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CHILDREN'S MOTOR LEARNING AND WORKING MEMORY: THE ROLE OF VISUAL AND VERBAL ANALOGY LEARNING

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Abstract

Introduction. Physical education teachers and coaches often face the problem of how to convey information to novice learners, particularly to children. The present study aims to examine how visual and verbal analogy learning affects basketball free-throw learning as well as working memory in 9- to 12-year-old children. ***Material and Methods.*** Forty-eight children (24 males, mean age: 10.5 ± 1.8 years) were selected through convenience sampling and randomly assigned to four groups, namely visual analogy, verbal analogy, explicit, and control groups. The task involved throwing a basketball from a distance of 3.05 meters. The participants completed 15 trials in the pretest, posttest, and retention phases and 720 trials in the acquisition phase. ***Results.*** The result of the paired sample t-test indicated that the visual analogy, verbal analogy, and explicit learning groups experienced a significant improvement in their performance through the skill acquisition phase as well as an improvement in their working memories ($p \leq 0.05$), while the control group did not exhibit such improvements ($p = 0.91$). In addition, one-way analysis of covariance (ANCOVA) showed that the analogy learning group outperformed other groups in both post-test and retention tests as well as in terms of motor learning and working memory ($p \leq 0.05$). ***Conclusions.*** The verbal analogy and the explicit learning groups were equally better than the control group. The findings of this study suggest that coaches in instructional environments should make further use of the advantages of visual analogy learning for children.

Key words: analogy learning, explicit learning, children, working memory, motor learning

Introduction

Physical education teachers and coaches often face the problem of how to convey information to novice learners, particularly to children. Usefulness of learning instructions largely depends on how a learner learns and processes these instructions [1]. A common method used in instructional environments is explicit learning style. In explicit learning, the learner first receives instructions on how to perform a skill by acquiring declarative knowledge and then learns a new motor skill [2]. In other words, here the learner should first become knowingly aware of the rules and facts concerning the movement of interest [3].

Cognitive capacity and working memory seem to act as a major condition for accumulating and applying declarative knowledge as well as for explicit motor learning [4]. However, overly prescriptive explicit instructions may have detrimental effects on the motor learning process [5]. Extensive studies have shown that skills learned through an explicit method diminish under physically and cognitively demanding conditions, like fatigue, psychological stress, and multitasking [6, 7, 8]. In other words, learners' ability to follow instructions is a function of their ability to memorize information and apply it while trying to learn. The neural framework for this ability is often conceptualized as working memory [9]. Working memory is considered as a brain process which enables temporary storage and manipulation of information needed for complex tasks like language, comprehension, learning, and reasoning. A considerable limitation of the working memory is its limited capacity to store information [10]. This capacity is far more limited in children compared to adults [3]. The central executive system focuses on constant monitoring and fast correction of information maintained by the working memory (updating function), flexible switching between tasks and mental sets (shifting function), and most important dominant responses (inhibition function) [11]. In other words, explicit learning requires a conscious effort to engage the working memory since this memory plays an important role in generating and using declarative knowledge [12]. Therefore, it seems that explicit learning excessively engages the working memory, further disrupting the process of motor learning [13].

When receiving instructions on a motor skill, children make an effort to process large amounts of explicit information, preferring to be taught using images and metaphors. In fact, evidence suggests that, during learning, children tend to process information implicitly in visual areas of the working memory [14, 15]. Presenting frequently large amounts of instructions may increase the load on the working memory which, in turn, can have detrimental effects on performance under pressure or during decision making [4]. Therefore, it is essential to use instructional techniques that prevent high cognitive loads.

The opposite of explicit learning is implicit motor learning where learning takes place without simultaneously accumulating declarative knowledge. Implicit learning gives learners no instructions and may even intentionally avoid changing the way they move [16]. This does not, however, mean that implicit learning is merely a learning style without instruction or feedback [17]. One technique of implicit learning is analogy learning [13, 17, 18].

Analogy represents a kind of instructions that help to learn how to perform a new movement by connecting it to an essentially similar concept [19, 20]. Studies have shown that analogy learning, during motor skill acquisition, diminishes reliance on information-cognitive processes [18]. Learning through analogy requires translation of information related to a known (but independent) concept into a concept that needs to be learned [19]. In the context of motor learning, task-related knowledge is presented through analogy instruction. However, it often creates a salient mental visual image that can make it suitable for the learner [21].

