it is not then surprising that no direct connection to reading comprehension was found. Hummel (2009) included an L2 vocabulary measure, but his participants may have been too advanced for a relationship between PSTM and vocabulary learning to be significant. In contrast, Chun and Payne (2004) found evidence for the relationship between PSTM and L2 reading comprehension, although they did not include any lower proficiency participants in their study. However, their results should be interpreted cautiously because they were analyzed based on the amount of look-up behaviour for new

words, and not on a direct measure of L2 vocabulary knowledge. Furthermore, their study included a low number of participants, and L2 proficiency measures were not used.

4.Conclusion

This study made a contribution to the literature by testing three proficiency levels and drawing on a consistent methodololy at each level to see if there was any relationship between PSTM and L2 reading ability. Although no significant relationships were found, the results of this study could be more reliable than those of prior studies. This is because in this study, the same research conditions were created for each level of proficiency. This included the use of the same type of reading and PSTM measures.

Overall, consistent with studies conducted with children learning to read in their L1, we can conclude that the role of PSTM in L2 reading is likely to be restricted to vocabulary learning at early stages. Future research could investigate the interplay between PSTM, L2 vocabulary learning and L2 reading comprehension at earlier stages of language learning, including children and adults as well as different types of reading, vocabulary, and simple span measures.

There were some limitations with this study. The first limitation was related to the lack of an L2 vocabulary test at three proficiency levels to see whether the relationship between PSTM and L2 reading ability could be mediated by L2 vocabulary learning ability as proposed by some studies (Masuora & Gathercole, 2005; Papagno, Valentine & Baddeley, 1991; Service, 1992; Service & Craik, 1993; Service & Kohonen, 1995). Due to the large number of reading tasks (one cloze, two short-answer and two L1 recall tests) and a non-word recognition task, it was not logistically possible to include an L2 vocabulary test in the current study. Furthermore, the volunteer participants had limited time, and the threat of test fatigue restricted the choice of tasks used in this study. Given these constraints, another separate study is needed to specifically investigate this relationship. The findings of future research may clarify the extent to which the relationship between PSTM and L2 reading ability is mediated by L2 vocabulary development, and any variance due to proficiency level.

Finally, in this study, only one measure of PSTM was included due to the time constraints mentioned above. Additional PSTM measures might be helpful to illuminate any

relationship between PSTM and L2 reading. These studies might use the non-word repetition test or non-word recognition test as measures of PSTM. Research suggests that non-words may yield a more reliable index of PSTM (e.g., Gathercole, Frankish, Pickering, & Peaker, 1999; Trofimovich, Ammar & Gatbonton, 2007) because they minimize the influence of background knowledge (e.g., L2 vocabulary knowledge) on PSTM as opposed to a word or digit span test. L2 reading research has not yet included studies of PSTM including multiple measures.

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Appendix

Pairs of English-non words(adapted from Gathercole, Pickering, Hall, & Peaker, 2001) used in the non-word recognition task.

1	pebkib bon deet (Identical sequence)	12	teeg chan mig pad geb dop nam teeg chan mig dop pad geb nam
2	peeb kol goob mab peeb goob kol mab	13	geed mun peb cheem tep nuck (Identical sequence)
3	pib kom gook tam (Identical sequence)	14	bick meep tooch leck nam gab bick tooch meep leck nam gab
4	neeg gop doob jat neeg doob gop jat	15	choom mit gab tid gep hag nool choom gab mit tid gep hag nool
5	pim goot neeb kig doog pim neeb goot kig doog	16	Jeck leem gan chut bock mon tud (Identical sequence)
6	meb teeb dook cam jawn meb teeb cam dook jawn	17	mitch tem jeeg lib cug bup neb mitch jeeg tem lib cug bup neb
7	teel nog gub pem chad (Identical sequence)	18	pock mun tob juck lid geb ged coom (Identical sequence)
8	jep cham tud gem deech pag (Identical sequence)	19	Toock jeel peeb modge dack lig neeb (Identical sequence)
9	noog teed gad gem pab chud noog teed pab gad gem	20	lon cam deech mot jooch ked gock lon cam deech mot

	chud		ked jooch gock
10	mep teeg keb chim nup jit mep keb teeg chim nup jit	21	dook mip chon teep jal noog goot dook mip teep chon jal noog goot
11	jick mip chool lod nug tep (Identical sequence)	22	kom chen meb lud tam dit loog (Identical sequence)