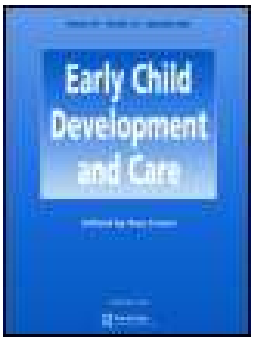

Early Child Development and Care

ISSN: 0300-4430 (Print) 1476-8275 (Online) Journal homepage: https://www.tandfonline.com/loi/gecd20

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To cite this article: Dimitris Chatzopoulos, Elena Foka, George Doganis, George Lykesas & Thomas Nikodelis (2020): Effects of analogy learning on locomotor skills and balance of preschool children, Early Child Development and Care, DOI: 10.1080/03004430.2020.1739029

To link to this article: https://doi.org/10.1080/03004430.2020.1739029

Published online: 10 Mar 2020.

EARLY CHILD DEVELOPMENT AND CARE
https://doi.org/10.1080/03004430.2020.1739029

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Effects of analogy learning on locomotor skills and balance of preschool children

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ABSTRACT
The purpose of this study was to compare the effects of explicit and analogy learning on preschool children's running, long jump, gallop and balance. The participants were 43 preschool children randomly assigned to the analogy learning group (22 children) or the explicit (21 children). In the explicit learning group explicit instructions were given about body and limb movements of the to-be-learned skill, whereas in the analogy group instructions were given in the form of analogies (i.e. using metaphors). The duration of the intervention was four lessons. Prior to and after the intervention, children were assessed for running, long jump, gallop, and balancing on one foot. The results showed that both groups improved significantly regarding locomotor skills, whereas only the analogy group improved in the balance task. The findings support the use of analogy learning as an alternative to explicit in acquiring locomotor skills and improving balance in preschool children.

ARTICLE HISTORY
Received 28 January 2020
Accepted 3 March 2020

KEYWORDS
Explicit learning; analogy learning; preschool children; balance; locomotor skills

Introduction

According to cognitive scientists, there are two approaches of motor learning termed explicit and implicit learning (Masters, van der Kamp, & Capio, 2013). Explicit learning is defined as learning generating verbal knowledge of movement performance (known as 'explicit knowledge' or 'declarative knowledge'), and it is dependent on working memory involvement (Kleynen et al., 2014). This mode of learning relies on the assumption that the establishment of a new sensorimotor association requires cognitive activity (working memory) to process the information and control the movement (Wulf, 2013). During the process of explicit learning, teachers provide information about the technical aspects (i.e. body and limb movements) of the to-be-learned movement and encourage learners to focus on their own body movements (internal focus of attention). For example, in basketball shooting, coaches instruct learners to'Follow-through by snapping wrist forward, so that the shooting hand is facing downward', and learners try to control their movements in a step-by-step fashion using explicit knowledge of what should be done (Lam, Maxwell, & Masters, 2009).

The second approach of acquiring a new motor skill is implicit motor learning, which is defined as learning which progresses with minimal increase in verbal knowledge of movement performance and without awareness (Kleynen et al., 2014). During implicit learning, a beginner learns a movement without being aware of the knowledge underlying movement execution (Masters et al., 2013). An implicit learner is unaware of the learning that is taking place and cannot verbalize how he performs a movement. For example, this is depicted, in the movie 'The Karate Kid' (Kamen, 1984), the trainer

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Mr. Miyagi taught his student Daniel-san how to deflect a punch using the 'wax on, wax off' analogy (Poolton & Zachry, 2007).

The difference between implicit and explicit learning is the extend of working memory engagement in movement production during practice (van der Kamp, Steenbergen, & Masters, 2018). Explicit learning promotes a reliance on working memory, whereas implicit attempts to minimize the use of it. During explicit learning, the beginner uses valuable cognitive resources from working memory to process and manipulate the many explicit instructions, and this interferes with the execution and learning of the new movement (Buszard et al., 2017). On the other hand, implicit learning is less working memory demanding than explicit (van Duijn, Hoskens, & Masters, 2019), and it is well documented that the acquisition of a new skill is directly constrained by the capacity of working memory to store and manage information (Gathercole, Durling, Evans, Jeffcock, & Stone, 2008). Therefore, it is argued that implicit learning is especially beneficial for persons with low working memory capacity e.g. young children (Tse, Fong, Wong, & Masters, 2017).

