Psychology of Sport & Exercise 41 (2019) 63–69

Contents lists available at ScienceDirect

Psychology of Sport & Exercise

journal homepage: www.elsevier.com/locate/psychsport

# Improving motor skill acquisition through analogy in children with autism spectrum disorders

Andy C.Y. Tse[a,*], Rich S.W. Masters[b]

[a] Department of Health and Physical Education, The Education University of Hong Kong, Hong Kong, China
[b] Te Oranga School of Human Development & Movement Studies, University of Waikato, Room TT.7.09A,New Zealand

ARTICLE INFO

*Keywords:*
Analogy
Instruction
Motor learning
Children
Autism spectrum disorder

ABSTRACT

Analogy benefits motor learning in children. The present study was to examine the effectiveness of analogy motor learning in children with ASD. Children (N = 48) diagnosed with ASD were randomly assigned to one of four groups: visual analogy, verbal analogy, explicit instruction and control. All groups, except the control group, were given instruction regarding a modified basketball-shooting task through acquisition phase. Results showed that all instruction groups were learning the skill in a similar manner. During retention and transfer tests, performance deteriorated for the verbal analogy, explicit instruction and control groups but not for the visual analogy group when comparing to the performance during the last block of learning phase. This study suggests that visual analogy may be a good instructional option to aid motor learning in children with ASD.

## 1. Introduction

Children with autism spectrum disorder (ASD) are characterized by significant impairments in communication, social interaction and the presence of restricted and repetitive behavioral patterns (American Psychiatric Association, 2016). Beyond these core deficits, motor difficulty has also been regarded as a significant feature of ASD (Downey & Rapport, 2012; Fournier, Hass, Naik, Lodha, & Cauraugh, 2010). An estimated 21%–100% of children with ASD display motor deficits, such as impaired balance and gait, slower speed of timed movement and exaggerated movement (Green et al., 2009; Jansiewicz et al., 2006; Pan, Tsai, & Chu, 2009). These motor deficits affect the ability to perform functional activities, which inevitably disrupt social interaction and communication (Bhat, Landa, & Galloway, 2011). For example, Mody et al (2017) showed that impaired gross motor skills were closely related to receptive language ability (Mody et al., 2017). MacDonald, Lord, and Ulrich (2013) found that poor object-control skills in school-aged children with ASD were associated with impaired social skills (MacDonald et al., 2013). Given these negative consequences, it is important to improve the motor ability of the population. In this context, an effective motor learning process is critical.

Information that facilitates motor learning is often presented by coaches or teachers as explicit, verbal instructions (Masters, 1992). If the correct information is conveyed by explicit verbal instructions, a learner will know clearly '*what*' to do and '*how*' to do it, which promotes faster motor learning. However, if instructions are overly explicit or prescriptive, there may be detrimental effects on the motor learning process (Williams & Hodges, 2005; Wulf & Schmidt, 1997). Extensive studies have shown that skills taught using an explicit approach are less robust in physically and cognitively demanding situations, such as fatigue, psychological stress and multi-tasking (Lam, Maxwell, & Masters, 2009; Law, Masters, Bray, Eves, & Bardswell, 2003; Masters & Poolton, 2012). Therefore, a less prescriptive approach, such as analogy learning, has been suggested by motor-learning scientists (Liao & Masters, 2001; Masters, 2000; Masters & Poolton, 2012).

Analogies have been used to aid learning of a new concept without necessity for explicit instruction, by relating it to a fundamentally similar concept (Gentner, 1983; Gentner, Anggoro, & Klibanoff, 2011; Newton & Newton, 1995). A great deal of work has been done to affirm the efficacy of analogy in children's education and cognitive development (Clement, 1993; Coll, France, & Taylor, 2005; Glynn & Takahashi, 1998; Newton & Newton, 1995; Smit & Finegold, 1995). For example, Vosniadou and Schommer (1988) asked children aged five to seven years to listen to four texts describing unfamiliar topics (e.g., how an infection heals), with or without analogies (e.g., an infection is like a war). The children were asked to recall information about the texts and to answer inferential questions about the topics (e.g., 'do you think that germs are bad?'). Children receiving analogies not only retained more information than those receiving no analogies, but also displayed information inference from the analogies (Vosniadou & Schommer,

* Corresponding author. Rm D4-2/F-03, Block D4, 10 Lo Ping Road, Tai Po, N.T., Hong Kong, China.
*E-mail addresses:* andytcy@eduhk.hk (A.C.Y. Tse), rich.masters@waikato.ac.nz (R.S.W. Masters).

https://doi.org/10.1016/j.psychsport.2018.12.002
Received 9 May 2018; Received in revised form 30 November 2018; Accepted 1 December 2018
Available online 03 December 2018
1469-0292/ 

1988). The ability to transfer information in this way was confirmed in a subsequent study by Donnelly and McDaniel (1993), which revealed that analogy instructed children were more able to answer inferential questions about a newly learned science concept associated with a collapsing star than explicitly instructed children.

