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The effects of analogy teaching on sport skill acquisition in children

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Abstract

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Keywords

analogy learning, motor skill, basketball

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Article

The effects of analogy teaching on sport skill acquisition in children

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Keywords: analogy learning, motor skill, basketball.

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1. Introduction

Teaching motor skills to novices has been the main task of physical educators, and studies in motor learning have always sought to discover better ways to optimize the skill acquisition process [1]. In motor skills instruction, movement information is presented transparently through the performer's demonstration, illustration, feedback, and verbal guidance [2].

Still, motor skills can be learned implicitly or explicitly. Implicit motor learning is the relatively passive accumulation of task-relevant knowledge that is normally processed at an unconscious level and cannot be easily verbalized [3]. Explicit knowledge is thought to occupy conscious attention or working memory resources [4, 5]. Furthermore, it is believed that explicit knowledge of movement mechanics may interfere with the execution of a motor skill by competing for available cognitive resources required for task execution [6] and/or by raising awareness of normally automatic processes to the level of consciousness [7]. The existing literature illuminates that explicit learners try to recall the principles they learned during training, which seems to: a) overload working memory, b) block the automated learning process, c) decrease pleasure, and d) probably decrease self-efficacy, as well [8]. However, Masters and Maxwell [3] and Masters [9] have argued that reducing the amount of explicit task-relevant knowledge accrued during learning may help to eliminate its negative effects on performance. Masters [9] introduced the concept of learning by analogy to promote the implicit acquisition of motor skills. Movement analogies reduce the number of task-relevant principles into a single "all-encompassing biomechanical 'metaphor'" [9]. A learner who focuses on a single analogical rule is less likely to receive explicit knowledge of other task parameters [10]. Thus, learning is predominantly governed by acquiring implicit knowledge processed at an unconscious level.

Additionally, it is difficult for this type of knowledge to be raised by the learner to the level of conscious control, which might hamper efficient task execution. Analogies are often used to aid the learning of a new concept by relating it to a fundamentally similar concept [11, 12]. The effectiveness of this approach has been affirmed in the academic education of children [13, 14].

Several studies have investigated the possibility of instruction by analogy to promote motor learning [15–17]. Many studies have shown that resilient motor performance is associated with decreased reliance on working memory resources [18, 19]. For instance, Capio et al. [18] showed that by learning the overhand throw in an errorless manner (errorless learning is a method wherein errors during learning are avoided, in contrast to trial-and-error [20]) (i.e., increasing throwing distance to the target), children improved the throwing skill and accuracy under a multi-task condition. They speculated that the cognitive demands for working memory resources in errorless learning programs were low; therefore, children benefited when they were required to perform the throwing skill with the presence of a concurrent secondary task. To our knowledge, a limited number of studies have examined the application. Nonetheless, none of the previous studies have examined the application of analogies in motor learning by children. If working memory resources are freed by analogy instructions, it is likely that children, particularly those aged 5 to 7, who tend to have slower information processing speed [21] and limited verbal working memory capacity [18, 22–24], might benefit from it.

In basketball, free throw (FT) is an unopposed attempt to score points by shooting from behind the free-throw line, a line situated at the end of the restricted area. Successful FT shooting requires accuracy, precision and good concentration, but more importantly, it requires good mechanics with the shot. As described by Elliott [25], an understanding and application of movement mechanics are necessary to use a good technique and to help athletes to developed their full potential. Several authors suggest that a player's shooting success can be enhanced with proper training using a scientific approach, for example using the method of implicit learning, especially analogy learning [26, 27]. Burns [26] and Hudson [28] highlight the importance of developing good shooting techniques by applying kinematics movement.

Owen [29] suggests that one of the reasons for the low percentages of success in FT is that most players never learned the proper technique at an early stage. Consequently, the identification of key components related to success in FT shooting is necessary for the development of proper feedback training and technique learning in novice basketball players.

