Hand Movement Improves Word Memory of Grade 1 Students

Tsz Wing Tsang

Department of Applied Social Sciences, The Hong Kong Polytechnic University,

Email: tsz-wing.tsang@connect.polyu.hk

Hui Jing Lu

Department of Applied Social Sciences, The Hong Kong Polytechnic University,

Email: huijing.lu@polyu.edu.hk

ORCiD: 0000-0003-4025-3160

Correspondence regarding this manuscript should be addressed to Hui Jing Lu, Department of Applied Social Sciences, The Hong Kong Polytechnic University, Hung Hom, Hong Kong. Email: huijing.lu@polyu.edu.hk

Word Count: 7527

Hand Movement Improves Word Memory of Grade 1 Students

Abstract

Moving the hands or chewing in the encoding stage enhances memory, because body movement activates the frontal cortex, which is crucial to the memory process. However, how hand movement facilitates word memory in an applied setting and whether it produces long-term effects remain unclear. Grade 1 students studied 15 new words through different strategies: fun hand movement, verbal repetition, listening (Study 1), copying words, and pure hand movement (Study 2). They recalled the words immediately, 25 minutes later, and 3 days later. Their memory performance was the best under the pure hand movement condition and poorest under the verbal repetition and listening conditions. Moreover, the 3-day delayed recall was similar to the immediate recall under the pure hand movement condition, whereas recall decreased after 3 days in other conditions. These findings demonstrate effective strategies of word memory for vocabulary learning in classroom settings.

Keywords: hand movement; memory; vocabulary learning; verbal repetition; word copying

Introduction

Vocabulary learning is essential to language proficiency (Graham & Santangelo, 2014; Han & Wei, 2016) and language development in the early years of life (Beck & McKeown, 1991; Rowe, 2012; Schmitt, 2008). Vocabulary learning improves not only productive language skills, such as writing and speaking (Davies & Pearse, 2000), but also receptive language skills, such as reading and listening (Matsuoka & Hirsh, 2010; Beck, McKeown, & Kucan, 2002; Neuman & Wright, 2014). Vocabulary learning gives rise to a chain of positive outcomes, including improved communication skills (Davies & Pearse, 2000; Rabadi, 2016) and high confidence levels (Burton & Humphries, 1992).

Because of the importance of vocabulary, a tremendous amount of time is spent on teaching vocabulary in lower grades of primary schools (Goossens, Camp, Verkoeijen, Tabbers, & Zwaan, 2014). An essential part in learning new vocabulary is memory (Gathercole et al., 1999; Michas & Henry, 1994). To successfully link between the form or pronunciation of a word and its meaning and accurately apply the word in speaking and writing, students should first be able to memorize the pronunciation, spelling, and written form of the word (Ehri & Rosenthal, 2007; Schmitt, 2008). Traditional learning methods, such as verbal repetition and word copying, enhanced performance in word memory in educational settings (Cazden, 1992; Kindle, 2009; Teale, 1984), and innovative learning strategies, such as moving the hands during the word memory process, facilitated the retrieval of words in a laboratory setting (Propper, McGraw, Brunyé, & Weiss, 2013). However, whether hand movement facilitates vocabulary memory in a real-life classroom setting remains unclear. This study investigated the effectiveness of hand movement for facilitating word memory in a classroom and compared the effectiveness of different methods of memorizing words.

Traditional Word Memorization Methods: Verbal Repetition and Word Copying

Verbal repetition and reading aloud are common practices for students to memorize words in a classroom (Polette, 2005). During the word learning phase, verbal repetition, a memory strategy of maintenance rehearsal, facilitates word memorization (Glenberg, Smith, & Green, 1977; Greene, 1987; Laufer, 1997; Rundus, 1971). Participants who read aloud while learning new words have performed better in memory recall or recognition tests than those who read silently (Gathercole & Conway, 1988; Hopkins & Edwards, 1972; Poulton & Brown, 1967) and those who read with mouth movement (without sound) (Conway & Gathercole, 1987). Compared with only listening to a teacher pronouncing a word, repeating the teacher's word aloud resulted in improved memory in word recall and recognition (Cho & Feldman, 2013). The advantages of reading aloud and verbal repetition can be partly explained by the production effect, which emphasizes the active production of phonemes when a learner is pronouncing a word (Hopkins & Edwards, 1972; MacLeod et al., 2010; Ozubko & Macleod, 2010). In contrast to silent reading, producing phonemes while reading aloud enables a learner to consolidate pronunciation information and phonetic details of a word (MacLeod et al., 2010). Moreover, compared with sounds produced by a teacher, phonological sounds produced by a learner showed greater effect in facilitating word spelling and thus improved word memorization (Cho & Feldman, 2013).

Word copying is another common practice for students of primary schools in learning new words (Strickland, 1998). However, word copying has been demonstrated to be less effective than reading for word memorization, likely because copying requires additional cognitive resources for writing with the hands (Bourdin & Fayol, 2002; Tindle & Longstaff, 2015). Tindle and Longstaff (2015) reported that after reading a list of words in the learning phase, adult participants recalled more words compared with those who had listened to and written down the list of words. Writing requires additional cognitive resources to transform phonological details into written words, to plan for movement, and to maintain visual feedback for word correction (Kellogg, 1996; Schweppe & Rummer, 2013). Those additional resources, which are devoted to information processing, could have been used for information storage to facilitate memory. Because cognitive resource trade-off exists between information processing and storage (McCutchen, 2000), while more resources are used for processing, fewer resources can be used for storage, and consequently, memory is hindered. Word copying is also less effective than retrieval practice for vocabulary learning (Jones et al., 2016; Goossens et al., 2014). Grade 2 students learned new words through repeated copying or through dictation practice followed by spelling check and correction. Those who learned through dictation showed higher spelling accuracy of the newly learned words than did those who learned through repeated copying in 1-day and 5-week delayed spelling tests (Jones et al., 2016). Grade 3 students who learned through recall practice outperformed those who learned through repeated copying in a 1-week delayed cued recall test (Goossens et al., 2014).