In the context of motor learning, analogy learning is thought to produce performance that is less likely to be disrupted by cognitively demanding conditions (e.g., Lam et al., 2009; Liao & Masters, 2001). Liao and Masters (2001), for instance, showed that learners instructed how to impart topspin to a table tennis forehand shot via an analogy (i.e., move the bat up the hypotenuse of a right-angle triangle), displayed stable performance in response to a laboratory stressor compared to learners instructed via explicit rules (e.g., keep the wrist firm, complete the swing with the racquet above the ball). Masters and Liao (2003) have speculated that analogy might integrate or 'chunk' the many 'bits' of information that constitute the rule structure of the to-be-learned skill into a form that requires less conscious processing, making the motor concept/movement easier to learn (Rich S. W. Masters, 2000; R. S. W. Masters & Liao, 2003). Examples of analogy use include asking basketball learners to shoot the basketball as if they are 'reaching for a cookie from a cookie jar' (Lam et al., 2009), or asking breaststroke learners to 'glide like a torpedo' (Seifert, Button, & Brazier, 2010). Recently, Tse, Fong, Wong, and Masters (2016) conducted a rope skipping study using both explicit and analogy instructions in typically developing (TD) children. Results showed that analogy instruction was feasible to induce motor learning in a child population. More importantly, the analogy instructed performance was more robust than explicitly instructed performance in a multitasking condition (Tse et al., 2016). Tse et al. (2016) explained the findings using the theoretical framework of working memory. A large body of literature shows that motor performance is closely associated with working memory (see Maxwell, Masters, & Eves, 2003 for more information). Tse et al. (2016) argued that the chunking characteristic of analogy learning might have freed up some working memory resources, leaving them available to handle the extra cognitive demands imposed by the secondary task, resulting in more robust motor performance in a multitasking condition. Given the aforementioned motor learning benefits of analogy learning in TD children, and the fact that children with ASD are generally deficient in working memory capacity (Andersen, Hovik, Skogli, Egeland, & Øie, 2013; Jiang, Capistrano, & Palm, 2014; Verté, Geurts, Roeyers, Oosterlaan, & Sergeant, 2006), it is hoped that analogy could also be applied to motor learning in children with ASD and induce similar motor learning benefits (i.e., robust motor performance) under cognitively demanding conditions. However, to date no study has examined this application.

The aim of the present study was to examine the use of analogy instruction for acquiring a basketball shooting skill in children with ASD and with mild intellectual disabilities (ID). The major reason for choosing autistic children with ID (i.e. classic autism) is that previous studies (Matson & Shoemaker, 2009; Postorino et al., 2016) had indicated a high prevalence rate of ID in children with ASD (over 47.6%, Postorino et al., 2016). Implication of the present study would be more significant if analogy instruction is shown to be beneficial in children with ASD and ID to acquire new motor skill. Meanwhile, presentation modality was of particular interest, i.e., whether a visual or auditory verbal modality is best for analogy use by children with ASD. Findings of previous studies suggest that children with ASD tend to rely more on visual information than phonological information in instructional interpretation (Quill, 1997; Trembath, Vivanti, Iacono, & Dissanayake, 2015). Therefore, different analogy presentation modalities (visual/verbal) may induce different motor performance in children with ASD. In the present study, we developed the 'cookie jar' analogy of Lam et al. (2009) study into visual (a picture depicting the movements associated with taking a cookie from a cookie jar) and verbal instructions. We also modified the number and content of the explicit instructions that were used in the Lam et al. (2009) study for easy understanding by our participants. Given the motor learning benefits of analogy previously shown in TD children (Tse et al., 2016), we hypothesized that either visual or verbal analogies would induce motor learning in children with ASD with increased shooting accuracy over the learning blocks, and that analogy groups (visual and verbal) would display more robust shooting performance (i.e., higher accuracy) than the explicit instruction and control groups during delayed tests. In addition, given the visual learning tendency of children with ASD (Trembath et al., 2015), the visual analogy instructed participants were expected to perform better than verbal analogy instructed participants during the delayed tests.