Experimental evidence is needed for developing task and equipment modification in beginner learning. As Farrow and Reid (2010) explain, "Nowadays a challenge is in making some recommendations for modifying equipment and games to help cultivate a love of gaming and developing skills acquisition. Therefore, analogy learning and learning by modification of equipment are both considered implicit learning. In analogy, the learning focus is on skill execution whereas in learning by modified equipment focus is on modification equipment and environmental constraints".

Additionally, research in the area of implicit learning and effectiveness in children is very limited. On the other hand, elementary and early childhood is a sensitive period of motor learning. Therefore, providing an environment where a child can develop motor learning is likely to be more effective in the future of the individual's exercise. In addition, currently, it is unclear whether analogy learning and learning through modified equipment can develop in a biomechanically and kinematically different way from explicit learning skills. Research in the field of analogy learning has used fewer children as subjects, and the effect of this method of implicit learning on motor skills in children has not been fully elucidated. Besides, implicit learning studies of modified equipment have only one manipulated variable (e.g., reduced racket weight in tennis or reduced ball size in basketball). However, the anthropometric characteristics of children such as height, weight, and body composition with respect to performance are yet to be investigated.

The primary objective of the current study was to examine the application of analogy learning to a modified basketball free throw shot skill. A common analogy, used by basketball coaches is to finish the shot as if your hand is reaching for a cookie from a cookie jar [30, 31]. This analogy guides the learner to the correct form of the movement and has the effect of imparting a backspin on the basketball, which improves the chances of success [31, 32]. Moreover, the study sought to determine the type of learning, i.e., analogy learning or explicit learning, suitable for promoting the children's acquisition of skills that are biomechanically and kinematically different from the same skill learned by explicit instructions, and to determine how the physical form of the skill evolves over practice.

2. Materials and methods

2.1. Participants

Forty-five right-handed healthy beginner male students (mean age 9.93 ±0.55 years; height 1.39 ±4.16 m; body mass 31.65±3.23 kg; beginner in basketball) participated in the study. The University Ethics Committee approved all procedures for the ethical use of human subjects following the Helsinki Declaration. Participation was voluntary and informed written consent was obtained from the participants before they were involved in the study. Considering the students' age, informed consent was retrieved from their parents. All of the students were informed about the purpose of the study. They were also fully aware of the physical risks that might arise from participation in this research.

A priori power analysis using G*Power was conducted to determine the sample necessary to draw a meaningful conclusion in the study [41, 42]. A power analysis of multivariate analysis with a power equivalent to 0.95 and alpha of 0.05 suggested that a sample size of 45 children would be sufficient to detect a medium effect size of 0.25. Similarly, a power determination for the analysis of variance with a power equivalent to 0.80 and an alpha of 0.05 revealed that a sample size of 30 children would be adequate to identify a medium effect size of 0.05 [43]. Therefore, a sample size of 45 was deemed adequate to avoid the problem of type II error. Subjects were randomly allocated to an explicit learning condition (n = 15), an analogy learning condition (n = 15), or an uninstructed control condition (n = 15).

2.2. Tasks

Each participant practiced a modified basketball FT 3 m away from the front of the basketboard in a standing position with the right hand using a small ball (i.e., 440 g with a circumference of 69.85 cm (27.5″)) and a rim with an inner diameter of 45.72 cm (18″) and with an adapted height of 2 m. This modified task was adopted to reduce the length of the learning process (because of the shorter shooting distance and lower rim height compared with the regular free throw position) and to allow the collection of kinematic data in a controlled laboratory environment. Ten FT attempts were recorded in a biomechanical laboratory with two-dimensional (2D) video data collection (i.e., using 240 Hz camera resolution).

2.3. Procedure

Participants in each learning condition (explicit, analogy, and control) performed 10 practice sessions (each session included 4 blocks of 15 trials) during the study period. After the 10-session practice program, a post-test took place, followed by a retention test conducted one week later, during which there was no FT practice. Participants in the explicit and analogy groups were given an instruction sheet containing eight written instructions (describing the correct technique to perform the shot) and a single analogy instruction (Table 1), respectively. CG participants received no instruction and were simply told to shoot using their methods. At the beginning of each block of trials, participants were reminded of the appropriate instructions.

