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Effect of association of imagery and physical practice on children's motor learning

Efeito da associação de prática imagética e física na aprendizagem motora em crianças

Patrícia Sayuri Takazono[1]
Luis Augusto Teixeira[1]

Abstract – Imagery training has been shown to induce motor learning in adults, but similar evidence in children is scarce. In this experiment, we aimed to evaluate the effect of association between imagery and physical practice compared to pure physical practice in the learning of a manual task in 9-10 year-old children. The task consisted of transporting a block and fitting it into a support with speed and steadiness, assessing movement time to complete the "reaching" and "transport" task components. The children were assigned to one of three groups: (a) physical practice (PHYS) (240 trials), (b) combination (COMB) of imagery (180 trials) and physical (60 trials) practice, and (c) control (CON), associating visual rotation (180 trials) and physical practice (60 trials). Performance was evaluated immediately and 24 h after practice. Results indicated that the PHYS group achieved a persistent performance gain in the "transport", but not in the "reaching" task component, while the COMB group achieved persistent performance gains in both movement components; no significant differences were found for the CON group. Our results suggest that imagery training improves the task mental representation in children, while physical practice provides sensory feedback on the performed movements. As a conclusion, the results suggest that combination of imagery and physical practice can be more effective than pure physical practice for children's motor learning.

Key words: Child; Learning; Motor activity; Motor skills.

Resumo – *Imagética dos próprios movimentos tem mostrado induzir aprendizagem motora em adultos, porém são escassas evidências similares em crianças. O objetivo deste experimento foi avaliar o efeito da associação entre prática imagética e prática física em comparação com prática física pura em uma habilidade manual em crianças de 9-10 anos de idade. A tarefa consistiu em transportar um bloco e encaixá-lo em um suporte com rapidez e estabilidade, avaliando-se o tempo de movimento para completar os componentes de "alcance" e "transporte". As crianças foram distribuídas em três grupos: (a) prática física (FIS) (240 tentativas), (b) combinação (COMB) de prática imagética (180 tentativas) e prática física (60 tentativas), e (c) controle (CON), com associação de rotação visual (180 tentativas) e prática física (60 tentativas). O desempenho foi avaliado imediatamente e 24 h após a prática. Os resultados indicaram que o grupo FIS obteve ganho persistente de desempenho no componente "transporte", porém não no componente "alcance", enquanto o grupo COMB alcançou ganho persistente de desempenho em ambos os componentes de movimento; não foram encontradas diferenças significantes para o grupo CON. Estes resultados sugerem que a prática imagética aprimora a representação mental da tarefa motora em crianças, enquanto que a prática física oferece informação de feedback sensorial sobre o os movimentos realizados. Como conclusão, nossos resultados sugerem que a combinação de prática física e imagética é um procedimento que pode ser mais efetivo do que prática física pura para aprendizagem motora em crianças.*

Palavras-chave: *Atividade Motora; Aprendizagem; Criança; Destreza motora.*

1 University of São Paulo. School of Physical Education and Sport. Laboratory of Human Engines Systems. São Paulo, SP, Brazil.

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INTRODUCTION

Imagery practice consists of the repeated mental rehearsal of movements themselves, without being physically executed. It has been proposed that imagery practice allows the formation of an internal model that is more flexible and independent of the effector[1]. One of the theories that support learning through imagery practice proposes that imagery helps in motor concentration and programming, facilitating the execution of specific movements[2]. In addition, there is evidence that when imagery and physical practices are combined, neuroplasticity is stimulated, inducing cortical reorganization[3,4].

There is evidence that in imagery practice, good simulation of effective movements is obtained, given the similarity between the time spent to execute and imagine a given movement[5-7], as well as by similar autonomic responses between imagined and executed movement[5,8]. Studies with imagery techniques of high temporal and spatial resolutions[9,10] have shown that the primary motor cortex is activated during imagination, although to a lesser degree than when movements are actually performed. However, more recent data have pointed out that the neural structures involved in imagery practice and physical practice are different. When compared, there is greater activation of the pre-motor cortex and supplementary motor area during motor training, whereas the visual cortex is more activated during imagery training. That is, the combined practice activates both motor and visual areas[11,12]. These findings suggest that individuals engaged in imagery practice may strengthen neural pathways relevant to the visuomotor regulation of movements. Thus, imagery practice could favor the acquisition of motor skills[3,12,13].

