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Effects of integrated physical exercises and gestures on preschool children's foreign language vocabulary learning

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Abstract

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Keywords

children, preschool, integrated, gestures, effects, exercises, physical, learning, vocabulary, language, foreign

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Abstract

Research suggests that integrating human movement into a cognitive learning task can be effective for learning due to its cognitive and physiological effects. In this study the learning effects of enacting words through whole-body movements (i.e., physical exercise) and part-body movements (i.e., gestures) were investigated in a foreign language vocabulary task. Participants were 111 preschool children of 15 childcare centers, who were randomly assigned to one of four conditions. Participants had to learn 14 Italian words in a four-week teaching program. They were tested on their memory for the words during, directly after, and six weeks after the program. In the integrated physical exercise condition children enacted the actions indicated by the words to be learned in physical exercises. In the non-integrated physical exercise condition children performed physical exercises at the same intensity, but unrelated to the learning task. In the gesturing condition, children enacted the actions indicated by the words to be learned by gesturing while remaining seated. In the conventional condition, children verbally repeated the words while remaining seated. Results confirmed the main hypothesis, indicating that children in the integrated physical exercise condition achieved the highest learning outcomes. Implications of integrated physical exercise programs for preschool children's cognition and health are discussed.

Keywords: learning, preschool children, physical exercise, gesturing

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There is no doubt that movement is essential for human life. Research has shown substantial health, cognitive and academic benefits as a result of regular school-based physical activities (e.g., Tomporowski, Davis, Miller, & Naglieri, 2008). Although these benefits have been found even when time for physical activities replaced part of the academic time (e.g., Sallis et al., 1997), the concern that time for physical activities is associated with a loss of academic time is considered a major obstacle to realizing greater involvement in school-based physical activities, and the time spent on physical education in schools is actually declining (United Nations Educational, Scientific and Cultural Organization, 2015). One promising approach to relieve this concern is to investigate ways to infuse physical activity within the classroom and find ways to integrate physical activity into learning tasks without compromising learning performance or even improve it. In this study we investigated whether such integrated physical exercises would result in better learning than non-integrated physical exercises. In addition, it was investigated whether the integrated physical exercises would lead to better learning than the same integrated activities without physical exercise. The latter type of activities refers to expressing information in gesture, which has been found effective for learning in children and young adults (e.g., Cook, Mitchell, & Goldin-Meadow, 2008; Goldin-Meadow, Cook, & Mitchell, 2009; Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001). Whereas the effects of gross motor or whole-body movements in the form of physical exercise on cognition and learning have mainly been explained by *physiological mechanisms*, the effects of more subtle or part-body movements, such as gestures, have mainly been explained by *cognitive mechanisms*.

Effects of whole-body movements

An important outcome arising from the effects of physical exercise, which can be defined as “planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness” (United States Department of Health, & Health Services, 1996), is that it elicits brain changes that facilitate learning and memory (Hillman, Erickson, & Kramer, 2008; Liu-Ambrose, Nagamatsu, Voss, Khan, & Handy, 2012). In an effort to uncover the underlying mechanisms of physical activity, Erickson, Hillman, and Kramer (2015) reviewed studies of physical activity on brain structure, brain function and academic achievement. They concluded that fitter and more active children showed a range of physiological benefits (e.g., greater grey matter volume in the hippocampus, more effective brain activity patterns), performed better on tasks that require executive control and associative memory, and showed higher academic achievement. There is extensive research supporting the finding that physical activity positively correlates to cognitive performance (for reviews, see Barenberg, Berse, & Dutke, 2011; Erickson et al., 2015; Fedewa & Ahn, 2011; Sibley & Etnier, 2003; Tomporowski, Davis, Miller, & Naglieri, 2008). It has become clear from those studies that the type of activity, level of intensity, duration of exercise required, aspects of cognition, and learner characteristics affect the relationship between physical activity and cognitive performance. For example, Sibley and Etnier’s (2003) meta-analysis revealed a positive impact on children’s cognition, which did not differ as a function of the type of physical activity (i.e., resistance training, perceptual-motor training, physical education classes, and aerobic exercises) on children’s cognition. The effect of physical activity on cognitive performance was the greatest for children in the young elementary and middle school age group. The effect of physical activity on children’s

cognition differed significantly on the type of cognitive assessment used. The largest effect was found for assessments on perceptual skills, followed by IQ, academic achievement, and math and verbal tests. Furthermore, a meta-analysis by Chang, Labban, Gapin, and Etnier (2012) showed that acute bouts of exercise can have beneficial effects on cognitive tasks executed during, immediately after, or after a delay following the exercise. Short bouts of exercise affect cognitive processes by increasing response speed and accuracy (Tomporowski, 2003), improving working memory capacity (Pontifex, Hillman, Fernhall, Thompson, & Valentini, 2009), as well as improved performance on free-recall tasks (Coles & Tomporowski, 2008). For example, Drollette et al. (2014) showed that, after 20 minutes of treadmill walking, preadolescent children had better performance on cognitive tasks gauging attention and inhibitory control compared with children who remained seated.