Table 1. Instructions given to participants in the explicit and analogy conditions [44]

Explicit / Instructions
"Support the ball with the hand of your non-shooting arm. Keep the forearm vertical before shooting. The shoulder, elbow, and wrist should align with the rim before shooting. During shooting, the ball should move from below the chin towards an upward and forward direction. Extend the elbow fully at the ball release. Follow through by snapping your wrist forward so the shooting hand faces downward. Release the ball with your fingertips. Hold follow-through (keep the wrist firm) until the ball reaches the rim".
Analogy / Instruction
"Shoot the ball as if you are trying to put cookies into a cookie jar on a high shelf."

The performance in each trial was determined according to the scores set by the American Alliance for Health, Physical Education, Recreation and Dance (AAPEHRD's) basketball test:

- 3 points if the ball enters the rim without hitting the rim or the board
- 2 points if the ball goes into the basket while hitting the board or the hoop
- 1 point when the ball does not enter the basket despite hitting the board or the rim.

To record the FT shots, a calibration space of 150 × 251 cm was measured to allow a complete view of the player during the FT recording. A 240 Hz camera was set parallel to the FT line to obtain a sagittal view of the player. Six markers (Fig. 1) were placed on the right side of the body to capture the motion of major joints and segments at the levels of the (1) shoulder (greater tubercle of the humerus), (2) elbow (between the lateral epicondyle of the humerus and head of the radius), (3) wrist (center of the right wrist joint,), (4) hip (greater trochanter of the femur), (5) knee (lateral epicondyles). The ball's entry into the basket was not recorded on video but registered manually for successful and missed shots. The Kinovea software was used to examine shooting kinematics. In each video frame, the following markers were manually digitized: shoulder, elbow, wrist, and knee. Connections were made between specific markers to create 2D coordinates of the following segments:

1. The right arm between the shoulder and elbow.
2. Right forearm between elbow and wrist.
3. Right hand between the wrist and pinky finger.
4. The right trunk between the shoulder and hip.
5. Right thigh between hip and knee.

Data collection was made using the following protocol:

1. The camera gathered raw data.
2. Raw data was gathered by manually tracking triggered markers, which replaced missing markers with the help of interpolation.
3. The data were filtered in 2D data.

Two phases of the structural components of the motion were used for acquisition and analysis. Phase one (flexion phase) represents the time between the onset of the knee flexion to the knee flexion peak, while phase two (extension phase) is the time between the onset of the knee extension to the knee extension peak.

The elapsed time of each acquisition was calculated for both phases for every trial. Hand speed at the time of the ball release and four joint angles (i.e., knee, shoulder, elbow, and wrist) were computed.

2.4. Data analysis

The acquisition stage consisted of 10 sessions containing 4 blocks of 15 attempts. At the first and tenth sessions, basketball throwing pre and post-test was also recorded during the kinematic test, followed by a test after 1 week. Descriptive and inferential statistics were used to analyze the data. The descriptive statistics section calculated the central indices (number of observations, mean, and standard deviation) related to experimental groups. In inferential statistics, using bootstrap confidence intervals, a repeated measure of variance analysis was performed to examine the in-group performance of the subjects based on the kinematic sections. Also, to evaluate the external function of analysis of variance (2 × 3) (group × test) Bonferroni's post hoc test was employed.

A between-group ANOVA was conducted to test the hypothesis that analogy instruction would produce similar effects on the learning experience as explicit instruction based on the measured kinematic variables. It is worth noting that the normality assumption was evaluated and deemed satisfactory before conducting the ANOVA test. The analysis was conducted at a 0.05 confidence level using SPSS version 20 for Windows.