Although imagery practice is widely used for sports training[13-15] and for rehabilitation in adults[2,4,16], its use in children is still limited[17]. Cognitive functions considered important for this type of practice, such as operational memory, attention and abstraction may not be fully developed in childhood due to the immaturity of some brain areas[18]. Evidence has suggested that onset of motor imagery is around the age of 5 years[19]. Between 7 and 8 years of age, it has been shown that children are able to perform imaginative training[20], because this control is consolidated, allowing the prediction of changes of their bodies and their kinematics, and thus, the anticipation of trajectories of movements and detection of deviations from what has been planned[20]. In addition, motor imagery depends on the interaction of neural networks, which include the posterior parietal cortex, the pre-motor cortex, and the cerebellum. These structures, involved in motor planning and predictive control, develop gradually throughout child development, with rapid differentiation between 6 and 10 years of age, which has implications for the development of anticipatory control[20-23]. A recent study has suggested that children aged 9-10 years are able to acquire and retain learning through imagery practice[23]. In addition, recent results have indicated that the association of imagery and physical practice may lead to learning effects superior to pure physical practice in adolescents with neural lesions[24].

To improve understanding of how motor imagery can be used in children's motor learning, further studies should assess the effectiveness of imagery practice. In particular, current literature lacks information on the effect of the association between imagery practice and physical practice in the learning of motor skills in children. The aim of this experiment was to compare the effect of the combination of imagery practice and physical practice in relation to gains obtained with pure physical practice in a manual ability in children aged 9-10 years. The performance indicator in the task was the speed of execution, with movement time per task component as the primary outcome. We hypothesized that combination of imagery with physical practice induces motor learning gains superior to pure physical practice.

METHODOLOGICAL PROCEDURES

Participants

Eighteen children of both sexes aged 9-10 years (M = 9.33, SD = 0.49), right handed, healthy, without history of neurological diseases, delayed neuropsychomotor development or learning disorders were selected. To participate, children demonstrated to be able to imagine themselves doing the experimental task. For this purpose, a Portuguese-language version of a children's specific imagery questionnaire, the Movement Imagery Questionnaire for Children, was used[25]. Parents were informed about the objectives and procedures of the research and agreed to the participation of their children in the study by signing a free and informed consent form. The experimental protocol was approved by the Local Research Ethics Committee (University of São Paulo, CAAE No. 51887915.2.0000.5391).

Equipment and task

Procedures were individually performed with constant supervision by the evaluator in a closed environment, where the child remained seated in a chair in front of a table, starting with the palm of the right hand downwards resting on the starting point located 20 cm to the right side regarding the sagittal axis. The manual practice skill was based on the same as that used by Allami[5]. The skill consisted of holding a plastic block (dimensions: 60 x 20 x 45 mm, weight: 80 g) with the index and thumb fingers and inserting it into a support as soon as possible. The block was located on the midline the participant's body, 30 cm away from the thorax. Half the block surface was gray, the other half white with black marks, which coincided with the marks of the support. Participants held the block on its gray side and carefully placed it inside the support. To make the task more difficult, a marble was placed unstable in a shallow hole made in the block surface. This characteristic required stability when transporting the block. In addition, two sticks were glued to the sides of the block to enforce children

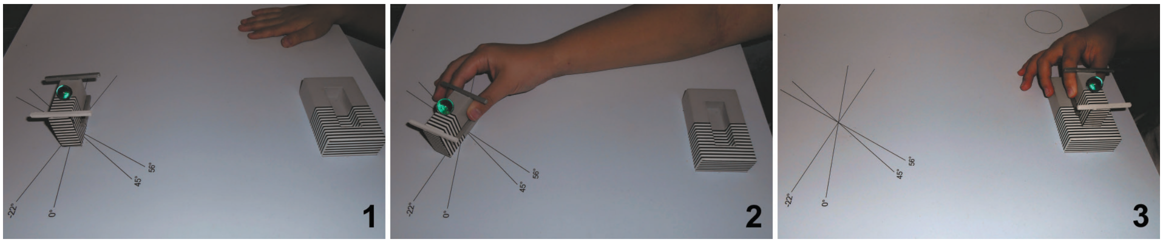

Figure 1. Representation of the task components: (1) initial position, (2) gripping the block and (3) fitting the block into the support.

to hold it in the region appropriate to the task execution (Figure 1). Angles of block orientation other than 0° required its rotation during approach to the fitting position. Evaluations were recorded by means of a commercial digital camera (Sony), with acquisition frequency of 60 Hz.