Moving the Hands or Fingers Improves Memory

Moving the hands or simply using fingers while encoding or retrieving information enhances memory performance. Researchers explained that moving the hands activates the frontal cortex, which is also responsive to memory tasks (Hanning & Deubel, 2018; Propper et al., 2013). For example, encoding and retrieval of information are associated with the left and right frontal cortices, respectively, in right-handed individuals (Habib, Nyberg, & Tulving, 2003; Tulving et al., 1994). Because hemisphere responses correspond to the opposite side of body movement, Propper and colleagues (2013) reported that clenching the right hand prior to the encoding phase and clenching the left hand prior to the retrieval phase resulted in optimal memory performance (recalled around 11 out of 36 words) compared with other left–right hand clenching and encoding–retrieving combinations (recalled around 7 out of 36 words), in a study with 51 young-adult participants. Apart from hand movement, body movements have been evidenced to improve memory of adults in studies of the chewing effect. Chewing activates the prefrontal cortex that involve in memory-related information processing (Onozuka et al., 2002) and enhances memory performance (Baker, Bezance, Zellaby, & Aggleton, 2004; Hirano et al., 2008). Studies of brain function have demonstrated that hand movement activates the network of the frontal cortex (Boecker et al., 1994; Kawashima et al., 1993) that is also involved in memory (Shallice et al., 1994; Swick & Knight, 1996; Tulving et al., 1994). Therefore, we hypothesized that moving the hands while learning new words improves word memory.

A usual practice involving hand movement in vocabulary learning is playing Scrabble. Scrabble is a popular word game consisting of a pile of letters that can be placed onto a board. The letters form words in rows read from left to right or in columns read downward. Scrabble has been employed as an effective educational tool for global English learners (Hebblethwaite, 2009; Voiniv, 2010). However, researchers have focused only on fun elements of Scrabble in vocabulary learning and emphasized the critical role of game playing in reducing boredom and raising students' interests during vocabulary learning (Lee, 1994; Nguyen & Khuat, 2003). They overlook the effectiveness of hand movement during Scrabble in facilitating the memorization of words.

Overview of the Present Study

Previous studies regarding the benefits of body movement on memory have been conducted only in laboratory settings and in adults (Hirano et al., 2008; Propper et al., 2013). This study explored the effectiveness of hand movement on word memory in a simulated educational setting. Because previous studies have reported that the proportion of words correctly recalled would decline after 25 minutes and 3 days (Chan, Manley, Davis, & Szpunar, 2018; Mantyla & Nilsson, 1988), we employed multiple recall tests, namely an immediate recall, a 25-minute delayed recall, and a 3-day delayed recall, to analyze short-term and long-term memory effects (Jones et al., 2016). We targeted Hong Kong Grade 1 students because they are at the age of systematically learning English words in class (Han & Wei, 2016) and the size of vocabulary strongly predicts students' reading proficiency (Senechal, Oulette, & Rodney, 2006) and literacy development (Tabors, Snow, & Dickinson, 2001) throughout primary school study.

To represent the hand movement condition and adapt the game to a class context, we used an easy version of Scrabble, in which students picked up plastic letters and placed them in a row to form a word. In Study 1, verbal repetition, the most common word learning method in class, and a control condition, in which students listened to a teacher spelling words, were also included to compare with the Scrabble condition. To control for the fun elements of Scrabble, in Study 2 we created a pure hand movement condition in which we replaced the plastic letters with wooden blocks and asked the students to place the blocks in a row to represent a word. That condition was compared with word copying, another traditional word learning method involving hand movement in a narrow range. We hypothesized that participants would perform best in free recall tests under the fun hand movement condition (i.e., Scrabble), second best in the pure hand movement condition, and poor when using the two traditional learning strategies of verbal repetition and word copying.

Study 1

Method

Participants. We recruited 184 right-handed Grade 1 students (105 girls, *mean age* = 6.81 years, *SD* = 0.43 years). To reduce variation among participants, only the right-handed students were recruited because information encoding involves different hemispheres depending on the handedness (Habib et al., 2003; Propper et al., 2013). The students were from similar working class communities and were of similar background. Written consent forms were obtained from the students' parents or legal guardians. Four students were excluded from analyses because they were absent from one or two recall tests. The students were randomly assigned to one of the three learning conditions: fun hand movement (n = 70), verbal repetition (n = 60), or control condition (n = 50). They received a small gift for participation.

Materials. A list of 15 English words was selected from the Dolch word list, a list of English words that appears in schoolbooks with a ranking of usage frequency (Farrell, Osenga, & Hunter, 2013). We adopted the Dolch word list, because it categorizes words into different levels according to primary school Grades 1 to 6. The 15 words were selected from the curriculum of Grade 3. They comprised adverbs, conjunctions, adjectives, verbs, and pronouns, and each word consisted of three to seven letters. The words were *always*, *because*, *best*, *both*, *carry*, *far*, *found*, *grow*, *keep*, *kind*, *never*, *own*, *start*, *those*, and *try*. Schoolteachers confirmed that those words had not been taught in the Grade 1 curriculum.

Design and procedure. The design was a 3 (between-subject, learning condition: fun hand movement vs. verbal repetition vs. control) × 3 (within-subject, recall time: immediate vs. 25-minute delay vs. 3-day delay) design. The dependent variable was the number of words recalled in free recall tests, in which the participants were asked to write down words with correct spelling that they had learned in a mock lesson.

To simulate classroom teaching, a group of 22–30 students were taught a mock lesson in either a regular Grade-1 classroom or a classroom where students had art lessons. Settings of the experiment classroom were similar to those of students' regular classrooms, and the mock lessons took place during the time of the last class of a school day or immediately after school. An experimenter, who was blind to the study hypotheses and acting as the class teacher, taught 15 new English words in a teaching session that lasted approximately 20 minutes. Three different teaching strategies were applied. All participants were taught by the same experimenter, who was trained to teach with different strategies.