Numerous studies have examined whether instruction in the form of analogy learning can enhance motor learning [6, 7, 13, 22]. Masters and Liao [23] made conjectures about how analogy instructions may reduce the complex rule structure for a learned skill in a way that reduces the amount of verbal information in order to need less conscious processing. Analogy concepts and symbols are far simpler and easier than explicit instructions [13]. With less information processing, more resources in the working memory are potentially available to handle a secondary task or cope with stress [4].

In other words, analogy learning results in stable performance under pressure [6, 7], for dual task conditions [24] as well as under conditions where complex decisions need to be made [18]. Analogy instructions may also be effective in reducing learners' reliance on conscious control processes during movement [25]. Previous studies also demonstrated that performance resulting from analogy instruction is stronger than when it is induced by explicit cognitive instructions [6, 7, 18, 22].

Effectiveness of analogy-based approaches has also been confirmed in academic teaching for children [26]. Some studies demonstrated advantages of analogy learning in helping children to understand their surrounding world [27, 28]. For example, Donnelly & McDaniel [27] showed that children who received analogy instructions were able to answer inferential questions about a newly learned scientific concept. Recently, Chatzopoulos et al. [21] demonstrated that, in learning balance and locomotion movements, pre-school children performed better analogy learning than under explicit learning conditions. In general, it can be argued that analogy instructions help children acquire new motor skills and that advantages of analogy can be used to reduce cognitive demand in motor learning. However, given the importance of promoting motor learning in children and the dearth of research in this area, it is essential to conduct further research in order to analyze and compare analogy learning and explicit learning in children.

However, most studies in this area involved analogy instructions in the form of auditory or verbal instructions. While analogies undoubtedly take visual forms, it is not known whether they can be actually regarded as non-declarative knowledge. Researchers have reported that audiovisual and verbal presentation of instructions has a different impact on how analogy concepts are perceived [29]. For example, Orgill & Bodner [30] found that can memorize a visual analogy instruction better than a verbal analogy instruction since the ability of recalling conceptual information and infer its meaning is stronger under visual analogy. In addition, Tse & Masters [26] recently showed that compared to verbal analogy learning, visual analogy learning can present a more suitable option for assisting motor learning in children with autism.

Therefore, it is essential to further explore this topic and different forms of analogy learning among children. In addition, as far as the authors know, no study has so far directly compared visual and verbal analogy learning as well as explicit learning in healthy children. Moreover, effects of these learning methods on working memory, as a measure of cognitive load, have not been sufficiently explored. Thus, the present study aims to examine the effects of a four-week basketball free-throw training using various techniques of visual and verbal analogy learning, versus traditional explicit learning, on working memory and motor learning of children aged 9 to 12.

Material and Methods

Participants

The sample consisted of 48 children (24 male children), aged 9 to 12 years ($M_{age} = 10.5 \pm 1.8$ years) selected through convenience sampling from a physical education class and randomly assigned to four groups of 12 (6 boys and 6 girls): explicit learning, visual analogy learning, verbal analogy learning, and control. The following inclusion criteria were used: 1) no history of diseases or injuries that may affect performance; 2) completing the consent form by parents for participation in the study; and 3) being 9 to 12 years old. We also used the following exclusion criteria: 1) unmotivated individuals for continued participation; 2) no regular presence in training sessions; and 3) emergence of any disease or injury that could affect performance. The parents of the participants completed informed consent forms before the experiment started. The participants were naïve regarding the task. The research design complies with the Declaration of Helsinki and was approved by the Ethics Committee.

Task

Basketball free-throw test

In this study, we used a basketball free-throw test similar to the one used by Tse & Masters [26]. A regular size 5 basketball weighing 25% less than a standard basketball was used to accommodate the children's motor abilities. To measure motor performance of the participants, they were instructed to shoot the basketball into a hoop placed 3.05 m away from the thrower. The basket was placed 2.43 m above the ground. All throws were made using the dominant hand. Scores were recorded using AAHPERD scoring for basketball shots. The following scoring scheme was used for this purpose: 5 points for shots made into the hoop; 3 points for shots hitting the hoop; 2 points for shots hitting the hoop and the backboard; 1 point for shots hitting the backboard; and 0 points for other shots [31].