3. Results

Table 2. Descriptive statistics of the study variables.

Observations		Pre		Post		
	Group	Mean	SD	Mean	SD	n
Shoulder	ANA	70.155	14.665	28.965	7.801	200
	IMPL	68.730	12.950	24.940	7.908	200
	CNTRL	82.835	10.000	51.505	5.588	200
Elbow	ANA	102.595	10.881	69.200	4.672	200
	IMPL	104.685	9.618	76.765	5.591	200
	CNTRL	108.485	5.863	82.930	4.953	200
Wrist	ANA	71.830	19.431	122.095	5.133	200
	IMPL	69.100	19.023	111.600	4.839	200
	CNTRL	74.665	10.410	104.005	6.662	200
Knee	ANA	25.235	7.265	63.770	5.702	200
	IMPL	27.375	9.913	68.640	5.309	200
	CNTRL	25.330	5.967	46.945	5.237	200
Hand Velocity	ANA	2.383	0.331	2.358	0.170	200
	IMPL	2.354	0.353	2.355	0.165	200
	CNTRL	2.478	0.142	2.404	0.150	200

Observations	Group	Pre Mean	Pre SD	Post Mean	Post SD	n
	ANA	66.530	10.153	60.980	4.844	200
T1	IMPL	65.165	9.814	61.315	7.488	200
	CNTRL	63.645	8.672	59.700	4.442	200
	ANA	43.595	5.931	32.490	4.536	200
T2	IMPL	43.960	6.716	31.905	3.513	200
	CNTRL	39.955	6.553	32.725	3.302	200
Performance	ANA	7.705	0.457	7.385	0.488	200
	IMPL	8.045	4.993	7.380	0.487	200
	CNTRL	7.855	0.353	7.635	0.483	200

Abbreviations: ANA = Analogy; IMPL = Implicit; CNTRL = Control

The descriptive statistics associated with learning motor tasks across the three groups in both pre and post-tests are summarized in Table 2. It could be seen that the mean range of motion in the observed body parts slightly decreased between both pre and post-tests.

The independent between-groups ANOVA yielded a statistically significant effect across the three groups in the post-tests F (8, 16) = 283.233, $P = 0.001$, $\eta^2 = 0.793$. Hence, the null hypothesis of no difference between the means was rejected. To further evaluate the differences between the three means, the significant ANOVA was follow-up with Bonferroni post-hoc tests. The kinematics actions of the knee, shoulder, elbow, and wrist were statistically significant ($p < 0.001$), as observed in Table 3.

Table 3. Post-hoc tests amongst the study variables

Variables	Group		Post Tests M. Diff	Post Tests SD Error	Post Tests Sig	Retention Tests M. Diff	Retention Tests SD Error	Retention Tests Sig.
Shoulder	ANA	IMPL	4.0250*	.71790	.0000	-.7650	.65222	.7239
		CNTRL	-22.5400*	.71790	.0000	-22.1100*	.65222	.0000
	IMPL	ANA	-4.0250*	.71790	.0000	.7650	.65222	.7239
		CNTRL	-26.5650*	.71790	.0000	-21.3450*	.65222	.0000
	CNTRL	ANA	22.5400*	.71790	.0000	22.1100*	.65222	.0000
		IMPL	26.5650*	.71790	.0000	21.3450*	.65222	.0000
Elbow	ANA	IMPL	-7.5650*	.50864	.0000	-11.3700*	.51275	.0000
		CNTRL	-13.7300*	.50864	.0000	-22.1000*	.51275	.0000
	IMPL	ANA	7.5650*	.50864	.0000	11.3700*	.51275	.0000
		CNTRL	-6.1650*	.50864	.0000	-10.7300*	.51275	.0000
	CNTRL	ANA	13.7300*	.50864	.0000	22.1000*	.51275	.0000
		IMPL	6.1650*	.50864	.0000	10.7300*	.51275	.0000
Wrist	ANA	IMPL	10.4950*	.56018	.0000	10.4550*	.92035	.0000
		CNTRL	18.0900*	.56018	.0000	15.3700*	.92035	.0000
	IMPL	ANA	-10.4950*	.56018	.0000	-10.4550*	.92035	.0000
		CNTRL	7.5950*	.56018	.0000	4.9150*	.92035	.0000
	CNTRL	ANA	-18.0900*	.56018	.0000	-15.3700*	.92035	.0000
		IMPL	-7.5950*	.56018	.0000	-4.9150*	.92035	.0000
Knee	ANA	IMPL	-4.8700*	.54197	.0000	-6.8500*	.43941	.0000
		CNTRL	16.8250*	.54197	.0000	15.2950*	.43941	.0000