Fun hand movement. The students were provided a pile of plastic letters from which they can select the required letters to form a word. The experimenter wrote a word on the blackboard in the front of the classroom and subsequently spelled and read the word for the class. The students were asked to use their right hands to choose letters and place them on their desks to form the word with correct spelling. The experimenter walked around to ensure that the students knew how to form a word with plastic letters.

Verbal repetition. The experimenter wrote a word on the blackboard and subsequently spelled and read the word aloud. For example, the experimenter taught the word "apple" by loudly saying "A-P-P-L-E, apple." The students were asked to repeat the experimenter and clearly spell the word as the experimenter did. The students spelled each word five times.

Control condition. The experimenter wrote down a word and subsequently spelled and read the word aloud slowly and clearly to the class five times. The students were silent and only listened to the experimenter.

Prior to the teaching session, a practice word (i.e., "apple") that the students already knew was used to familiarize them with the learning process and the condition to which they were assigned. After the teaching session, the students were allowed 10 minutes to immediately free recall the 15 newly learned words and write them down on an answer sheet. After all answer sheets were collected, the students had a 25-minute break in which they played a mini-game that served as a distractor task. Then, the students were asked to recall and write down the 15 words again. The students completed the same free recall task again 3 days later.

In addition to the three free recall tests, the students under the fun hand movement and verbal repetition conditions answered two questions to indicate how interesting the learning activity was on a 4-point Likert scale (*1* for *not at all* to *4* for *very much*). The two questions were as follows: (1) *"Is the learning activity interesting?"* and (*2) "Do you feel excited for the learning activity?"* The mean scores of the two questions for each participant represented the interest level of a learning strategy and were employed as a control in analyses.

Results

Independent sample *t* test results showed that the students found learning with fun hand movement ($M = 2.76$, $SD = 0.84$) more interesting compared with learning with verbal repetition ($M = 2.21$, $SD = 0.85$; $t(128) = 3.71$, $p < .001$, $d = 0.65$). These results suggest that the fun hand movement condition differed from the verbal repetition condition in the elements of fun.

INSERT TABLE 1 ABOUT HERE

The number of correctly recalled and spelled words was recorded as the dependent variable. Table 1 shows the mean and standard deviation of words recalled under each condition. A 3 (learning condition) × 3 (recall time) analysis of variance (ANOVA) showed a main effect of learning conditions ($F(2, 177) = 51.2$, $p < .001$, $\eta_p^2 = 0.37$), a main effect of recall time ($F(2, 354) = 20.6$, $p < .001$, $\eta_p^2 = 0.10$), and an interaction ($F(4, 354) = 4.08$, $p < .01$, $\eta_p^2 = 0.044$). We applied Bonferroni Multiple Comparison Procedure to conduct all post hoc tests in this paper. To be specific, more words were recalled across the three recall tests in the fun hand movement condition ($M = 4.95$, $SD = 2.95$) than in the verbal repetition

($M = 1.99$, $SD = 1.79$, $p < .001$) and control ($M = 2.12$, $SD = 2.30$, $p < .001$) conditions, and no significant differences were found between verbal repetition and control ($p = 1.00$). Across the three learning conditions, memory performance was better in the immediate recall ($M = 3.66$, $SD = 2.64$) than in the 25-minute ($M = 2.96$, $SD = 1.94$, $p < .01$) and 3-day ($M = 2.44$, $SD = 2.04$, $p < .001$) delayed recall, and significant difference was observed between 25-minute and 3-day recall ($p < .05$) (Figure 1a).

INSERT FIGURE 1 ABOUT HERE

The interaction was caused by the different decay patterns of memory performance from immediate recall to 3-day delayed recall under different learning conditions. Under the fun hand movement condition ($F(2, 138) = 6.41$, $p < 0.01$, $\eta_p^2 = 0.09$), the participants recalled significantly more words in the immediate recall ($M = 5.60$, $SD = 2.81$) than in the 25-minute ($M = 4.37$, $SD = 2.27$; $p < .001$) and 3-day ($M = 4.89$, $SD = 3.55$; $p < .05$) delayed recall tests, whereas they recalled similar number of words in 25-minute delayed and 3-day delayed recall tests ($p = .18$).

Under the verbal repetition condition ($F(2, 118) = 26.38$, $p < .001$, $\eta_p^2 = 0.31$), memory performance in the immediate recall ($M = 2.70$, $SD = 1.98$) was superior to that in the 25-minute delayed recall ($M = 2.12$, $SD = 1.64$; $p < .01$), which in turn was superior to that in the 3-day delayed recall ($M = 1.17$, $SD = 1.37$; $p < .001$).

Under the control condition ($F(2, 98) = 6.81$, $p = .002$, $\eta_p^2 = 0.12$), no significant difference in memory performance was observed between the immediate recall ($M = 2.68$, $SD = 3.14$) and 25-minute delayed recall ($M = 2.40$, $SD = 1.91$; $p = .59$), but the 25-minute delayed recall was superior to the 3-day delayed recall ($M = 1.28$, $SD = 1.21$; $p < .001$).

Learning with fun hand movement achieved the most favorable memory outcome, and memory decay varied under different learning conditions.

Discussion

In each recall test, at different time points, the participants recalled more words under the fun hand movement condition than under the verbal repetition or control conditions. Moreover, learning with Scrabble demonstrated a long-lasting effect, in which the students performed similarly in the two delayed recall tests, whereas learning through verbal repetition or by only listening to the teacher showed a dramatic decrease from the immediate to the 3-day delayed recall. These results suggest that Scrabble is a more effective and sustainable method of vocabulary learning compared with verbal repetition. The benefit of using Scrabble to learn may be caused by hand movements activating brain areas related to memory (Propper et al., 2013) or by fun elements in the game that enhanced students' motivation to learn (Voinov, 2010). However, we did not reach a clear conclusion based on the results of Study 1. In Study 2, we distinguished between the effects of hand movement and fun.