n-back test

In this test, which involves using the computer program n-back [32], participants receive a sequence of consecutive visual stimuli. A participant should indicate whether the current stimulus matches the one from n steps earlier. The larger n is, the more difficult the task. Generally, n is a number from 1 to 3. In this study, n = 2 was selected. Once the data for a participant was recorded and the type of the test (2-back test) was selected, the participant entered a 30-second initial test stage where he/she could see the results after pressing each button. The initial stage could be repeated until the participant was ready for the main task. The 3-minute main task involved stimuli in the form of numbers 1 to 9 shown consecutively for 1 second each. The participant would start the comparison from the third stimulus on; that is, the participants were required to compare the third stimuli with the first one (two earlier steps), and then press the Yes button if the two stimuli matched and the No button otherwise. This process would continue by comparing the fourth stimulus with the second one, the fifth one with the third one, and so on. Then, at the end of the 3-minute period, each participant was shown the result in the form of a table indicating incorrect response, no response, correct response, success rate and mean response time for each individual trial.

Table 1. Individual characteristics of the participants

Individual characteristics		Groups (Mean ± SD)				p
		Explicit	Visual analogy	Verbal analogy	Control	
n		12	12	12	12	-
Age (year)		10.63 ± 1.23	10.50 ± 1.24	10/41 ± 0.90	10.41 ± 0.99	0.93
Free-throw accuracy (pretest)		2.21 ± 0.67	2.33 ± 0.67	2.30 ± 0.71	2.20 ± 0.59	0.95
Working memory (pretest)	Incorrect response	46.50 ± 8.46	47.91 ± 7.39	47.0 ± 8.48	48.58 ± 8.95	0.93
	No response	5.50 ± 3.17	4.50 ± 3.84	6.8 ± 2.15	4.33 ± 3.52	0.50
	Correct response	68.00 ± 8.92	67.58 ± 1.04	66.91 ± 9.03	67.80 ± 9.65	0.99
	Success rate	56.66 ± 7.43	56.31 ± 8.37	55.76 ± 7.53	55.90 ± 8.04	0.99
	Mean response time	425.08 ± 48.48	449.50 ± 54.74	434.00 ± 45.76	428.93 ± 49.13	0.97

* – significant at $p < 0.05$.

Figure 1. The participants in the visual analogy group watched the image of a child putting a cookie in a jar on the table (similar to Tse and Masters [26]).

Procedure

First, the participants were selected through convenience sampling. The present study was conducted in four phases: pretest, acquisition, posttest, and retention test. Free-throw accuracy and participants' working memory were measured in pretest, posttest, and retention test. First in the pretest, the participants performed 15 free throws in an outdoor basketball court. They then took the n-back test. After the pretest session, the participants were randomly assigned to four groups, namely Group 1. visual analogy, Group 2. verbal analogy, Group 3. explicit instruction, and Group 4. control. The participants in the experimental groups practiced basketball free throws over a period of four weeks with two sessions consisting of six 15-trial blocks per week (720 trials in total). The 15-trial blocks were separated by 3-minute intervals. To minimize the examiner effect on the research procedure, the same examiner was used throughout the whole process for all participants. Before each 15-trial block, the experimental groups received verbal or visual analogy or explicit instructions twice. The participants in the visual analogy group were in the start position and watched the image of a child putting a cookie in a jar on the table (Fig. 1). The participants in the verbal analogy group were told to throw the ball as if trying to imitate a child putting a cookie in a jar on the table. The participants from the explicit instruction group were instructed to stand with their feet together, look at the hoop, use their dominant hand to carry the ball and their non-dominant hand to support the ball from below, move the ball upward, and release it once their arm was in the upright position. Immediately after the acquisition sessions, the participants attended the posttest step consisting of 15 free-throw trials. The retention test took place 48 hours following posttest. During the retention test, the participants performed 15 free-throw trials similar to the procedure followed in pretest and posttest. No instructions were provided in pretest, posttest, and retention test as the participants performed 15 free-throw trials, while the examiner was recording their scores immediately. The control group did not have any particular motor activity during this period. The participants in this group only attended the pretest, posttest, and retention steps. All groups took the n-back test during pretest and posttest.

Data Analysis

The assumptions of equal variance and normality of the data were tested and acceptably confirmed for all data. One-way analysis of covariance (ANCOVA), one-way analysis of variance (ANOVA), dependent t-test and Bonferroni post hoc tests were used to compare the groups. The data were analyzed at $\alpha \leq 0.05$ in SPSS 24.