Effects of part-body movements

More subtle movements, such as gestures, are typically integrated into the learning task and are only effective when they are meaningful for or congruent with the learning task (Kelly, McDevitt, & Esch, 2009; Macedonia & Klimesch, 2014; Trofatter, Kontra, Beilock, & Goldin-Meadow, 2015). There is increasing evidence that gesturing has positive effects on learning of different types of cognitive tasks, such as math (e.g., Cook et al., 2008; Goldin-Meadow et al., 2001; Novack, Congdon, Hemani-Lopez, & Goldin-Meadow, 2014), and language (e.g., Allen, 1995; Kelly et al., 2009; Macedonia & Klimesch, 2014; Tellier, 2008; Thomas & Lleras, 2009; Trofatter et al., 2015).

The theoretical framework of grounded or embodied cognition has been used to explain the positive effects of this type of movement on learning. Embodied

cognition is based on the notion that cognitive processes develop from goal-directed interactions between organisms and their environment (Barsalou 1999, 2008; Glenberg, 1997). It assumes that cognitive processes are grounded in perception and action (Barsalou, 1999). Ample evidence for the embodied cognition framework comes from psychological research in a variety of domains, such as research on action semantics (e.g., Lindemann, Stenneken, Van Schie, & Bekkering, 2006), language comprehension (e.g., Zwaan & Taylor, 2006), and neuroscience (e.g., Glenberg et al., 2008). This research shows that visual and motor processes in the brain are active during the performance of cognitive tasks such as reading, comprehension, mental arithmetic, and problem solving, while semantic codes are activated during the performance of motor tasks, suggesting that cognitive and sensorimotor processes are closely intertwined. An explanation for the positive effects on learning is that embodying knowledge through making gestures results in a distinct, visuospatial representational format that can enrich the way information is coded, i.e., the construction of higher quality cognitive schemas (Goldin-Meadow et al., 2001; Paas & Sweller, 2012). Higher-quality cognitive schemas are associated with better and less cognitively demanding learning (Goldin-Meadow et al., 2001; Ping & Goldin-Meadow, 2010), which materializes in faster and more accurate performance on a learning test. An alternative explanation holds that gesturing shifts some of the load from verbal working memory to other cognitive systems. This explanation is consistent with results from cognitive neuroscientific research showing that gesture is represented in cortical areas that differ from those that handle verbal materials (e.g., Decety et al., 1997),

Speech gestures, consisting of pantomimic and non-pantomimic gestures, can assist memory. Pantomimic gestures convey meaning even when verbal speech is

absent (Cohen & Otterbein, 1992). The present study focused on learning of a foreign language vocabulary by acting out the meaning of words through pantomimic or enactment gestures. Empirical work has demonstrated that meaningful engagement of the motor system during language processing enhanced memory encoding and retrieval. Performance on free-recall as well as cued-recall tasks is better when the verbal instructions can be enacted while learning ('enactment effect': Cohen & Otterbein, 1992; Engelkamp & Cohen, 1991). Gestures have a representational function, connecting different modalities such as the verbal, visual and motor modality. Enactment effects induced by gestures promote deeper semantic or conceptual processing, facilitating memory performance of younger and older adults on recognition and cued-recall tasks (Feyereisen, 2009).

Empirical evidence

Several studies have provided evidence for the positive effects of gestures on language learning. Macedonia and Klimesch (2014) showed that encoding of novel words from an artificial language was deeper when information was presented through enactment (involving gestures) rather than audiovisually. Tellier (2008) assessed learning vocabulary words from a foreign language. Preschool children had to either to listen and repeat each word, watch a gesture related to the word, and reproduce the gesture (gesture group), or listen and repeat a word, and watch a picture related to the word (picture group). She found that children in the gesture group performed better than children in the picture group in recall tests. Gesturing can be a powerful aid for long-term recall of complex learning such as learning first and foreign languages in preschool children (Rowe, Silverman, & Mullan, 2013).