Experimental design and procedures

Participants were randomized into three groups (n = 6 each). Each group received a different training combination, totaling 240 trials. In the physical practice group (PHYS), children performed the experimental task in an exclusively physical way. In the combined imagery-physical practice group (COMB), a block of 180 trials was initially performed through imagery, which was immediately followed by a block of 60 physical trials. A greater proportion of imagery practice was offered because this distribution has been shown to lead to superior learning outcomes in adults[5]. In the control group (CON), children imagined a task of visual rotation in 180 trials and performed 60 physical practices of the same task as the other groups. In this case, the evaluator demonstrated the block rotation, and afterwards children were asked to imagine the same rotation of the block, but without associated manual movements. At each rotation, when the segment was aligned with a mark in a circle, children should indicate the end of the imagery trial by raising the right index finger. This condition aimed to determine the effects of imagery that may be related to non-motor phenomena, such as attention[5].

For practice, verbal instruction was associated with the demonstration of movements by the evaluator, with movement performed in front of the participant. Subsequently, the participant physically performed five trials to get familiarized with the task, with a single block orientation. In this way, children have learned to place their right thumb and index fingers on the block surface (pinch-like), and to adjust the movement speed to successfully insert the block into the support, without letting the marble fall. The practice step was performed in a single session of 240 trials in approximately 50 min. In physical practice, after verbal instruction, demonstration and familiarization with the task, participants were instructed to close their eyes while the evaluator positioned the block on the table surface, with spatial orientation of the support fixed at zero degree, while the block orientation was altered by the evaluator in a pseudo-random manner at -22°, 0°, 45° and 56° each trial. The verbal command "go" was used as the signal to start the test: the children opened their eyes to reach and grasp the block with a pinch-like grip (between thumb and forefinger), carry it and correctly insert it into the support (the marks in the block should correspond to those of the support). Then, children returned to the starting position and closed their eyes, waiting for the next trial. The block orientation was pseudo-randomly varied between trials. Participants were instructed not to speak or perform any other movement during the experiment. The goal of movement speed associated with manual steadiness in the block transportation was reinforced every 10 trials. No feedback was given to the children about their performance.

In imagery practice, children remained seated in their initial position with their right hand resting on the starting point. They were guided to imagine the sensations that they would have when performing the movements. The instruction was as follows: "Close your eyes and imagine yourself sitting in front of a table, performing the movement that I just demonstrated and that you also performed. Imagine you grasping the block, lifting it and taking it to the support, as fast as possible and without dropping the marble. Imagine this movement, thinking of all the sensations it provides". The sequence of procedures was equivalent to that of physical practice, with pseudo-random variation of the initial block orientation among trials in both imagery practice and physical practice. After imagining making the complete fit of the block into the support, the participant was requested to elevate his right index finger, signaling to the evaluator the end of the movement imagination. Inter-trial intervals were approximately 10 s, and intervals of 1 min. every 60 trials were allowed.

Data analysis

Performance was assessed by quantifying the average movement time of 3 physical trials in the following periods: before practice (pre-test), immediately after the end of physical practice (post-test), and 24 h after practice (retention). Movement time was measured based on images, considering the following visually detectable events: movement time of the "reach" component, starting with the first frame with perceptible displacement of the right hand at the beginning of the reach, and as the end of this component, the contact of the index finger and thumb with the block, movement time of the "transport" component, having as a starting point the detection of the first vertical displacement of the block, considering as the end of this component the visual detection of the fit of the block into the support. Trials in which the marble was dropped during the execution of the motor task were excluded from the analysis and immediately retried.