Results

Table 1 reports descriptions of individual characteristics and research variables. As seen in this table, all groups had similar scores in terms of free-throw accuracy as well as working memory in the pretest phase.

Motor Performance

The results of ANCOVA on posttest free-throw accuracy data while controlling for pretest data as the covariant variable indicated a significant group effect ($F (3,48) = 17.98$, $p = 0.0001$, partial $\eta^2 = 0.55$). Results of Bonferroni post hoc test suggested that in posttest, visual analogy group (3.62 ± 0.44) outperformed verbal analogy (3.01 ± 0.57, $p = 0.01$), explicit (2.96 ± 0.46; $p = 0.01$), and control (2.18 ± 0.52, $p = 0.001$) groups. In addition, visual analogy and explicit groups had similar performance which was better than the control group ($p = 0.001$). The dependent t-test results demonstrated that all three groups, namely visual analogy ($t = -7.30$, $p = 0.0001$, 95% CI = -1.68, -0.90, Cohen's d = 2.3), verbal analogy ($t = -3.18$, $p = 0.009$, 95% CI = -1.19, -0.21, Cohen's d = 1.09), and explicit ($t = -3.44$, $p = 0.006$, 95% CI = -1.23, -0.27, Cohen's d = 1.33), experienced a significant difference from pretest to posttest. No significant

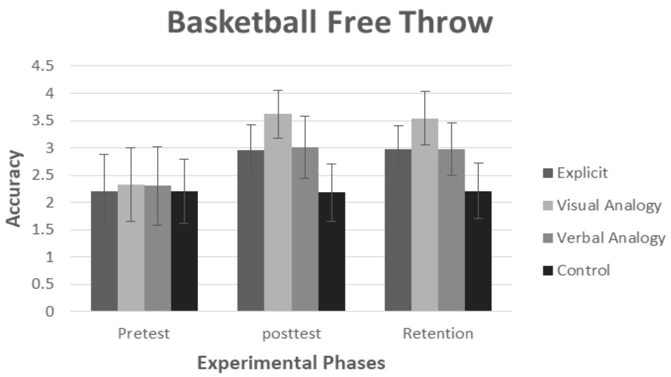

Figure 2. Basketball free throw scores during pretest, posttest, and retention for all experimental groups and the control group. Error bars represent standard deviation.

difference was observed in the control group from pretest to posttest (t = -0.90, p = 0.92, 95% CI = -0.24, 0.26, Cohen's d = 0.03, Fig. 2).

Motor Learning

The results of ANCOVA on free-throw accuracy data in retention test while controlling for pretest data as the covariant variable indicated a significant group effect (F (3,48) = 14.88, p = 0.0001, partial η^2 = 0.50). Results of Bonferroni post hoc test suggested that in posttest, visual analogy group (3.54 ± 0.49) outperformed verbal analogy (2.98 ± 0.48, p = 0.04), explicit (2.98 ± 0.43, p = 0.04), and control (2.21 ± 0.51, p = 0.0001) groups. In addition, visual analogy and explicit groups had similar performance which was better than the control group (p = 0.003 and p = 0.002, respectively). The dependent t-test results demonstrated that all three groups, namely visual analogy (t = -4.48, p = 0.001, 95% CI = -1.80, -0.61, Cohen's d = 2.08), verbal analogy (t = -3.36, p = 0.006, 95% CI = -1.13, -0.23, Cohen's d = 1.15), and explicit (t = -3.45, p = 0.005, 95% CI = -1.27, -0.28, Cohen's d = 1.4), experienced a significant difference from pretest to retention test. No significant difference was observed in the control group from pretest to retention (t = -0.10, p = 0.91, 95% CI = -0.36, 0.32, Cohen's d = 0.01, Fig. 2).

Working Memory

Incorrect Response

The results of ANCOVA on the number of posttest incorrect responses while controlling for pretest data as the covariant variable indicated a significant group effect (F (2,48) = 22.41, p = 0.0001, partial η^2 = 0.61). Results of Bonferroni post hoc test suggested that in posttest, visual analogy group (35.5 ± 0.5.77) represented a smaller number of incorrect responses compared to verbal analogy (41.00 ± 7.00, p = 0.001), explicit (41.08 ± 9.02, p = 0.0001), and control (47.83 ± 8.57, p = 0.0001) groups. In addition, visual analogy and explicit groups had similar performance with a smaller number of incorrect responses than the control group (p = 0.003 and p = 0.007, respectively). The dependent t-test results demonstrated that all three groups, namely visual analogy (t = 7.63, p = 0.0001, 95% CI = 8.83, 15.99, Cohen's d = 2.22), verbal analogy (t = 5.28, p = 0.0001, 95% CI = 3.5, 8.49, Cohen's d = 0.77), and explicit (t = 7.49, p = 0.0001, 95% CI = 3.82, 7.00, Cohen's d = 0.64), experienced a significant difference from pretest to posttest. No significant difference was observed in the control group from pretest to posttest (t = 1.29, p = 0.22, 95% CI = -0.52, 2.02, Cohen's d = 0.08, Fig. 3).