Previous research has also provided evidence for the positive effects of physical activity on language learning. Pesce, Crova, Cereatti, Casella, and Bellucci (2009) investigated the effects of physical activity on children's memorization of vocabulary words from a foreign language. They taught 11-12 year old children words from a foreign language and examined their performance on immediate and delayed recall when they were engaged in circuit training, team games or did not exercise at all. They concluded that acute bouts of physical activity might facilitate memory storage efficiency by minimizing rehearsal and shortening consolidation time. Focusing on the synergistic effects of physical activity and academic performance (Lees & Hopkins, 2013), physical activity programs incorporating short bouts of acute exercise could be effectively applied during daily school schedules to promote physical activity and enhance cognitive performance in children (Drollette et al., 2014). The role of school-based physical activity programs in increasing physical activity during the school day either through recess or breaks or by integrating physical activity with academic content has been investigated in several studies (Bartholomew & Jowers, 2011; Castelli, Hillman, Hirsch, Hirsch, & Drollette, 2011; Davis et al., 2011; Donnelly & Lambourne, 2011; Hillman et al., 2009, Kibbe et al., 2011; Lambourne et al., 2013; Mahar et al., 2006; Telford et al., 2012; Vazou & Smiley-Oyen, 2014). In general, these studies report positive associations between physical activity and learning outcomes in elementary and high school children (Erwin, Fedewa, Beighle, & Ahn, 2012). Classroom-based physical activity is considered an enjoyable way to promote physical activity and foster executive function in children (Vazou & Smiley-Oyen, 2014).

However, there is a dearth of research in younger children in early childhood settings. Interventions in early years have tremendous effects on children's cognitive

and social development (Ramey & Ramey, 1998), therefore it is considered important to examine the effects that can be found in this specific age group. One of the few intervention programs targeting preschool children found that when they were engaged in moderate to vigorous physical activity play, they showed better self-regulation skills, which resulted in higher math and literary achievement scores (Becker, McClelland, Loprinzi, & Trost, 2014). Moreover, Trost, Fees, and Dziewaltowski (2008) developed a ‘move and learn’ intervention program integrating gross motor movements in all aspects of a preschool curriculum. They found that at the end of the intervention, children were more physically active and also showed more enthusiasm, and attention to the learning tasks. However, learning outcomes were not measured in this study. In a review, Best (2010) concludes that aerobic exercise can have direct and beneficial effects on executive function, which is crucial for enhancing cognitive development and learning in early childhood.

The present study

Taken together, the results of the unrelated lines of research into the cognitive and physiological effects of part- and whole-body movements on learning suggest that an intervention combining both effects by integrating task-relevant physical exercises into the learning task could be more effective than interventions targeting only non-integrated physical exercises or task-relevant gestures. In this study four conditions were compared to investigate this suggestion in preschool children.

The main hypothesis was that an *integrated physical exercise condition* in which children learn foreign language vocabulary by performing physical exercises to enact the meaning of those words would lead to the highest immediate and delayed retention performance. The *integrated physical exercise condition* was compared to a

non-integrated physical exercise condition, a *gesturing condition*, and a *conventional condition*. In the *non-integrated physical exercise condition* children performed physical exercises at the same intensity during learning, but unrelated to the learning task. In the *gesturing condition* children enacted the actions indicated by the words to be learned by gesturing while remaining seated, and in the *conventional condition* children verbally repeated the words while remaining seated. Based on the results of previous research, it was expected that the *non-integrated exercise condition* and the *gesturing condition* would show higher immediate and delayed retention performance than the conventional condition. Finally, children in the two exercise conditions were expected to be equally active, but more active than children in the non-exercise conditions (i.e., gesturing and conventional condition).

Method

Participants

Participants were 125 preschool children (64 boys and 61 girls) with a mean age 4.94 years ($SD = .56$). Fifteen childcare centers were recruited for this study. However, in the analysis 111 participants were included due to missing data. Participants were recruited from four childcare centers in total in the integrated, four centers in the non-integrated, four centers in the control condition and three childcare centers in the embodied condition. The study was approved by the Human Research Ethics Committee of the University of Wollongong. All parents completed a written consent form about their children's participation in the research. Only children who attended childcare for 2 days or more per week were eligible to participate in the study. Children who had prior knowledge or relatives speaking the Italian language at home were excluded from the study. Also, children with developmental disorders

and/or learning difficulties did not participate in the study. The childcare centers were randomly assigned, in such a way that there were children from 3-4 centers in total per condition. The resulting number of participants in each condition was: thirty-one in the integrated condition, 23 in the non-integrated condition, 31 in the gesturing condition, and 26 in the conventional condition. Children received stickers when they completed the activity and after testing as a reward for their effort.