Masters (1992) introduced the concept of analogy learning as a strategy for reducing the amount of explicit knowledge and promoting the implicit acquisition of motor skills. In analogy learning the complex structure of the to-be-learned movement is integrated into metaphors that can be reproduced by the learner (Kleynen et al., 2014). For example, in basketball shooting Lam et al. (2009) reported that by using the analogy 'Shoot as if you are trying to put cookies into a cookie jar on a high shelf' the analogy group performed better under pressure compared to explicit. Moreover, Wulf, McConnel, Gärtner, and Schwarz (2002) used the analogy 'Hit the ball as if using a whip, like a horseman driving horses' on practicing volleyball 'tennis' serves and reported greater accuracy of the serves in analogy group compared to explicit. In contrast to the plethora of studies involving adult population studies (Komar, Chow, Chollet, & Seifert, 2014; Tzetzis & Lola, 2015; Wu, Porter, & Brown, 2012), only a limited number involved preschool children. For instance, Tse et al. (2017), used the analogy 'jump like a rabbit', in order to teach children (5–7 years) rope skipping and reported no significant differences between explicit and analogy learning.

Fundamental movement skills (FMS) are prerequisite in order to participate successfully in physical activities and sports. There are three categories of FMS (Gallahue, 1996): (a) locomotor skills, such as run, jump and gallop (b) non-locomotor skills, such as static balance and twists, and (c) manipulative skills, such as catch, throw and kick. Research shows that children with better-developed FMS are more likely to enjoy sports and to develop a lifelong commitment to physical activity than those with less-developed FMS (Williams et al. 2008). The purpose of the present study was to compare the effects of explicit and analogy learning on the development of preschool children's FMS.

The difference between explicit and analogy learning is the extent of working memory involvement, with explicit learning demanding more resources than analogy (van Duijn et al., 2019). Moreover, it is well documented that learning a new motor skill is constrained by the capacity of working memory to store and manage information (Tse & Masters, 2019). Taking under consideration children's limited working memory capacity and that analogy instructions releases working memory resources, it was hypothesized that preschool children would perform better in fundamental movement skills under analogy learning conditions compared to explicit learning ones.

Methods

Participants

Sample size was determined using G*Power (version 3.1.7) setting a medium effect size at $f = .25$, alpha at .05, and power at .80, the required total sample size is 34 (Faul, Erdfelder, Lang, & Buchner, 2007). The sample of the study was a convenience sample and consisted of forty-three children (22 boys and 21 girls; mean age = 5.62 years, SD = .65 years, range from 4.5 to 6.5) who attended a preschool centre. The children were free of acute musculoskeletal injuries and had no diagnosed learning disabilities. The sample was stratified by sex, to ensure equal representation of boys and girls in the two groups. The analogy group consisted of 22 children (11 boys, 11 girls, mean age = 5.65 years, SD = .67 years), and the explicit group were 21 (11 boys. 10 girls, mean age = 5.54 years, SD = .56 years). The research was conducted in accordance to the ethical guidelines of local University. Informed consent was obtained from the guardian of the participants, and they could withdraw from the study at any time. No participant withdrew because of injury or any other adverse experience.

Procedures

The intervention consisted of four lessons (two weeks, twice a week, 30 min per lesson), and the teacher and the content lessons of both groups were the same. The difference between the two groups was the way instructions were given to the children (explicit or analogy instructions). Each lesson began with warm-up activities, to steadily increase children's heart rate (3 min, moving to an action song). For example 'If You're Happy and You Know It!', (https://www.youtube.com/watch?v=71hqRT9U0wg), or 'Jump, Run and Shout!' (https://www.youtube.com/watch?v=hft6uJQIF4g), which include several skills (e.g. running and jumping) and children performed the skill every time they heard the name of the skill.

After the warm-up the teacher presented a skill and gave explicit instructions in the explicit group and analogies in the analogy group. In each lesson 3–5 min were allocated on each skill depending on the intensity of the activity and the interest of the children. Action songs were used in order to engage children with the activities. Moreover, games as 'Simon says' or 'Freeze' were used with the corresponding skills. At the end of each lesson a cool down-song with low tempo was used to progressively decrease children's heart rate.

A panel of three experienced physical education (PE) teachers (more than 5 years of teaching experience in FMS), were asked to participate in two meetings to determine the explicit and analogy instructions that best suit to teaching the skills. The teachers of the panel were informed about the aim of the study and they were given the following criteria for the development of the analogies: (a) they should lead to the desired movement and (b) they should be meaningful to preschool children. The explicit instructions for the skills were adopted from Professional Development Service for Teachers (PDST) (2017) (Table 1).

In both groups the speed running was demonstrated and the song 'Run and walk' (https://www.youtube.com/watch?v=j7qdWyHMjwE) was used. Moreover, the teacher played the rhythmic values of eighth (♪) on tambourine, and the children synchronized their running with it. The analogy instruction for speed running was 'Imagine as if you are playing drums with your elbows on a drum hanging at a wall'.