No Response

The results of ANCOVA on the number of no-response trials in posttest while controlling for pretest data as the covariant variable indicated a significant group effect (F (2,48) = 4.56, p = 0.007, partial η^2 = 0.24). Results of Bonferroni post hoc test suggested that in posttest, visual analogy group (1.58 ± 0.1.56) was similar to verbal analogy (3.75 ± 1.86, p = 0.1) and explicit (3.00 ± 1.27, p = 0.63) groups in terms of no-response trials, with a smaller number of no-response trials only than the control group (4.16 ± 2.58, p = 0.005). No significant difference was found between verbal analogy and explicit groups (p = 0.99). The dependent t-test results demonstrated that all three groups, namely visual analogy (t = 2.72, p = 0.0001, 95% CI = 0.56, 5.27, Cohen's d = 1.08), verbal analogy (t = 3.69, p = 0.004, 95% CI = 0.94, 3.72, Cohen's d = 1.16), and explicit (t = 3.87, p = 0.003, 95% CI = 1.07, 3.92, Cohen's d = 1.14), experienced a significant difference from pretest to posttest. No significant difference was observed in the control group from pretest to posttest (t = 0.14, p = 0.88, 95% CI = -2.37, 2.70, Cohen's d = 0.05, Fig. 3).

Correct Response

The results of ANCOVA on posttest number of correct responses while controlling for pretest data as the covariant variable indicated a significant group effect (F (2,48) = 16.45, p = 0.0001, partial η^2 = 0.53). Results of Bonferroni post hoc test suggested that in posttest, visual analogy group (82.91 ± 6.68) represented a larger number of correct responses than verbal analogy (75.25 ± 7.49, p = 0.007), explicit (75.91 ± 8.71, p = 0.006), and control (68.00 ± 9.37, p = 0.0001) groups. In addition, no significant difference was found between verbal analogy and explicit groups (p = 0.99), while both outperformed the control group in terms of the number of correct responses (p = 0.006 and p = 0.006, respectively). The dependent t-test results demonstrated that all three groups, namely visual analogy (t = -6.00, p = 0.0001, 95% CI = -20.95, -9.71, Cohen's d = 1.83), verbal analogy (t = -6.66, p = 0.0001, 95% CI = -11.08, -5.57, Cohen's d = 1), and explicit (t = -7.30, p = 0.0001, 95% CI = -10.30, -5.53, Cohen's d = 0.89), experienced a significant difference from pretest to posttest. No significant difference was observed in the control group from pretest to posttest (t = -0.61, p = 0.55, 95% CI = -4.19 2.36, Cohen's d = 0.09; Fig. 3).

Correct Response

The results of ANCOVA on posttest number of correct responses while controlling for pretest data as the covariant variable indicated a significant group effect (F (2,48) = 16.45, p = 0.0001, partial η^2 = 0.53). Results of Bonferroni post hoc test suggested that in posttest, visual analogy group (82.91 ± 6.68) represented a larger number of correct responses than verbal analogy (75.25 ± 7.49, p = 0.007), explicit (75.91 ± 8.71, p = 0.006), and control (68.00 ± 9.37, p = 0.0001) groups. In addition, no significant difference was found between verbal analogy and explicit groups (p = 0.99), while both outperformed the control group in terms of the number of correct responses (p = 0.006 and p = 0.006, respectively). The dependent t-test results demonstrated that all three groups, namely visual analogy (t = -6.00, p = 0.0001, 95% CI = -20.95, -9.71, Cohen's d = 1.83), verbal analogy (t = -6.66, p = 0.0001, 95% CI = -11.08, -5.57, Cohen's d = 1), and explicit (t = -7.30, p = 0.0001, 95% CI = -10.30, -5.53, Cohen's d = 0.89), experienced a significant