Materials

Measurement of memory performance: free-recall and cued-recall tests.

Children were taught 14 words from a foreign language (i.e. Italian). The selected words were: fast, slow, dance, soccer, broom, low, high, swim, fly, jump, march, catch, throw, and roll. The selection of the words was based on every day actions familiar to the children. Also, it was reassured that the words in Italian were no more than three syllabi. The suitability of the chosen words in terms of pronunciation and meaning of the actions for preschool children was evaluated by a teacher with an Italian background. Each day, children were taught seven different words. The order of the to-be-learned words was counterbalanced across the different days and weeks. Static pictures with children doing the relevant activities were displayed to children. After the presentation of each word, the researcher pronounced the words in Italian and children repeated the words afterwards. In the free-recall tests, children were asked how many and which words they could recall regardless of their presentation order. In the cued-recall tests, children were shown the pictures and were asked to say the Italian word. The maximum score on the free-recall and cued-recall test was 14 and the minimum score was 0. For each correctly recalled word, children received 1 point.

Measurement of physical activity. Children were fitted with an accelerometer (Actigraph models GT1M, GT3X and GT3X+/BT, Pensacola, FL), which was positioned over the anterior aspect of the right hip. The accelerometer was attached on an elastic belt, which was worn around the waist. Children and parents were instructed via written consent forms that the accelerometer should be worn every day during the intervention lessons. Accelerometers are instruments measuring variations in time differences in force or acceleration and thus assessing the magnitude and volume of movement as a function of time. The accelerometer collects data known as activity “counts” measured in time sampling intervals or epochs (Cliff, Reilly, & Okely, 2009). Measurements with the Actigraph accelerometer have been found to be valid, and reliable in children aged 3-5 years (Cliff et al., 2009). Because of the sporadic and intermittent type of physical activity in children, we used epochs of 15 s to estimate time in higher intensity activity (moderate and vigorous-intensity physical activity; see, e.g., Rowlands, 2007; Cliff et al., 2009). Lesson times were recorded and filters used to analyze only the data from the start to the end of the lesson each day. Data were reported as the average activity counts per minute, representing total physical activity or movement as a function of time during the lesson. Data were also reported as minutes spent in moderate and vigorous-intensity physical activity, as higher intensity physical activity might potentially be important for cognitive functioning in children (Davis et al., 2007). Age-appropriate cut-points (Pate, Almeida, McIver, Pfeiffer, & Dowda, 2006) that have been shown to be the most accurate in young children (Janssen et al., 2013) were used to define activity intensity. Out of 790 cases of accelerometry data, 66 cases were removed, because some children did not wear the monitor during the whole intervention session.

Design and Procedure

A mixed 4 (Condition: integrated, non-integrated, gesturing, conventional) x 3 (Time of Testing; during, directly after, follow up) experimental design with repeated measures on the latter factor was used. The dependent variables were children's performance on the free-recall and cued-recall tests.

The study consisted of three phases: instruction, learning and testing.

Instruction phase. Children were presented once with each English word to ensure that they understood the meaning of all words. Instructions given to children lasted for 20 minutes. Children were told that they would play a memory game and that they had to listen carefully to the teachers' instructions. After these instructions, they were asked questions about what they had learned. It was explained to them that they had to repeat the words after the instructor and perform an activity at the end of each word.

Learning phase. Children were assigned to a condition at center level, as it was not feasible to randomize children across conditions within each center. There were four different conditions in which children were taught the Italian words by using a different approach. Each one of the seven words that were taught per day was presented once at a time for one minute until finishing all the words. All the words were presented both auditory and visually. Children had to repeat each word after the word was presented by the instructor. The total duration of the learning phase was four weeks, consisting of one 15-minute session per day for 2 days per week.

In the integrated physical exercise condition, children enacted the actions indicated by the words to be learned by physically exercising. For example, for the word "fly", children ran and moved their hands as if they were flying. The integrated physical exercise condition was a combination of the non-integrated physical exercise

and gesturing condition. In the non-integrated physical exercise condition, children performed physical exercises at the same intensity during learning, but these were unrelated to the learning task. In this condition, children were running or walking for all the words regardless the meaning of the word. In the gesturing condition, children enacted the actions indicated by the words to be learned by pantomimic gestures while remaining seated. For example, for the word “fly”, children moved their hands as if they were flying while they remained seated. In the conventional condition, children verbally repeated the words while remaining seated.