Observations			Post Tests			Retention Tests		
Variables	Group		M. Diff	SD Error	Sig	M. Diff	SD Error	Sig.
	IMPL	ANA	4.8700*	.54197	.0000	6.8500*	.43941	.0000
		CNTRL	21.6950*	.54197	.0000	22.1450*	.43941	.0000
	CNTRL	ANA	-16.8250*	.54197	.0000	-15.2950*	.43941	.0000
		IMPL	-21.6950*	.54197	.0000	-22.1450*	.43941	.0000
T1	ANA	IMPL	-.3350	.57521	1.0000	1.7500*	.44928	.0003
		CNTRL	1.2800	.57521	.0793	.9700	.44928	.0937
	IMPL	ANA	.3350	.57521	1.0000	-1.7500*	.44928	.0003
		CNTRL	1.6150*	.57521	.0155	-.7800	.44928	.2492
	CNTRL	ANA	-1.2800	.57521	.0793	-.9700	.44928	.0937
		IMPL	-1.6150*	.57521	.0155	.7800	.44928	.2492
Performance	ANA	IMPL	.0050	.04857	1.0000	.0700	.04901	.4611
		CNTRL	-.2500*	.04857	.0000	-.1650*	.04901	.0024
	IMPL	ANA	-.0050	.04857	1.0000	-.0700	.04901	.4611
		CNTRL	-.2550*	.04857	.0000	-.2350*	.04901	.0000
	CNTRL	ANA	.2500*	.04857	.0000	.1650*	.04901	.0024
		IMPL	.2550*	.04857	.0000	.2350*	.04901	.0000

*. The mean difference is significant at the .05 level.
Abbreviations: ANA = Analogy; IMPL = Implicit; CNTRL = Control

Moreover, to determine whether there are differences between the groups in the retention ability tests, the null hypothesis of no difference between the groups was also tested. A statistically significant difference was observed across the three groups F (8,16) = 332.057, $P = 0.001$, $\eta^2=0.818$. The post-hoc follow-up tests via Bonferroni revealed that the kinematic range of motion in the elbow, knee, and wrist, as well as T1, are different between the groups $P < 0.001$ (see Table 3). It is worth highlighting that the effect size related to the statistically significant effects is classified as large according to the previous guidelines [43].

4. Discussion

Our controlled study examined the effects of explicit and analogy learning on basketball FT shooting performance among healthy children. The analogy group's performance was significantly better in the skill taught. The explicit learners achieved lower scores compared to the analogy learners.

Considering the low capacity of children's working memory [31] and the low demands for working memory resources during analogy learning, our hypothesis that the analogy group would perform better than the explicit one was confirmed.