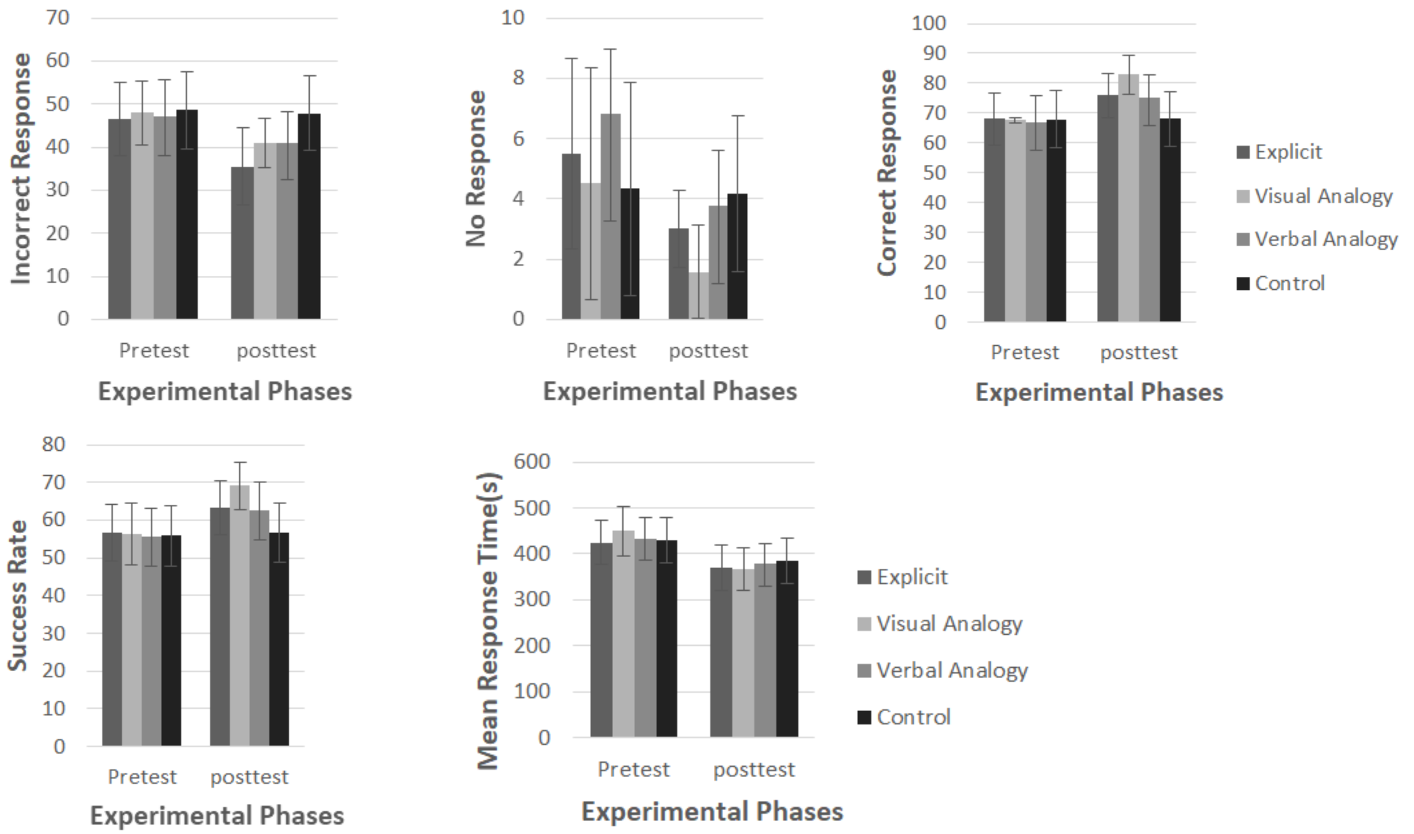

Figure 3. Working memory (all subscores Incorrect Response, No Response, Correct Response, Success Rate, and Mean Response Time) during pretest and posttest for all experimental groups and control group. Error bars represent standard deviation.

difference from pretest to posttest. No significant difference was observed in the control group from pretest to posttest (t = -0.61, p = 0.55, 95% CI = -4.19 2.36, Cohen's d = 0.09; Fig. 3).