Testing phase. Children were tested individually on their ability to recall the Italian words. During testing, children were asked to verbally recall as many words as they could remember from the learning phases (free-recall test) and subsequently based on the presentations with the words (cued-recall test). Words recalled were also considered correct when minor spelling errors or singular-plural substitutions had occurred. The total duration of the assessment was 15-20 minutes per child. The total number of words remembered in the free-recall and the number of correct words in the cued-recall test were calculated separately for the week 2 (during), week 4 (directly after), and week 10 (follow up).

In the assessment during the learning phase at the end of week 2, the possible short-term or acute effects of embodiment and physical activity on learning were examined. The assessment directly after the learning phase in week 4 occurred at the end of the intervention and evaluated the medium-term effects of embodiment and physical activity on children’s ability to learn a foreign language. The final follow-up assessment was administered six weeks after the learning phase in week 10 to determine how well the learned words were maintained in the children’s memory.

Moreover, emphasis was put on observing children's learning progress. The assessments in the three different time periods were administered in identical form.

A pilot study was first conducted by the researcher to test the efficacy and feasibility of the forthcoming procedure. The researcher performed the teaching and testing together with three research assistants, who had received a 4-hour training session on how to teach and test children before the experiment.

Results

Mixed 4 (Condition: integrated, non-integrated, gesturing, conventional) x 3 (Time of Testing; during, directly after, follow up) analyses of variance (ANOVAs) with condition as between-subject variable and time of testing as within-subject variable were performed. The dependent variables were performance on free-recall and cued-recall tests¹. Effect size was measured via partial eta squared, in which small, medium, and large effects were operationalized as .01, .06, and .14, respectively (Cohen, 1988).

Free-recall

A mixed ANOVA was performed to examine the effects of condition and time of testing on the free-recall tests. Mauchly's test indicated that the assumption of sphericity was met, $\chi^2(2) = 3.46, p = .177$. The ANOVA showed that there was a main effect of time of testing, $F(2, 214) = 50.21, p \leq .001, \eta^2 = .33$, indicating that the scores on the free-recall test differed significantly across the weeks of measurement. Polynomial contrasts tests revealed that there was a quadratic relationship for the time

¹ Task enjoyment and task complexity were also measured. There were no effects on these measures and for reasons of length we deleted this information from the manuscript. Statistics can be obtained from the first author.

of testing, $F(1, 106) = 74.12, p \leq .001, \eta^2 = .41$. From week 2 to week 4, the number of recalled words increased, whereas from week 4 to week 10 it decreased. Children could recall more words in week 4 ($M = 1.83, SD = 1.56$) than in week 10 ($M = 1.32, SD = 1.56$), and more words than in week 2 ($M = .48, SD = .73$). Finally, children in week 2 ($M = .48, SD = .73$) could remember fewer words than in week 10 ($M = 1.32, SD = 1.56$). There was also a significant main effect of condition on free-recall test performance, $F(3, 107) = 5.14, p = .002, \eta^2 = .13$ (see Table 1). Post hoc tests revealed that children in the integrated condition ($M = 1.73, SD = 1.34$) remembered more words than children in the non-integrated condition ($M = .97, SD = 1.01$), $p = .006$, the gesturing condition ($M = 1.24, SD = 1.35$), $p = .049$, and the conventional condition ($M = .77, SD = .90$), $p \leq .001$. There were no differences on free-recall test performance among children in the non-integrated condition ($M = .97, SD = 1.01$) and the gesturing condition ($M = 1.24, SD = 1.35$), $p = .327$, as well as the non-integrated condition ($M = .97, SD = 1.01$) and the conventional condition ($M = .77, SD = .90$), $p = .473$, and between children in the gesturing condition ($M = 1.24, SD = 1.35$) and the conventional condition ($M = .77, SD = .90$), $p = .076$. Figure 1 displays the average total number of correctly recalled words. Finally, the interaction between time of testing and condition was not significant, $F(6, 214) = 1.98, p = .070$.