The analysis of the imagery questionnaire was done in a segmented way for each imagery modality: internal visual, external visual and kinesthetic. This analysis was done using ANOVA of non-repeated measures for the single group factor. Movement time data were separately analyzed for the reach and transport components. Primary outcome analyses for movement time were performed using two-way ANOVA, 3 (group) x 3 (phase: pre-test x post-test x retention), with repeated measures in the second factor. *Post* *hoc* comparisons were made using the Newman-Keuls test. Significance level of 5% was adopted in all analyses.

RESULTS

The percentage of retried trials during physical practice due to falling marbles was 6.67% in the PHYS group and 5.83% in the COMB group. For reliability assessment, the analysis of 10% of transport component trials was repeated after an interval of 3 weeks. This evaluation indicated that in 94% of trials, movement times were coincident between the two evaluation moments, indicating good measurement reliability. The imagery capacity analysis values between groups for each modality are presented in Table 1. The imagery capacity analysis indicated that there were no significant differences between groups, with F values (2, 15) < 0.3 and p values > 0.8 among analyses in the three imagery modalities.

Table 1. Mean and standard deviations in the MIQ-C score for each group in each imagery modality.

	Internal visual	External visual	Kinesthetic
	Mean (SD)	Mean (SD)	Mean (SD)
PHYS	5.92 (0.75)	5.67 (0.52)	5.96 (0.81)
COMB	5.83 (0.86)	6.04 (0.73)	6.00 (0.52)
CON	5.88 (0.89)	5.75 (1.23)	5.96 (0.53)

Note. standard deviation (SD) indicated in parentheses.

Analysis of variance for both movement times, for the reach and transport components, indicated significant interaction between group and test factors: reach, F (4, 30) = 2.71, p = 0.05; transport, F (4, 30) = 7.02, p = 0.001. *Post-hoc* comparisons for the reach component indicated that for the COMB group, smaller values were found in post-test and retention in relation to pre-test, without significant differences between tests performed after practice. For the PHYS group, lower values were found in post-test compared to pre-test, but only a trend of lower times in retention com-

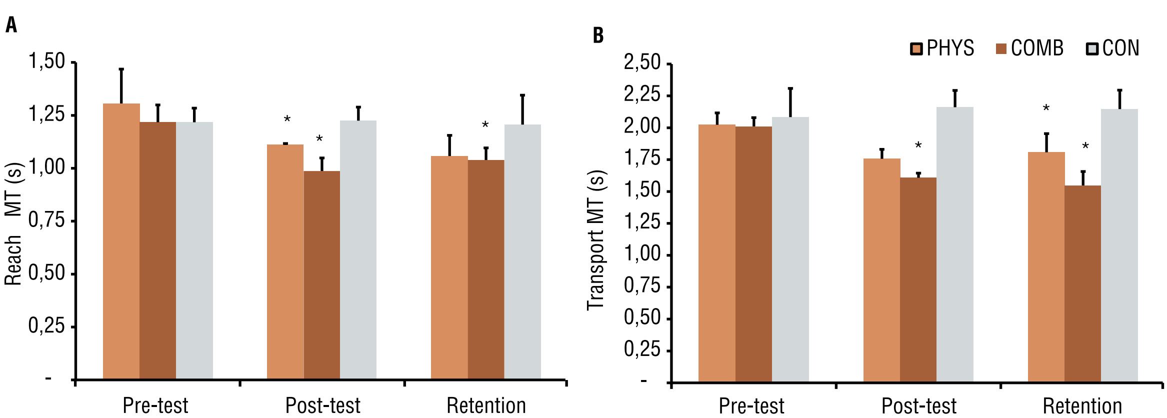

Figure 2. Comparison of movement times (standard deviation in vertical bars) for the components (A) reach and (B) transport between groups (PHYS, physical practice; COMB, combination of imagery-physical practice; CON, control) in each test. *represents significant difference in relation to the respective pre-test

pared to pre-test (p = 0.07), with no significant differences between tests performed after practice. *Post-hoc* comparisons for the transport component indicated lower values in post-test and retention compared to pre-test for both experimental groups, PHYS and COMB, without significant differences between tests performed after practice. No significant differences were found between tests for the CON group and no differences between groups in each test in both movement components were found (Figure 2).