Success Rate

The results of ANCOVA on posttest success rate data while controlling for pretest data as the covariant variable indicated a significant group effect (F (2,48) = 16.45, p = 0.0001, partial η^2 = 0.53). Results of Bonferroni post hoc test suggested that in posttest, visual analogy group (69.09 ± 5.56) had performance similar to verbal analogy (62.70 ± 6.24; p = 0.007) and explicit (63.26 ± 7.26; p = 0.006) groups, with higher success rate only compared to the control group (56.66 ± 7.8; p = 0.0001). In addition, no significant difference was found between verbal analogy and explicit groups (p = 0.99), while both had higher success rate than the control group (p = 0.006 and p = 0.006, respectively). The dependent t-test results demonstrated that all three groups, namely visual analogy (t = -6.00, p = 0.0001, 95% CI = -17.46, -8.09, Cohen's d = 1.83), verbal analogy (t = -6.66, p = 0.0001, 95% CI = -9.23, -4.46, Cohen's d = 1), and explicit (t = -7.30, p = 0.0001, 95% CI = -8.58, -4.61, Cohen's d = 0.89), experienced a significant difference from pretest to posttest. No significant difference was observed in the control group from pretest to posttest (t = -0.61, p = 0.55, 95% CI = -3.49, 1.95, Cohen's d = 0.09, Fig. 3).

Mean Response Time

The results of ANCOVA on posttest mean response times while controlling for pretest data as the covariant variable indicated a significant group effect (F (2,48) = 16.26, p = 0.0001, partial η^2 = 0.53). Results of Bonferroni post hoc test suggested that in posttest, all three experimental groups had similar mean response times which were shorter than the mean response time of the control group: visual analogy (366.75 ± 46.33), verbal analogy (378.41 ± 42.67, p = 0.99), explicit (369.58 ± 48.50, p = 0.99), and control (385.29 ± 48.32, all three at p = 0.0001). The dependent t-test results demonstrated that all three groups, namely visual analogy (t = 22, p = 0.0001, 95% CI = 79.55, 45.94, Cohen's d = 1.24), verbal analogy (t = 10.69, p = 0.0001, 95% CI = 44.14, 67.02, Cohen's d = 2.51), and explicit (t = 19.25, p = 0.0001, 95% CI = 49.15, 61.84, Cohen's d = 1.15), experienced a significant difference from pretest to posttest. No significant difference was observed in the control group from pretest to posttest (t= -0.05, p = 0.95, 95% CI = -28.43, 29.93, Cohen's d = 0.01, Fig. 3).

Discussion

The present study aimed to compare different forms of explicit and analogy learning in terms of their impact on children's motor learning. Drawing on the research background in this area, we believed that analogy learning in any form would probably outperform explicit learning. However, our findings suggest that visual analogy learning not only enhanced performance and learning compared to cases where other methods like verbal analogy and explicit learning were used but it also caused the working memory to function better to some extent. On the other hand, no difference was found between verbal analogy and explicit learning although both groups outperformed the control group. Our findings are extensively consistent with Tse and Masters [26]. In their study on improving motor skill acquisition through analogy in children with autism spectrum disorders, they found that visual analogy learning enhanced motor learning in children with autism spectrum disorders in comparison to verbal analogy learning as well as explicit learning techniques and therefore it can be argued that, like children with autism spectrum disorders, normal children also have more chances in visual analogy learning than in other conditions to learn motor skills like basketball free throw.

In addition, studies have shown that learning through receiving visual information results in a more stable performance, learning, and memory compared to learning through receiving verbal information [33]. For example, Lindner et al. [33] demonstrated that visual stimuli used in classrooms can enhance students' learning and recall compared to verbal stimuli. This enhanced performance is thought to be even stronger at younger ages and during childhood [34]. Thus, this can be cited as one of the reasons why visual analogy learning works better than verbal analogy learning. It seems that the children in the visual analogy learning were able to exhibit higher quality in extracting key information on free-throw skills to develop their motor learning [26].

The children in the visual analogy group reported an improved functioning of working memory compared to the verbal analogy and explicit learning groups. Previous studies have shown that the working memory is more often targeted by demands linked to the processing of instructions [6, 13]. Limited working memory capacity has been shown to influence learning [35]. This will cause disruption in motor and cognitive performance. When the number of rules to be processed by a learner reaches the maximum personal capacity, adding only one more instruction can disrupt performance [36]. In other words, the cognitive demands associated with conceptualization and implementation of explicit instructions are higher compared to the demands placed by analogy instructions; that is, as suggested by previous studies [6, 13], analogy instructions are less working memory demanding. However, in the present study, this advantage of analogy learning was only observed in the visual analogy group. Analogy includes all motion-specific information classified into a simple unit of information [18]. This information will provide more positive impacts if it is presented in a visual form as well [33]. In other words, visual analogy learning conditions in the present study are believed to have properly released the working memory resources to modify motions, thereby enhancing motor learning and performance.