The action song 'Jump Up, Jump In' (https://www.youtube.com/watch?v=jnfsPan6Qo4) was used for jumping, and the children were asked to jump every time they heard the word 'jump' in the song. Interchangeably, the teacher played the rhythmic values of half on tambourine and the children

Table 1. Explicit instructions.

Run	Gallop
Lift your knees high and bring your heels close to your bottom.	Turn hips and shoulders to the direction of movement.
Look ahead.	Establish one leg as the lead
Run on the balls of your feet.	Keep trail leg behind lead leg.
Bend your elbows and swing your arms.	Arms are bent and lifted to waist level.
Jump	*Balance*
Bend the knees, hips and ankles.	Stand still with your foot flat on the ground.
Swing the arms back then quickly forwards and upwards.	Hold your bent leg away from your other leg.
Push off from both feet together, with the toes being last part of the body to leave the ground.	Keep head stable with eyes focused forward on a target.
Land on both feet bending the hips, knees and ankles to absorb the impact.	Trunk stable and upright.

synchronized their jumping with it. The instruction in the analogy group for jumping was: 'Jump like a kangaroo over a stream'.

The song 'See the pony galloping' (https://www.youtube.com/watch?v=xjodOtEpxj0) was used for gallop. Interchangeably, the teacher played the rhythmic values doted eighth and sixteenth on the tambourine to imitate the sound of gallop. The analogy used for gallop was: 'Move your arms like a pendulum clock and make sounds like galloping horses do: clip-clop'.

The teacher demonstrated the one leg stance in both groups and the song 'Balance on one Foot' (https://www.youtube.com/watch?v=aQ2Vco_giiE) was used. The analogy instruction for balance was 'Stand like a stork and point your nose to a fly on the wall'.

Measurement instruments

Locomotor skills

The Test of Gross Motor Development (Ulrich, 1985) was used for the qualitative assessment of the fundamental locomotor skills speed running, gallop and standing long jump. Each skill includes 4 behavioural components that are presented as performance criteria. The children performed three trials of each skill and received a score '1' when a criterion performance was correct two out of three times, otherwise received '0'. The scores for each skill are summed and the perfect score is 4, if all performance criteria are performed correctly two out of three times. Ulrich (1985) reported reliability coefficients ranging from .84 to .90 with a mean of .85, for ages 4–6 and validity coefficient of .81. One week prior to the instruction the children were videotaped and assessed by two experienced instructors. The interater reliability coefficient was r =.91.

Balance measurement

Single leg balance was assessed using a force platform with a sampling rate of 100 Hz (KINVENT, France, www.k-invent.com). The depended variables were peak-to-peak amplitude of Centre of Pressure (CoP) in the Medio/Lateral (CoP-X) and Anterior/Posterior direction (CoP-Y). The children were asked to stand as quiet as possible for 15 s on their dominant leg by flexing the leg that was not being tested. Furthermore, they didn't wear shoes, their arms were hanging relaxed at the sides and they were focused at a cross placed on a wall at eye level 2 m away. Each child performed one practice trial before testing and performed two trials with a pause of approximately 30 sec. The mean of the two trials was used for statistical analysis. The reliability of the measurement was reported to be good to excellent (ICC-CoP-X = 0.71 and ICC-CoP-Y = .76) (Chatzopoulos, 2019).

Statistical analyses

Levene's test and normality checks were carried out and the assumptions were met only for balance data. Therefore, analysis of covariance (ANCOVA) was conducted to test the differences between the explicit and analogy group in balance. The final measurement of balance was the dependent variable and the respective initial was the covariate. The paired samples t-test was applied for assessing the differences between the initial and final values of balance in the same group. Furthermore, effect sizes of ANCOVA are presented as partial eta square values (ηp^2) and for t tests as Cohen's d values.

Regarding the variables running, jumping and gallop, the Shapiro Wilks test showed that the data did not present a normal distribution. For this reason the Mann–Whitney test was used to examine the differences between the groups and Wilcoxon signed-rank test to compare the values within each group before and after the intervention. Effect sizes of the non-parametric tests were calculated using the formula $r = \frac{z}{\sqrt{n}}$, (z: standardized test statistic, n: total number of the sample for Mann–Whitney, whereas for Wilcoxon total number of pairs; .1 small effect, .3 moderate effect and .5 and above large effect). Significance level was set at $p \leq .05$.

Results

Descriptive statistics of the dependent variables are presented in Table 2.