Therefore, another benefit of analogy learning as children's enhanced manipulative motor skill acquisition was confirmed in addition to the balance, locomotor skill, and automatization benefits of analogy learning [45]. The motor skill learning studies need more quality aspects, including standardization and specific explanation of motor skill acquisition and automaticity. To our knowledge, only one study favoured movement automaticity after implicit learning compared to explicit learning [46]. However, instructions provided in the explicit group do not exceed the children's WMC. Buszard et al. [47] demonstrated that children's WMC was positively associated with following instructions, implying that many instructions in a single motor skill learning can be overwhelming and negatively influence learning, especially by the lower WMC capacity children. We believe that exceeding 4 instructions for the children in the explicit group might have limited performance benefits in FT skill practices in our study. Thus, our results in favour of the analogy group showed that children bypassed the declarative stages of learning while performing the free throw. The current study's findings show that teaching through analogies helped healthy children more than explicit instructions in FT skills. The improvement can be attributed to providing a single analogy to integrate the complex structure of the to-be-learned skill into an easy-to-recall comparison that could have reduced the recruitment of WMC, allowing better sensory-motor functioning.

For instance, the analogy group may have responded instinctively to correct the arm movements, apply force impulse during arm extension, and increase their coordination due to a clear focus on their performance. This increased awareness of afferent input to the sensory-motor region of the cerebral cortex might have improved their biomechanically efficient performance.

Children with intellectual disabilities have a poorly functioning working memory and have difficulties to comply with many instructions [31]. Considering that analogy learning is less dependent on working memory than explicit learning [16], analogy learning may benefit preschool children with intellectual deficits.

Considering that analogies decrease dependence on working memory [16], motor skill learning using analogies may provide significant support to children with a poorly functioning working memory who cannot comply with many instructions. Although developing a single ideal pattern may not result from analogy learning, sufficient movement patterns could be developed while preserving functional variability [48, 49]. Moreover, participants responding to familiar metaphors will likely achieve higher motor outcomes [50]. Because of the analogy, learners can develop procedural knowledge without overloading working memory or developing declarative knowledge. Reduced working memory loading via information-integrated biomechanical metaphors is linked to the acquisition of inter-joint coordination structures for beginner learners [51] and higher retention of motor performance and self-efficacy [8].

The significant contribution of analogies may be the familiarity felt while performing desired skills. This familiarity can create a better socio-emotional learning environment, make the task "look easier", and promote self-efficacy, decreasing anxiety levels and supporting successful performance [50].

A promoted self-awareness and better regulation of sensory-motor inputs in the verbal analogy learning environment may shift the focus to the process rather than the result. This can be a valuable tool for rapidly improving the ideal emotional state and enhancing motor kinematics, movement strategy, and motor performance [52]. Therefore, motor learning with an analogy method induced a solid socio-emotional environment that could be helpful for those with emotional regulation problems and a sense of self-efficacy.

However, individual differences and personal characteristics associated with conscious control may be a significant determinant of motor learning, i.e. successful performance. For this reason, we strongly suggest analyzing personal behavioral and psychological characteristics in motor learning studies to identify personal qualities that gain better skill acquisition via implicit and explicit learning environments. Generalizing beyond the scope of the study is not recommended.

5. Conclusions

Our results underline the significance of instructions used in motor learning practices. The analogy learning training method combined with the modified equipment is recommended for children (aged 10–12) to learn FT in basketball. The conclusions may illuminate the innovative instructional approach for coaches seeking accelerated motor skill acquisition.

The study findings are considered a specific contribution to the literature; future studies with larger and more diverse samples could enhance our understanding of the effectiveness of analogy learning in motor skill acquisition.

Also, future motor learning studies can focus on developing adequate analogy instructions for teaching sports skills and sport-specific enhanced learning settings among healthy children. Another comparison to the analogy of motor learning may be specific motor learning with the haptic disturbance in future research.

Limitations

Certain limitations are acknowledged in this study. The study focused on a specific age group (10–12-year-old children), sports (basketball) and motor skills (FT); hence, the findings may not be generalizable to other age groups or sports. The study design did not include long-term retention or learned skill transfer analysis. While the sample size was determined through a priori power analysis, forty-five right-handed healthy beginner male students may limit the generalizability of findings to broader populations, female students or other age groups. The participants were beginners in basketball, which may limit the applicability of results to more experienced athletes or individuals with different skill levels. Extrapolating these findings to other sports or activities requires caution, as skill acquisition processes may vary across domains

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