It was unexpected that recall performance in the control condition was similar to that in the verbal repetition condition. Previous studies showed that reading aloud resulted in superior memory of a word list compared with reading silently (Gathercole & Conway, 1988; MacDonald & MacLeod, 1998) or only listening to the words (Cho & Feldman, 2013; Dodson & Schacter, 2001), because the production effect rendered words read aloud more memorable than other words that were not pronounced by participants. However, those studies were conducted in laboratory settings and included adults as participants. Moreover, the superior memory effect after reading aloud compared with remaining silent was observed only when the two conditions were manipulated within participants, whereas no difference between the two conditions was observed if they were manipulated between participants

(Dodson & Schacter, 2001). This study was conducted with Grade 1 students in a classroom setting simulating a real English lesson, and a between-subject design was applied. Therefore, our result of no significant difference between learning through verbal repetition and remaining silent does not contradict the literature on the effects on word memorization.

Study 2

By using Scrabble to learn vocabulary, Study 1 maximized external validity while inevitably compromising internal validity by including both hand movement and fun elements. Study 2 addressed this problem by presenting a pure hand movement condition, in which participants used their hands to move small wooden blocks instead of plastic letters to represent newly learned words. Study 2 also included word copying, which is a traditional learning strategy also involving hand movement, albeit to a lesser degree.

Method

Participants. From six classes in four local primary schools, 131 right-handed Grade 1 students (75 girls; *mean age* = 6.76 years, *SD* = 0.35 years) were recruited. Those primary schools were at the same ranking in terms of academic performance, and the students were from similar socioeconomic backgrounds. The participants were randomly assigned to the hand movement ($n = 71$) or word copying ($n = 60$) conditions. They received a small gift for participation

Procedure. The materials used for learning and the procedure were identical to those in Study 1, except for different learning strategies. Under the hand movement condition, the students were provided a pile of small wooden blocks. After the teacher spelled and read a word, they were asked to use their right hand to place several blocks in a row to represent the word. The number of blocks used was equal to the number of letters in the word. If the word taught was “apple,” the students placed five small wooden blocks in a row. Under the word copying condition, after the teacher spelled and read a word that was written on the blackboard, the students were asked to copy the word five times on paper.

Results

Independent sample *t* test results showed that the students reported slightly higher interest in the hand movement strategy (M = 2.33, SD = 0.73) than in the word copying strategy (M = 2.10, SD = 0.76; $t(129) = 1.77$, $p = .08$, $d = 0.31$) strategy. This result suggests that the interest levels of the two learning strategies were not very much different and interest should not be the main factor causing any difference of memory performance between the two conditions.

A 2 (between-subject, learning condition: hand movement vs. word copying) × 3 (within-subject, recall time: immediate vs. 25-minute delay vs. 3-day delay) ANOVA was performed to compare memory effects at different time points under the two learning conditions (Figure 1b). Results showed a main effect of learning conditions ($F(1, 129) = 81.4$, $p < .001$, $\eta_p^2 = 0.39$); memory performance in the hand movement condition (M = 6.23, SD = 2.88) was superior to that in the word copying condition (M = 3.15, SD = 1.42, $p < .001$) across the three recall tests. The results also showed a main effect of time of recall ($F(2, 258) = 8.65$, $p < .001$, $\eta_p^2 = 0.06$) that more words were recalled in the immediate recall (M = 5.09, SD = 2.15) than were recalled in the 25-minute (M = 4.67, SD = 2.12, $p < .05$) and the 3-day (M = 4.31, SD = 1.99, $p < .001$) delayed recall, and an interaction between learning conditions and time of recall ($F(2, 258) = 7.19$, $p = .001$, $\eta_p^2 = 0.053$).

Under the hand movement condition, memory performance across the three recall tests was similar ($F(2, 140) = 0.07$, $p = .94$, $\eta_p^2 = 0.001$). The participants recalled similar numbers of words in the immediate recall (M = 6.30, SD = 2.79) and the 25-minute delayed recall (M

= 6.18, *SD* = 3.06; $p = .74$) and between the immediate and the 3-day delayed recall (*M* = 6.23, *SD* = 2.83; $p = .81$).

Under the word copying condition ($F(2, 118) = 39.50$, $p < .001$, $\eta_p^2 = 0.40$), more words were recalled in the immediate recall test (*M* = 3.88, *SD* = 1.52) than in the 25-minute delayed test (*M* = 3.17, *SD* = 1.18; $p < .001$), which in turn were more than the number of words recalled in the 3-day delayed test (*M* = 2.40, *SD* = 1.14; $p < .001$). Learning words by moving the hands showed superior memory outcomes to learning through word copying, and learning by moving the hands exhibited a long-lasting memory effect from immediate to 3-day recall.

Discussion

Learning by purely moving the hands resulted in superior memory to learning through word copying across three recall time points. Moving the hands exhibited a long-lasting effect, in which memory performance after three days was similar to immediate recall, whereas the 3-day delayed recall in the word copying condition was inferior to the immediate and 25-minute recall. The difference between the two learning strategies is attributed to the interest levels of the tasks or the degree of hand movement. However, the interest in purely moving the hands was similar to that in word copying. This suggests that the students found learning by moving their hands no more interesting than word copying. Therefore, the degree of hand movement is the remaining factor that can enhance memory. Moving the hands activates the frontal cortex, which is involved in memory, more than a static state does (Salvolini & Scarabino, 2006). Activation of the frontal cortex facilitates information encoding and may thus enhance memory. Moreover, the hand movement effect outperformed the effect of visual input. In our study, the participants had no visual input of letters or words while moving the small blocks, whereas they saw how words were spelled when copying the words. Although previous studies have demonstrated that learning words with visual stimuli achieved superior memory than learning without visual input (Cohen, Horowitz, & Wolfe, 2009; Penney, 1989), the hand movement condition led to better memory in our results than the word copying condition, suggesting that moving the hands while encoding is an effective strategy to improve memory.