DISCUSSION

The present study compared the effect of association between imagery and physical practice with pure physical practice in the acquisition of a manual motor skill in children aged 9-10 years. We hypothesized that combined physical-imagery practice induces motor learning gains superior to pure physical practice. The results partially confirmed our hypothesis, since better retention of the "reach" component was observed in the COMB group compared to the PHYS group, as the mean MT values in both movement components tended to be lower in the COMB group than in the PHYS group. These results indicate a trend toward better learning by combining physical and mental practice compared to pure physical practice. On the other hand, both experimental groups, COMB and PHYS, obtained significant retention in the transport component, suggesting learning similarity between experimental groups for this component. The performance similarity of the CON group between tests indicates that the observed performance gains were not due to evaluation trials or experimental procedures. These results suggest that children aged 9-10 years can benefit from the combination of physical and imagery practice.

The performance improvement presented by the COMB group may be due to the fact that the combined practice reinforced two forms of representation. It is possible that the representation improved, regardless of the muscular activation of the effector limb developed by the imagery practice, and then with the execution and sensory feedback of the physical practice, different neural networks involved in both types of practice have been activated[5,12]. The less potent effect of imagery practice on children in our results compared to previous studies with adults[3,5] could be explained by the fact that children have some cognitive functions considered important for this type of practice not yet fully developed, such as operational memory, attention and abstraction[18]. Previous studies involving imagery practice differ in the types of tasks used, ages, characteristics of children, designs and methods used[14,26]. Investigations with combined practice have presented interesting results and interpretations on the benefits of imagery practice. More than verifying whether isolated imagery practice promotes learning or not, the use of combined practice allows us verifying how much imagery practice influences learning[3,5]. In one of the few studies that evaluated intervention with mental practice in children, Taktek et al.[27] found, through the task of throwing a ball, that combined physical and mental practice provided equivalence in performance in the retention test and superiority in the transfer test in tasks when compared to pure physical practice. These results were attributed to the fact that combined practice allowed the formation of a more flexible internal task model, with greater potential for adaptation to a new motor task. Regarding long-lasting effects, a finding of interest was the persistence of performance gain by practice after 24 h in the COMB group. Previous studies also verified persistence of effects of imagery practice after a night of sleep[28]. Taken together, these results support the notion that imagery practice can induce stable performance gains in children when associated with physical practice.

Evidence indicates that isolated imagery practice is inferior to physical and combined practices, being more effective only compared to the absence of practice[15]. In addition, physical practice seems to be essential for learning a new skill, since it is related to the perception the learner has about his performance[25]. When performing the skill physically, the learner obtains information about the achievement of the task that only physical practice allows through the action-perception interaction. In the case of isolated imagery practice, there is no feedback derived from movements, which can prevent motor learning gains observed when imagery and physical practice are combined[15]. Studies that tested the combined practice proportionally[5,15] or with greater proportion of imagery practice (75%) compared to physical practice (25%)[5], led to the conclusion that imagery practice plays an important role in performance gain, while combined practice with lower imagery practice rate (25%) seems to be less effective in inducing performance improvements[5].

CONCLUSION

The results of this experiment indicate the positive role of the association of imagery and physical practice in children motor learning, with superior retention of performance gains in the "reach" component and equivalent in the "transport" component compared to pure physical practice. Thus, the results suggest that the combination of physical and imagery practice could be an advantageous procedure for promoting motor learning in children aged 9-10 years. However, some caution is needed with the generalization of findings revealed in this study due to the limited number of children evaluated. Once the potential use of imagery practice to promote motor learning in children aged 9-10 years has been evidenced, in future studies a higher number of children should be evaluated.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest statement

The authors have no conflict of interests to declare.

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Ethical approval
Ethical approval was obtained from the Human Research Ethics Committee of the School of Physical Education and Sport of the University of São Paulo, CAAE No. 51887915.2.0000.5391, in accordance with the standards set by the Declaration of Helsinki.

Author Contributions
PST; LAT conceived and designed the experiments. PST performed the experiments. PST; LAT analyzed data. PST; LAT contributed with reagents/materials/analysis tools. PST; LAT wrote the paper.

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CORRESPONDING AUTHOR

Patrícia Sayuri Takazono
Professor Mello Moraes Avenue, 65,
São Paulo, SP, Brazil.
Zip code: 05508-030.
E-mail: patricia.takazono@usp.br