Cued-recall

A mixed ANOVA was performed to examine the effects of condition and time of testing on the cued-recall tests. Mauchly's test indicated that the assumption of sphericity was violated, $\chi^2(2) = 22.83, p \leq .001$. Therefore, the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\epsilon = .84$). The results showed that performance on the cued-recall tests was differentially affected by the

time of testing, $F(1.68, 179.26) = 153.16, p \leq .001, \eta^2 = .59$. Polynomial contrasts revealed a quadratic relationship for time of testing, $F(1, 107) = 175.39, p \leq .001, \eta^2 = .62$. From week 2 to week 4, the number of recalled words increased, whereas from week 4 to week 10 it decreased. Children could recall more words in week 4 ($M = 4.42, SD = 2.35$) than in week 10 ($M = 3.84, SD = 2.48$), and in week 2 ($M = 1.21, SD = 1.20$). There was also a significant main effect of condition on cued-recall test performance, $F(3, 107) = 6.74, p \leq .001, \eta^2 = .16$ (Table 1). Post hoc tests revealed that children in the integrated condition ($M = 4.00, SD = 2.25$) remembered more words than children in the gesturing condition ($M = 3.17, SD = 2.04$), $p = .044$, and in the conventional condition ($M = 2.09, SD = 1.49$), $p \leq .001$. There were no significant differences between children in the non-integrated condition ($M = 3.20, SD = 1.55$) and the integrated condition ($M = 4.00, SD = 2.25$), $p = .073$, as well as the non-integrated ($M = 3.20, SD = 1.55$) and the gesturing condition ($M = 3.17, SD = 2.04$), $p = .944$. Children in the non-integrated condition remembered more words ($M = 3.20, SD = 1.55$) than children in the conventional condition ($M = 2.09, SD = 1.49$), $p = 0.17$, and children in the gesturing condition ($M = 3.17, SD = 2.04$) remembered more words than children in the conventional condition ($M = 2.09, SD = 1.49$), $p = .012$ (see Figure 1). Finally, the interaction between time of measurement and condition was not significant, $F(5.03, 179.26) = 2.45, p = .085$.

Physical Activity

Two separate ANOVAs were performed to assess the levels of physical activity across the different conditions and verify that the level of physical activity did not differ between the integrated and non-integrated exercise conditions. In addition, the analysis was used to verify whether the children in the exercise conditions were more active than the children in the gesturing and conventional condition. The units of

measurement of level of physical activity were counts per minute as well as minutes of moderate- to vigorous-intensity physical activity (Pate, Almeida, McIver, Pfeiffer, & Dowda, 2006). Results showed that there was a significant effect of condition on counts per minute, $F(3, 720) = 39.73$ $p \leq .001$, $\eta^2 = .14$. Post-hoc tests with Games-Howell correction revealed that there were no differences found between the integrated condition ($M = 938.07$, $SD = 552.76$) and the non-integrated condition ($M = 807.56$, $SD = 552.76$), $p = .238$, and between the gesturing condition ($M = 517.57$, $SD = 348.89$), and the conventional condition ($M = 534.66$, $SD = 311.32$), $p = .957$. Both in the integrated condition ($M = 938.07$, $SD = 552.76$) and the non-integrated condition ($M = 807.56$, $SD = 552.76$) more counts per minute were recorded than in the gesturing condition ($M = 517.57$, $SD = 348.89$), $p \leq .001$, and the conventional condition ($M = 534.66$, $SD = 311.32$), $p \leq .001$.

There was a significant effect of condition on the total time spent in moderate- to vigorous-intensity physical activity (MVPA), $F(3, 720) = 35.20$, $p \leq .001$, $\eta^2 = .13$. Post-hoc tests with Games-Howell correction revealed that there were no differences in time spent in MVPA between the integrated condition ($M = 3.85$ $SD = 3.20$) and the non-integrated condition ($M = 3.47$, $SD = 3.40$), $p = .759$, and between the gesturing condition ($M = 1.92$, $SD = 1.68$), and the conventional condition ($M = 1.75$, $SD = 1.17$), $p = .656$. Both in the integrated condition ($M = 3.85$ $SD = 3.20$) and the non-integrated condition ($M = 3.47$, $SD = 3.40$) children spent more time on MVPA than children in the gesturing ($M = 1.92$, $SD = 1.68$), $p \leq .001$, and conventional condition ($M = 1.75$, $SD = 1.17$), $p \leq .001$.

Discussion

The main goal of this study was to investigate the effects of enacting words through full-body movements in the form of physical exercise and part-body movements in the form of gesturing on learning a foreign language vocabulary. The results confirmed the hypotheses, indicating that the integrated condition, in which children used physical exercises to enact words to be learned, outperformed all other conditions for free-recall performance. For cued-recall recall performance, similar results were obtained, but results of the children in the integrated physical exercise condition did not differ from those of the children in the non-integrated physical exercise condition.