Combined Analysis of Study 1 and 2

To examine whether the difference of memory performance under different conditions was caused by interest levels of learning activities, we combined the data of Study 1 and 2 for analysis with the following reasons. Participant recruitment procedure of Study 1 and 2 was similar; the participants of both studies came from similar communities and background; they were at the same age and were all Grade-1 students; and they differed only in the learning condition to which they were assigned. The participants reported their interest levels in the four learning conditions, which were fun hand movement (i.e., Scrabble), verbal repetition, pure hand movement, and word copying. By combining the data, we were able to include the interest level as a control variable to examine whether the difference of memory performance under different conditions was due to interest levels of learning activities.

Single-factor ANOVA results showed significant differences of interest levels among the four conditions ($F(3, 257) = 8.72$, $p < .001$, $\eta_p^2 = 0.09$). The findings of post hoc analysis showed that learning with fun hand movement ($M = 2.76$, $SD = 0.84$) was more interesting than learning through verbal repetition ($M = 2.21$, $SD = 0.85$; $p < .001$), hand movement ($M = 2.33$, $SD = 0.73$; $p < .01$), and word copying ($M = 2.10$, $SD = 0.76$; $p < .001$), whereas the other three conditions did not differ in interest level. These results suggest that only in the Scrabble condition, the enhanced memory can be attributed to fun elements in the learning stage.

Controlling for the self-reported interest levels in the learning phase, a 4 (between-subject, learning condition: fun hand movement vs. verbal repetition vs. pure hand movement vs. word copying) × 3 (within-subject, recall time: immediate vs. 25-minute delay vs. 3-day delay) analysis of covariance showed a main effect of learning condition ($F(3, 256) = 57.28$, $p < .001$, $\eta_p^2 = 0.40$), that more words were recalled under the hand movement condition than were recalled in the other three conditions (all $p < .001$); a main effect of recall time ($F(2, 512) = 4.22$, $p = 0.02$, $\eta_p^2 = 0.02$), that memory decayed significantly from the immediate recall to the 3-day delayed recall (all $p < .001$); and an interaction ($F(6, 512) = 4.31$, $p < .001$, $\eta_p^2 = 0.05$). The memory decay patterns from the immediate to the 3-day delayed recall varied among the learning conditions. Specific results were similar to those in results of Study 1 and 2 when the self-reported interest levels were controlled.

General Discussion

The present study showed that hand movement is an effective learning strategy for word memorization. The participants under both hand movement conditions outperformed those learning through verbal repetition, word copying, or listening in immediate, 25-minute, and 3-day delayed free recall tests. Moreover, the 3-day delayed memory in the two hand movement conditions remained the same as the 25-minute delayed memory, unlike in the other three conditions, in which memory after 3 days was poorer than in the immediate and 25-minute recall. Consistent with the findings of previous studies (Berniger et al., 2019; Habib et al., 2003; Propper et al., 2013), moving the hands during the encoding stage enhanced learning and memory performance, and our findings showed that the effect on memory is sustainable for at least 3 days. Body movements, such as moving the hands (Propper et al., 2013) and chewing (Hirano et al., 2008), activate the frontal brain areas related to memory and may facilitate information consolidation during the encoding stage and thus improve memory. The effect of movement on memory has been demonstrated before, but this study showed that it is also effective in applied settings, such as classroom learning.

The combined analysis showed that memory performance in the fun hand movement, or Scrabble, condition was poorer than that in the pure hand movement condition. Learning by playing fun games was effective in vocabulary memorization, because students were interested in learning tasks and demonstrated high motivation toward learning (Lee, 1994; Uberman, 1998). In the Scrabble condition, the effect of fun plus the effect of hand movement should produce the greatest enhancement of memory. However, our findings showed that pure hand movement resulted in the best memory performance. Such a surprising result may be explained by the sharing of cognitive resources. The fun hand movement condition required the participants to devote some cognitive resources to search for the required letters to form a word. Thus, fewer cognitive resources remained for word information encoding and maintenance. By contrast, the pure hand movement condition required the participants to only move small identical blocks without searching, and more cognitive resources could be employed for memorization. It is possible that the detrimental effect of cognitive energy costs caused by searching in the fun hand movement condition counteracted or even outweighed the beneficial effect of fun on memory, resulting in poorer memory performance than in the pure movement condition.

Study Limitations and Implications for Educational Research

This study has several limitations. First, the participants might have different knowledge bases of English vocabulary. Although we selected words from the Grade 3 curriculum and confirmed with school teachers that those words had not been taught in class, the participants may have learned some of those words in other ways, such as in extracurricular reading materials or tutorial centers. Although random assignment of the participants to different conditions should balance pre-experimental differences among the participants, future studies can have students indicate words they do not know from a long list of words and select words that are new to all participants. Second, this study adopted a between-subject design to investigate the effects of different learning strategies on word memorization; however, each participant's basic memory ability could be a confounding variable. Future studies can adopt within-subject design and have each participant receive different learning conditions to compare their effects on word memorization. Third, the longest recall interval in this study was 3 days. Although the forgetting curve proposed by Ebbinghaus showed a gradual decline of information retention as the recall intervals increase (Ebbinghaus, 1913), the hand movement condition in this study demonstrated equal memory performances for immediate recall and 3-day delayed recall. Future studies can extend the recall interval to a week or even a month to explore the long-term effects of learning with hand movement. Fourth, only the right-handed students were recruited in this study, and the sample size of around 60 participants in each condition was relatively small. Future studies can involve participants of both left and right handedness and employ a larger sample size to increase the generalizability of the study results. Despite those limitations, this is among the first studies to test whether the hand movement effect on memory can improve vocabulary learning in a simulated educational setting in primary school students. The findings of this study suggest innovative learning strategies for memorizing English words and expanding vocabulary in young children.