Balance mediolateral direction (CoP-X)

The independent t-test showed that there were no significant differences between the two groups at the beginning of the intervention ($t = .884$, $p = .382$, 95% CI [−.60, 1.54], Cohen's $d = .27$). Covariance analysis showed that the treatment group performed significantly better than the control group at the end of the intervention ($F_{1,40} = 6.41$, $p = .01$, partial eta squared $\eta p^2 = .13$). Paired sample t-tests showed that the intervention group improved significantly from pre to post test ($t = 4.52$, $p < .001$, 95% CI [.953, 2.573], Cohen's $d = 1.40$). On the contrary the control group showed no significant improvement ($t = .94$, $p = .35$, 95% CI [−.42, 1.13], Cohen's $d = .19$).

Balance anterior/posterior direction (CoP-Y)

The independent t-test showed that there were no significant differences between the two groups at the beginning of the intervention ($t = 1.04$, $p = .30$, 95% CI [−.963, 3.043], Cohen's $d = .32$). Covariance analysis showed that the treatment group performed significantly better than the control group at the end of the intervention ($F_{1,40} = 8$, $p = .007$, partial eta squared $\eta p^2 = .16$). Paired sample t-tests showed that the intervention group improved significantly from pre to post test ($t = 2.87$, $p = .009$, 95% CI [.50, 3.13], Cohen's $d = .6$). On the contrary the control group showed no significant improvement ($t = 1.19$, $p = .247$, 95% CI [−1.19, .52], Cohen's $d = .24$).

Run

Mann–Whitney U test showed that there was no significant difference between the two groups at the beginning ($U = 215$, $Z = -.41$, $p = .67$, effect size $r = .06$) and at the end of the intervention ($U = 205$, $Z = -.67$, $p = .49$, effect size $r = .1$). Wilcoxon signed rank test showed that there was a significant improvement in analogy group ($T = 78$, $Z = -3.35$, $p < .001$, effect size $r = .51$) and explicit ($T = 105$, $Z = -3.49$, $p < .001$, $r = .53$) between pre- and post-measurement.

Gallop

Mann–Whitney U test showed that there was no significant difference between the two groups at the beginning ($U = 183$, $Z = -1.30$, $p = .19$, effect size $r = .2$) and at the end of the intervention ($U = 217$, $Z = -.36$, $p = .71$, effect size $r = .05$). Wilcoxon signed rank test showed that there was a significant improvement in analogy group ($T = 190$, $Z = -3.96$, $p < .001$, effect size $r = .6$) and explicit ($T = 171$, $Z = -3.83$, $p < .001$, $r = .58$) between pre- and post-measurement.

Jump

Mann–Whitney U test showed that there was no significant difference between the two groups at the beginning ($U = 196$, $Z = -1.12$, $p = .26$, effect size $r = .17$) and at the end of the intervention ($U = 192$, $Z = -1.01$, $p = .30$, effect size $r = .16$). Wilcoxon signed rank test showed that there was a significant

Table 2. Peak-to-peak amplitude of centre of pressure (CoP) in the medio/lateral (CoP-X) and anterior/posterior direction (CoP-Y), run, gallop and jump of the analogy and explicit groups from pre- and post-tests.

	Analogy group		Explicit group	
	Pre	Post	Pre	Post
CoP-X (cm)	6.46 ± 1.51	4.70 ± .93*[a]	5.99 ± 1.95	5.63 ± 2.03
CoP-Y (cm)	10.29 ± 3.38	8.48 ± 2.58*[a]	9.25 ± 3.10	9.96 ± 2.69
Run	2.45 ± .85	3.04 ± .72[a]	2.38 ± .80	3.19 ± .81[a]
Gallop	1.95 ± .57	3.13 ± .56[a]	1.71 ± .71	3 ± .89[a]
Jump	1.18 ± .39	2.86 ± .71[a]	1.33 ± .48	3.09 ± .76[a]

*Significant difference between the two groups ($p<.05$).
[a]Significant difference within groups ($p<.05$).

improvement in analogy group ($T = 253$, $Z = -4.18$, $p < .001$, effect size $r = .64$) and explicit ($T = 231$, $Z = -4.12$, $p < .001$, $r = .63$) between pre- and post-measurement.

Discussion

The present study examined the effects of explicit and analogy learning on balance performance and locomotor skills of preschool children. Given (a) the low capacity of children's working memory and (b) the low demands for working memory resources during analogy learning (Tse & Masters, 2019), it was hypothesized that the analogy group would perform better compared to the explicit one. The results of the study showed that the hypothesis was only partially confirmed, as the analogy group was superior only in the balance task, and both groups showed significant improvements regarding the locomotor skills.