Overall, the scores on the tests were very low, even on the cued-recall test. This can be attributed to the fact that learning a foreign language vocabulary can be considered a very difficult task for 4 to 5 year old children. Most importantly, children were exposed to the Italian words only during the learning phase and no other stimuli were provided to them during the day. Possibly, longer learning sessions and greater exposure during the day (e.g., more repetitions) would be needed to achieve higher performance scores. The results on the free-recall test, which can be considered more difficult than the cued-recall test, revealed that the integrated condition outperformed all other conditions during, directly after, and six weeks after the learning phase. Although children in the non-integrated and the gesturing condition showed higher performance than children in the control group, these differences were not significant. On the cued-recall task, all conditions outperformed the conventional condition. The integrated condition outperformed the gesturing condition, but not the non-integrated exercise condition. In addition, cued recall performance in the non-integrated and gesturing condition did not differ. In both free-recall and cued-recall tests, performance was the highest in the integrated condition, followed by non-integrated,

gesturing and conventional condition. The pattern was the same for the delayed test, followed by the follow up and lastly the immediate test.

In general, the results of the integrated and gesturing conditions indicate that children's learning of a foreign language vocabulary is positively affected by the cognitive effects of enacting the words through physical exercises or gestures. The positive effects on learning of the non-integrated physical exercise condition are reflective of the physiological effects of physical activities. Interestingly, the results indicate that embodying knowledge through physical exercises that are integrated in the learning task is a particularly effective learning strategy in young children. It is also clear that the effectiveness of this strategy is caused its integrated character, because physical exercise of the same intensity in the non-integrated condition resulted in lower free recall performance. This study corroborates findings of previous studies that accentuate the benefits of physical activity on learning and programs that successfully integrated physical activity into school classrooms in older children and elicited positive effects on academic achievement (Kibbe et al., 2011). At the same time, the principles of the embodied cognition framework were confirmed by the positive effects of movements in the form of physical exercise and gestures on learning performance. This study provided a unique contribution to the existing research literature by testing the effects of an integrated intervention program for preschool children, which integrated physical exercises into the learning task.

An alternative explanation for the effectiveness of the integrated physical activities and gestures on learning is that participants in these conditions not only made movements, but also observed other classmates making movements, because of the classroom based experimental setup. Episodic memory is based on the storage and retrieval of temporally dated, spatially located, and personally experienced events or

episodes. Episodic information about a word is the information about the event of which the word was the crucial element (Tulving & Thomson, 1973). Observing others' movements could support episodic memories as encoding of the words relied on the context or the situation elements. Moreover, numerous studies have shown that observing gestures can have positive effects on learning (e.g., Church, Ayman-Nolley, & Mahootian, 2004; Cook, Duffy, & Fenn, 2013; Ping & Goldin-Meadow, 2008). According to research on the mirror neuron system, when people look at others' people actions, they activate neurons that are related to the same action in the motor cortex (Rizzolatti & Craighero, 2004). In the present study, children in the integrated condition may have activated the relevant neurons linked with the physical activity actions in their motor cortex, which enhanced by the gestures, transformed that information into knowledge (Rizzolatti & Craighero, 2004). Future research could investigate whether the same effects on learning can be observed during individual learning sessions. This would provide the opportunity to differentiate effects of performing and observing movements on learning.

It is clear that more evidence needs to be obtained in replication studies to be conclusive about the positive effects of integrated physical exercise on children's learning. In addition, similar future studies in the other domains, such as math and science, and with other target groups, such as adolescents, need to be conducted to determine whether the current results can be generalized across domains and target groups.

The current study has important educational implications. The results suggest that adding gestures or physical exercise to the learning of cognitive tasks leads to better learning than conventional strategies in which students learn by reading or listening to learning materials. The integration of physical activity into a language

learning task by asking children to enact words through physical exercises seems especially effective for learning. An additional benefit of regular physical exercise, which has been found in previous research, is its positive effect on children's physical and mental health. Therefore, implementing integrated physical exercises in early education programs can be expected to have pervasive long-term effects on achievement and academic success especially for children from low-SES backgrounds (Barnett, 1998).

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Table 1

Means and Standard Deviations for Performance on the Different Types of Tests for the Different Conditions as a Function of Times of Testing.