Implications for Educational Practice

In practice, findings of this study provide insights into primary school teachers who would like to apply novel methods to effectively teach vocabulary. Because teaching strategies are essential in enhancing learning motivation of students (Lessard, Larose, & Duchesne, 2018), applying novel ways such as playing scrabble and avoiding uninteresting methods such as copy and rote may interest and engage students in vocabulary learning.

Moreover, we found that comparing with playing scrabble, purely moving hands during the encoding phase of vocabulary learning revealed the same and even better facilitative effect on word memory of students. The finding delivers an important message to educators that pure hand movement is not only a simple motion, but also playing an influential role in promoting the effectiveness of learning new words. To expand the ecological validity of these findings, future studies can be implemented in naturalistic classroom settings by asking schoolteachers to apply the hand movement strategy in language lessons (e.g., Porta & Ramirez, 2019).

Conclusion

Moving hand during the learning phase improves memory of word memory in Grade 1 students. Students' performance in immediate recall of newly learnt words was best while learning through pure hand movement and poorest while learning through verbal repetition, and the performance under fun hand movement of playing scrabble and copying words conditions were in the middle. Students' performance in 25-minute delayed recall and 3-day delayed recall declined under all learning strategies expect pure hand movement. These findings shed light on educational research of vocabulary learning and provide insights for primary schoolteachers into development of teaching strategies that improve students' word memory.

Data availability statement. The data that support the findings of this study are openly available in Open Science Framework at http://doi.org/10.17605/OSF.IO/NFSP7.

References

Baker, J. R., Bezance, J. B., Zellaby, E., & Aggleton, J. P. (2004). Chewing gum can produce context-dependent effects upon memory. *Appetite*, *43*(2), 207–210.

Beck, I. L., & McKeown, M. G. (1991). Conditions of vocabulary acquisition. In R. Barr, M. L. Kamil, P. Mosenthal, & D. D. Pearson (Eds.), *Handbook of reading research* (pp. 789–814). New York: Longman.

Beck, I. L., McKeown, M. G., & Kucan, L. (2002). *Bringing words to life: Robust vocabulary instruction*. New York, NY: Guilford.

Berniger, V. W., Richards, T. L., Nielsen, K. H., Dunn, M. W., Raskind, M. H., & Abbott, R. D. (2019). Behavioral and brain evidence for language by ear, mouth, eye, and hand and motor skills in literacy learning. *International Journal of School and Educational Psychology, 7*(Sup1)*,* 182–200.

Boecker, H., Kleinschmidt, A., Requardt, M., Hanicke, W., Merboldt, K. D., & Frahm, J. (1994). Functional cooperativity of human cortical motor areas during self-paced simple finger movements: A high-resolution MRI study. *Brain*, *117*(6), 1231–1239.

Bourdin, B., & Fayol, M. (2002). Even in adults, written production is still more costly than oral production. *International Journal of Psychology*, *37*(4), 219–227.

Burton, S. H., & Humphries, J. A. (1992). *Mastering English Language* (2nd ed.). New York: Palgrave.

Cazden, C. (1992). *Whole language plus: Essays on literacy in the United States and New Zealand.* New York: Teachers College Press.

Chan, J. C. K., Manley, K. D., Davis, S. D., Szpunar, K. K. (2018). Testing potentiates new learning across a retention interval and a lag: A strategy change perspective. *Journal of Memory and Language*, *102*(1), 83–96.

Cho, K. W., & Feldman, L. B. (2013). Production and accent affect memory. *The Mental*

Lexicon, *8*(3), 295–319.

Cohen, M. A., Horowitz, T. S., & Wolfe, J. M. (2009). Auditory recognition memory is inferior to visual recognition memory. *Proceedings of the National Academy of Sciences*, *106*(14), 6008–6010.

Conway, M. A., & Gathercole, S. E. (1987). Modality and long-termmemory. *Journal of Memory and Language*, *26*(3), 341-361.

Dodson, C. S., & Schacter, D. L. (2001). “If I had said it I would haveremembered it”: Reducing false memories with a distinctiveness heuristic. *Psychonomic Bulletin & Review*, *8*(1), 155–161.

Davies, P. & Pearse, E. (2000). *Success in English teaching*. Oxford: Oxford University Press.

Ebbinghaus, H. (1913). *Memory: A contribution to experimental psychology*. New York, NY: Teachers college Press.

Ehri, L. C., & Rosenthal, J. (2007). Spellings of words: A neglected facilitator of vocabulary learning. *Journal of Literacy Research*, *39*(4), 389–409.

Farrell, L., Osenga, T., & Hunter, M. (2013). Comparing the dolch and fry high frequency word lists. *Readsters*, *1*(1), 1–14.

Gathercole, S. E., & Conway, M. A. (1988). Exploring long-term modalityeffects: Vocalization leads to best retention. *Memory and Cognition*, *16*(2), 110–119.

Gathercole, S. E., Service, E., Hitch, G. J., Adams, A. M., & Martin, A. J. (1999). Phonological short-term memory and vocabulary development: Further evidence on the nature of the relationship. *Applied Cognitive Psychology*, *13*(1), 65–77.

Glenberg, A., Smith, S. M., & Green, C. (1977). Type I rehearsal: Maintenance and more. *Journal of Verbal Learning and Verbal Behavior*, *16*(3), 339–352.

Goossens, N. A. M. C., Camp, G., Verkoeijen, P. P. J. L., Tabbers, H. K., & Zwaan, R. A.

(2014). The benefit of retrieval practice over elaborative restudy in primary school vocabulary learning. *Journal of Applied Research in Memory and Cognition*, *3*(3), 177–182.

Graham, S., & Santangelo, T. (2014). Does spelling instruction make students better spellers, readers, and writers? *Reading*, *27*(9), 1703–1743.

Greene, R. L. (1987). Effects of maintenance rehearsal on human memory. *Psychological Bulletin*, *102*(3), 403-413.