During explicit learning, coaches and teachers often focus on technical aspects (body movements) and concentration on a learner's body parts and motions, unknowingly using internal attention instructions to teach skills. A large body of studies has shown that applying internal attention instructions can lower the level of performance and motor learning [37]. In the present study, the participants in the explicit instructions group were asked to "stand with their feet together, look at the hoop, use their dominant hand to carry the ball and their non-dominant hand to support the ball from below, move the ball upward, and release it once their arm was in the upright position". Such instructions seem to focus on internal aspects of attention, thereby deteriorating motor learning and performance [37]. However, studies have also indicated that in the analogy learning style, the learner's attention shifted away from his/her body parts toward an external focus of attention [22]. So, this can be another potential reason for the better performance of the analogy learning group in this study.

It is important to note, however, that the verbal analogy group had performance similar to that of the explicit learning group while underperforming compared to the visual analogy group. The instructions provided to the individuals in the verbal analogy group to imagine a child picking a cookie from a jar on the table probably got them to focus their attention on parts of their bodies, e.g., their hands, while performing a throw (internal attention), causing diminished free-throw performance in children because of detrimental effects on automatic motor control processes [37]. On the other hand, this number of instructions, however small it was, negatively influenced children's working memory, as reflected to some extent in their working memory scores. Finally, it seems that further pressure on the working memory of the children in the verbal learning group potentially decreased children's performance and learning compared to the visual analogy group [38].

On the other hand, we also compared verbal analogy and explicit instructions to show that both groups outperformed the control group, equally leading to better motor learning and performance as well as an enhanced function of the working memory in children. Most studies in this area have shown that analogy learning works better than explicit instructions in terms of enhancing motor learning [6, 7, 13, 22]. Compared to explicit learning models, analogy learning models contain fewer instructions and, because of reduced working memory demands, are assumed to be able to further enhance motor learning [38], particularly under pressure and stress [4].

Our results failed to support the findings of the literature in demonstrating outperformance of verbal analogy learning over explicit learning, and in this respect our findings are inconsistent with major studies that showed verbal analogy functions better than explicit learning [6, 7, 13, 21]. For example, our results on comparing verbal analogy and explicit learning are not in line with Lola & Tzetzis [39], who showed that verbal analogy learning produced better outcomes than explicit learning. The findings are also inconsistent with a part of the results found by Chatzopoulos et al. [21], who showed that compared to explicit learning, analogy learning improved balance performance in children. However, this improvement was not observed in other locomotion skills and, therefore, the second part of their findings is consistent with the present study. Like our study, Tse and Masters [26] also found no evidence to suggest that the verbal analogy group outperformed the explicit learning group in children with autism spectrum disorders.

Another potential reason for the difference between our results and the findings of the majority of previous studies [6, 7, 13, 21] on the similar performance of verbal analogy and explicit learning groups may lie in the fact that children have a different ability to process information. During childhood, the brain and behavior may undergo reorganization over the course of development [40]. According to the sensory-motor hypothesis, in early childhood learning depends on the processing function of the motor sensor, while in later stages, it may further rely on cognitive processes. Thus, in the present study, it is possible that some children were still in their sensory-motor stage of their development, while others might have passed this stage and were more capable of processing more complex information. These developmental models match our findings well demonstrating that the difference in movement-specific reinvestments could be potentially caused by differences in the ability to learn through analogy [26].

However, it is important to note that we did not directly measure children's reinvestment and this can present one limitation of our study. Another limitation of the present study is its small sample size, which should be reconsidered by researchers in future studies. However, one advantage of the present study was the skill acquisition time. Unlike most previous studies, we tried to increase acquisition time from several trials in one day to eight 90-trial sessions over a period of one month, potentially leading to more reliable results. Like a number of studies by Masters and his colleagues, we used similar analogy models for basketball free throws. It is recommended that future studies use other models of analogy for other motor skills to determine the extent to which visual and verbal analogy learning can influence motor learning. Our findings can be applied to instructional and sports environments particularly for children.

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