The significant improvements regarding the locomotor skills in the explicit group could be attributed to the small amount of explicit instructions given in the present study (four instructions). Perhaps the amount of the four instructions provided in the explicit group did not exceed the working memory capacity (WMC) of the children. Buszard et al. (2017) demonstrated that working memory capacity of children was positively associated with following instructions when the demands placed on working memory were over 5 instructions. Especially children with low WMC were not able to hold 5 instructions in an active state in mind whilst performing a basketball task (Buszard et al., 2017). According to Cowan (2010), the amount of the instructions that can be held in working memory and processed depends on task demands and is limited to 3–4 items. Therefore, future studies investigating the effects of analogy and explicit learning on motor performance should take under consideration the number of explicit instructions. For instance, Bobrownicki, MacPherson, Collins, and Sproule (2019), used 4 analogy and 4 explicit instructions and reported no significant differences between the two groups in a dart-throwing task. On the other hand Capio, Uiga, Lee, and Masters (2019) reported significant improvement in the analogy group after a single analogy instruction in softball batting ('Swing your bat like you are breaking a tree in front of you with an axe'), and performance decrements of the explicit group using 8 explicit instructions. Perhaps the impaired performance in the explicit group reported in previous studies was not only the result of the nature of the instructions (explicit vs analogy), but also the result of the large number of instructions given in the explicit group. Clearly more studies are needed regarding the optimal number of explicit instructions for preschool children.

The findings of the present study support the view that a single analogy instruction seems to be equally effective as many detailed explicit instructions in teaching locomotor skills. This may be attributed to the capacity of a good analogy to integrate the complex structure of the to-be-learned skill into an easy to recall metaphor that can be reproduced by the learner. For instance, in the locomotor skill gallop the 'clock pendulum' analogy was used without further instruction related to arm/leg coordination. Nonetheless, the children in the analogy group improved significantly their arm/leg coordination. An explanation may be provided by the ecological dynamic theory, according to which, during a movement cycle, one set of limbs is considered as leading the other one (Faugloire, Bardy, & Stoffregen, 2009). It seems, therefore, that during gallop the arm movements lead the entire coordination, and by giving adequate analogy instruction related only to the arm movement, a global reorganization of arm-leg coordination may result. Future studies are needed to develop adequate analogy instructions for teaching locomotor skills in preschool children.

The results of the present study revealed that balance performance of the analogy group improved significantly between pre and post-test, whereas there was no significant improvement in the explicit group. The improved balance performance of the analogy group could be attributed to the different focus of attention in the two learning groups. There are two types of focus during a balance task: visual focus and attention focus (Wulf, 2013). Visual focus during balance tasks is typically kept constant by asking participants to look straight ahead, whereas attention focus refers to the performer's concentration which can be internal (focus on his movements) or external (away from his/her body and limps, e.g. focus on the effects). Jackson and Holmes (2011) demonstrated that conscious control of the movements (internal focus) during a balance task resulted in disruption of coordinated control processes compared to external focus (e.g. on markers attached to the balance platform). It seems that conscious attempts to control the movement of a balance task following explicit instructions, results in disruption of any automatic control processes of balance. On the contrary, directing the attention of the performer away from his movements allows him to use more 'natural' movements to control his balance (Wulf & Lewthwaite, 2016). It is well documented that analogy instruction directs children's attention away from their body movements compared to explicit (Komar et al., 2014), and this may resulted to enhanced balance performance.

The present study supports the finding of Orrell et al. (2006) who reported that the analogy group improved significantly the dynamic balance performance (stabilometer platform), by using the analogy 'Stand like a soldier on guard outside Buckingham Palace'. Due to the limited number of studies investigating the effects of analogies on preschool children's balance performance, future studies exploring this aspect is warranted.

Children with intellectual disabilities have a poorly functioning working memory and have difficulties to comply with many instructions (van Abswoude, Santos-Vieira, van der Kamp, & Steenbergen, 2015). Taken under consideration that analogy learning is less depended on working memory, compared to explicit (Lam et al., 2009), analogy learning maybe beneficial for preschool children with intellectual deficits. Future research is needed to investigate the potential benefits of analogy learning in children with intellectual disabilities.

Limitation

The limitation of the study refers to the motivation of the children, as it was not controlled.

Conclusion

The findings of the present study showed that both groups improved significantly regarding the locomotor skills, and only the analogy group performed better in the balance task. Overall, the findings support the use of analogy learning as an alternative to explicit instruction in acquiring locomotor skills and improving balance in preschool children.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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