Habib, R., Nyberg, L., & Tulving, E. (2003). Hemispheric asymmetries of memory: The HERA model revisited. *Trends in Cognition Sciences*, *7*(6), 241–245.

Han, M., & Wei, N. (2016). An analysis on English vocabulary teaching in primary schools. *International Journal of Arts and Commerce*, *5*(5), 95–100.

Hanning, N.M. & Deubel, H. (2018). Independent effects of eye and hand movements on visual working memory. *Frontiers in Systems Neuroscience*, *12*, ArtID: 37.

Hebblethwaite, B. (2009). Scrabble as a tool for Haitian Creole literacy. *Journal of Pidgin and Creole Languages*, *24*(2), 275–305.

Hirano, Y., Obata, T., Kashikura, K., Nonaka, H., Tachibana, A., Ikehira, H., & Onozuka, M. (2008). Effects of chewing in working memory processing. *Neuroscience Letters*, *436*(2), 189–192.

Hopkins, R. H., & Edwards, R. E. (1972). Pronunciation effects in recognition memory. *Journal of Verbal Learning and Verbal Behavior*, *11*(4), 534–537.

Hudson, R. L. (1969). Category clustering for immediate and delayed recall as a function of recall cue information and response dominance variability. *Journal of Experimental Psychology*, *82*(3), 575–577.

Jones, A. C., Wardlow, L., Pan, S. C., Zepeda, C., Heyman, G. D., Dunlosky, J., &Rickard, T. C. (2016). Beyond the rainbow: Retrieval practice leads to better spelling than does rainbow writing. *Educational Psychology Review*, *28*(2), 385–400.

Kawashima, R., Yamada, K., Kinomura, S., Yamaguchi, T., Matsui, H., Yoshioka, S., & Fukuda, H. (1993). Regional cerebral blood flow changes of cortical motor areas and prefrontal areas in humans related to ipsilateral and contralateral hand movement. *Brain Research*, *623*(1), 33–40.

Kellogg, R. T. (1996). A model of working memory in writing. In C. M. Levy & S. E. Ransdell (Eds.), *The science of writing. Theories, methods, individual differences and applications* (pp. 57–71). Mahwah, USA: Lawrence Erlbaum Associates.

Kindle, K. J. (2009). Vocabulary development during read-aloud: Primary practices. *The Reading Teacher*, *63*(3), 202–211.

Laufer, B. (1997). What's in a word that makes it hard or easy: Some intralexical factors that affect the learning of words. In N. Schmitt & M. McCarthy (Eds.), *Vocabulary: Description, acquisition, and pedagogy* (pp. 140-155). Cambridge: Cambridge University Press.

Lee, W. R. (1994). *Language Teaching Games and Contest.* Oxford: Oxford University Press.

Lessard, V., Larose, S. & Duchesne, S. (2018). Does mathematics tracking influence student motivation? Exploring the classroom experience. *International Journal of School & Educational Psychology*, *8*, 21–35.

McCutchen, D. (2000). Knowledge, processing, and working memory: Implications for a theory of writing. *Educational Psychologist*, *35*(1), 13–23.

MacLeod, C. M., Gopie, N., Hourihan, K. L., Neary, K. R., & Ozubko, J. D. (2010). The production effect: Delineation of a phenomenon. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *36*(3), 671–685.

MacDonald, P. A., & MacLeod, C. M. (1998). The influence of attentionat encoding on direct and indirect remembering. *Acta Psychologica*, *98*(2-3), 291–310.

Mantyla, T., & Nilsson, L. (1988). Cue distinctiveness and forgetting: Effectiveness of self-generated retrieval cues in delayed recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *14*(3), 502–509.

McCutchen, D. (2000). Knowledge, processing, and working memory: Implications for a theory of writing. *Educational Psychologist*, *35*(1), 13–23.

Matsuoka, W. & Hirsh, D. (2010). Vocabulary learning through reading: Does an ELT course book provide good opportunities? *Reading in a Foreign Language*, *22*(1), 56–70.

Michas, I. C., & Henry, L. A. (1994). The link between phonological memory and vocabulary acquisition. *British Journal of Developmental Psychology*, *12*(2), 147–163.

Neuman, S. B., & Wright, T. S. (2014). The magic of words: Teaching vocabulary in the early childhood classroom. *American Educator*, *38*(2), 4–13.

Nguyen, T. T. H., & Khuat, T. T. N. (2003). Learning vocabulary through games. *Asian EFL Journal*, *5*(4), 90–105.

Onozuka, M., Fujita, M., Watanabe, K., Hirano, Y., Niwa, M., Nishiyama, K., & Saito, S. (2002). Mapping brain region activity during chewing: A functional magnetic resonance imaging study. *Journal of Dental Research*, *81*(11), 743–746.

Penney, C. G. (1989). Modality effects in delayed free recall and recognition: Visual is better than auditory. *The Quarterly Journal of Experimental Psychology*, *41*(3), 455–470.

Polette, K. (2005). *Read and write it out loud! Guided oral literacy strategies*. New York: Pearson.

Porta, M. E., & Ramirez, G. (2019). The impact of an early intervention on vocabulary, phonological awareness, and letter–sound knowledge among Spanish-speaking kindergarteners. *International Journal of School & Educational Psychology*, *8*, 1–15.

Poulton, E. C., & Brown, C. H. (1967). Memory after reading aloud and reading silently. *British Journal of Psychology*, *58*(3-4), 219–222.

Propper, R. E., McGraw, S. E., Brunyé, T. T., & Weiss, M. (2013). Getting a grip on memory: Unilateral hand clenching alters episodic recall. *PLoS One*, *8*(4), e62474.

Rabadi, R. I. (2016). Vocabulary learning strategies employed by undergraduate EFL Jordanian students. *English Language and Literature Studies*, *6*(1), 47–58.