Type of test	Time of testing			
	Week 2	Week 4	Week 10	Total
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
Free recall (0-14)				
Integrated condition	.98 (.81)	2.63 (1.81)	1.58 (1.41)	1.73 (1.34)
Non-integrated condition	.13 (.34)	1.65 (1.15)	1.13 (1.55)	.97 (1.01)
Gesturing condition	.39 (.72)	1.71 (1.40)	1.61 (1.93)	1.24 (1.35)
Conventional condition	.31 (.62)	1.19 (.98)	.81 (1.10)	.77 (.90)
Cued recall (0-14)				
Integrated condition	1.81 (1.38)	5.61 (2.79)	4.58 (2.58)	4.00 (2.25)
Non-integrated condition	1.07 (.83)	4.30 (1.67)	4.24 (2.16)	3.20 (1.55)
Gesturing condition	1.15 (1.10)	4.37 (2.22)	4.00 (2.81)	3.17 (2.04)
Conventional condition	.71 (1.15)	3.15 (1.77)	2.40 (1.56)	2.09 (1.49)

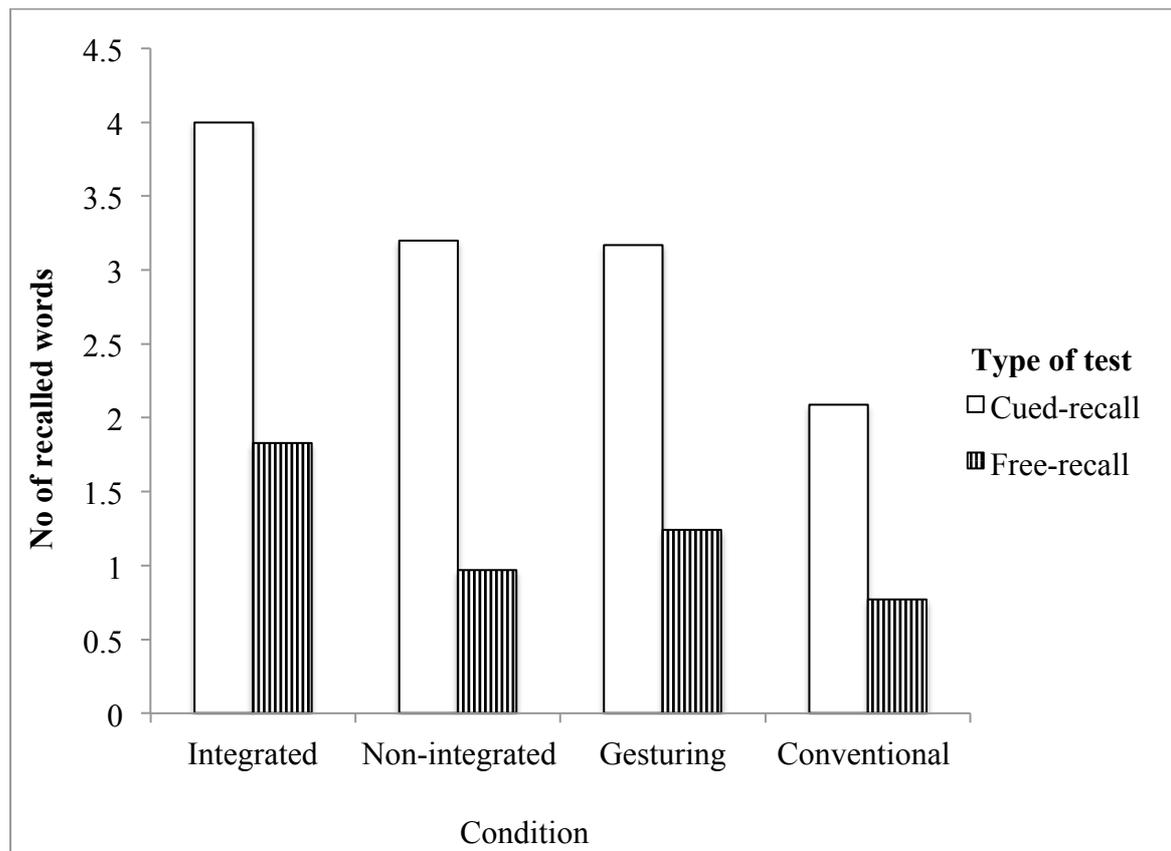


Figure 1. Average total number of correctly recalled words on the free-recall and cued-recall tests in the different conditions.