Rowe, M. L. (2012). A longitudinal investigation of the role of quantity and quality of child-directed speech in vocabulary development. *Child Development*, *83*(5), 1762–1774.

Rundas, D. (1971). Analysis of rehearsal process in free recall. *Journal of Experimental Psychology*, *89*(1), 63–77.

Salvolini, U., & Scarabino, T. (2006). *High field brain MRI.* Berlin, Heidelberg: Springer.

Schmitt, N. (2008). Instructed second language vocabulary learning. *Language Teaching Research*, *12*(3), 329–363.

Schweppe, J., & Rummer, R. (2013). Attention, working memory, and long-term memory in multimedia learning: An integrated perspective based on process models of working memory. *Educational Psychology Review*, *26*(2), 285–306.

Senechal, M., Oulette, G. & Rodney,D. (2006). The misunderstood giant: On the predictive role of vocabulary to reading. In S. B. Neuman & D. Dickinson (Eds.), *Handbook of early literacy research. Vol 2*. (pp. 173–182). New York, NY: Guilford Press.

Shallice, T., F, Fletcher, P., Frith, C. D., Grasby, P., Frackowiak, R. S., & Dolan, R. J. (1994). Brain regions associated with acquisition and retrieval of verbal episodic memory. *Nature*, *368*(6472), 633–635.

Strickland, D.S. (1998). *Teaching phonics today: A primer for educators.* Newark, DE: International Reading Association.

Swick, D., & Knight, R. T. (1996). Is prefrontal cortex involved in cued recall? A neuropsychological test of PET findings. *Neuropsychologia*, *34*(10), 1019–1028.

Tabors, P., Snow, C., & Dickinson, D. (2001). Homes and schools together: Supporting language and literacy development. In D. Dickinson & P. O. Tabors (Eds.), *Beginning literacy with language* (pp. 331–334). Baltimore: Brookes.

Teale, W. (1984). Reading to young children. In H. Goelman, A. Oldberg, & F. Smith (Eds.), *Awakening to literacy* (pp. 110–121). London: Heinemann.

Tindle, R.,& Longstaff, M. G. (2015). Writing, reading, and listening differentially overload working memory performance across the serial position curve. *Advances in Cognitive Psychology*, *11*(4), 147–155.

Tulving, E., Kapur, S., Craik, F. I. M., Moscovitch, M., & Houle, S. (1994). Hemispheric encoding, retrieval asymmetry in episodic memory: Positron emission tomography findings. *Proceedings of the National Academy of Sciences of the United States of America*, *91*(6), 2016–2020.

Uberman, A. (1998). The use of games for vocabulary presentation and revision. *English Teaching*, *36*(1), 20–27.

Voinov, V. (2010). Words should be fun: Scrabble as a tool for language preservation in Tuvan and other local language. *Language Documentation and Conservation*, *4*(1), 213–230.

Table 1.

Means (Standard Deviations) of Items Recalled in Free Recall Tests at Three Time Points Under Different Learning Conditions

	Immediate Recall	25-minute Later	3-day Later
Study 1			
Fun Hand Movement (*n* = 70)	5.60 (2.81)	4.37 (2.27)	4.89 (3.55)
Verbal Repetition (*n* = 60)	2.70 (2.00)	2.12 (1.64)	1.17 (1.37)
Control (*n* = 50)	2.68 (3.14)	2.40 (1.91)	1.28 (1.21)
Study2			
Pure Hand Movement (*n* = 71)	6.30 (2.79)	6.18 (3.06)	6.23 (2.83)
Word Copying (*n* =60)	3.88 (1.52)	3.17 (1.18)	2.40 (1.14)

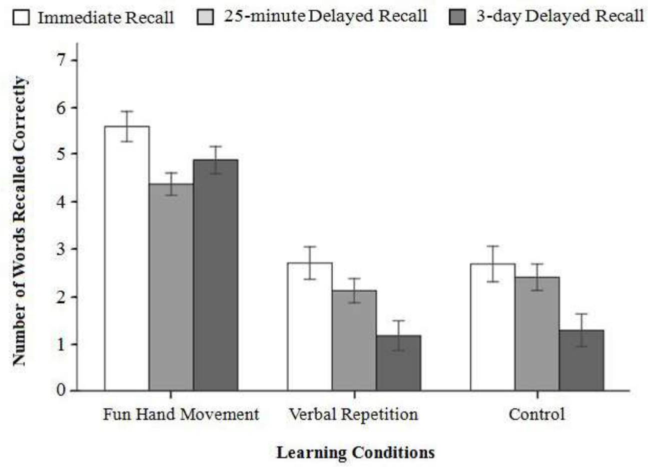

Figure 1a. Number of Words Recalled Correctly in Fun Hand Movement, Verbal Repetition, and Control Conditions (Error Bars Represent Standard Error)

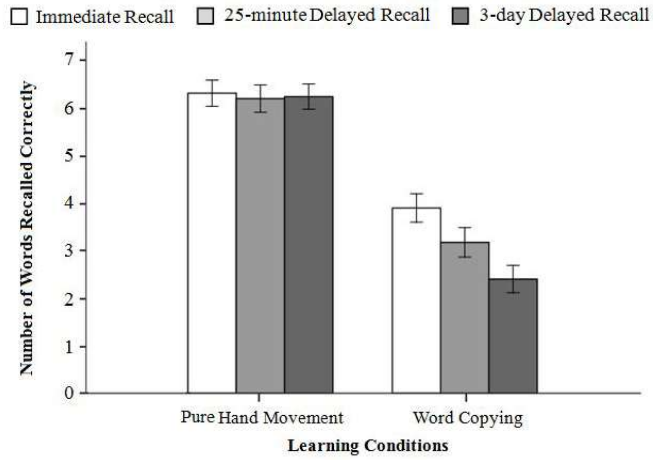

Figure 1b. Number of Words Recalled Correctly in Pure Hand Movement and Word Copying Conditions (Error Bars Represent Standard Error)