## 2. Methodology

### 2.1. Participants

In total, 48 children (40 boys and 8 girls; mean age: 10 years, 10 months, SD: 2.00) from three local special schools for children with intellectual disability were successfully recruited with the following inclusion criteria: (1) aged 9–12 years; (2) ASD diagnosis based on the Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-5, American Psychiatric Association, 2016); (3) IQ over 50 based on participant's personal record as assessed by the Chinese version of the Wechsler Intelligence Scale- Forth Edition (Wechsler, 2010); (4) ability to follow instructions with the assistance of the researcher; (5) no formal basketball training experience, and (6) no history of reading disabilities according to their parents. Exclusion criteria were: (1) one or more co-morbid psychiatric disorders as established by a structured interview based on the DSM-5; (2) a complex neurological disorder (e.g., epilepsy, phenylketonuria, fragile X syndrome, tuberous sclerosis); and (3) visual and auditory deficits. An experienced physician evaluated each participant and determined the ASD diagnosis. In addition to the formal diagnosis by a physician, we also collected parent ratings using the traditional Chinese version of the Social Responsiveness Scale, Second Edition (SRS-2; Constantino & Gruber, 2012) to screen for autistic traits and autism behaviors. Consistent with Pan et al. (2017), we did not use the Autism Diagnostic Interview-Revised (ADI-R, Lord et al., 1994) or the Autism Diagnostic Observation Schedule Lord et al., 2000 because the instruments were not available as Chinese-language versions for research. Nevertheless, we believe that the experienced physician accurately and reliably diagnosed ASD. Medication usage and records of after-school therapy (e.g., speech therapy, occupational therapy) were also collected from parents. They were then randomly assigned to one of four instruction groups: visual analogy, verbal analogy, explicit and control (see Table 2 and Fig. 2 for more information). To assess the working memory characteristics of participants and to control for the potential confounding effects of working memory on the results, the Corsi block-tapping test (Corsi, 1972; Schellig, 1997) and digit span test (Thorndike, Hagen, & Sattler, 1986) were administered to compare the visuospatial and phonological component of working memory (Baddeley, 1992) between the groups. Written consent was obtained from participants' parents/guardians and schools and the study was approved by the university Ethics Committee. Baseline demographic characteristics including working memory spans of different components of the four groups were comparable to each other with $ps > .05$ as shown by Table 1.

### 2.2. Apparatus

A digital camera (1920 × 1080 pixels, 24 fps; Canon G15 Power Shot) was used to record the motor performance of the participants throughout the study. A portable hoop (Spordas Hang-A-Hoop) and a regular size 5 basketball weighing 25% less than a standard basketball (Spordas Max BB Trainer: circumference: 69.90 cm; weight: 481.94 g) were used to suit the motor ability of children with ASD. The hoop height and the distance from the throwing line to the hoop were

**Table 1**
Demographic statistics of participants in visual analogy group, verbal analogy group, explicit instruction group and control group.

| | Visual analogy group (n = 12) | Verbal analogy group (n = 12) | Explicit instruction group (n = 12) | Control group (n = 12) | *p* |
|---|---|---|---|---|---|
| Gender | 10 boys and 2 girls | 10 boys and 1 girls | 10 boys and 2 girls | 10 boys and 3 girls | 0.70 |
| Age (years) | 9.92 ± 1.15 | 10.25 ± 1.03 | 9.94 ± 1.16 | 10.33 ± 1.08 | 0.64 |
| Weight (kg) | 34.92 ± 5.53 | 34.66 ± 3.75 | 37.58 ± 2.27 | 37.67 ± 3.11 | 0.11 |
| Height (m) | 1.40 ± 1.71 | 1.39 ± 2.11 | 1.39 ± 1.54 | 1.36 ± 1.41 | 0.98 |
| BMI (kg/m$^2$) | 17.92 ± 2.53 | 18.20 ± 2.62 | 19.51 ± 1.93 | 19.61 ± 1.02 | 0.12 |
| IQ | 76.56 ± 17.45 | 78.40 ± 18.01 | 76.75 ± 18.44 | 80.15 ± 17.80 | 0.59 |
| WMI Standard scores | 84.42 ± 12.26 | 82.08 ± 13.13 | 86.75 ± 10.27 | 80.00 ± 11.67 | 0.54 |
| SRS-2 T-scores | 83.41 ± 5.80 | 80.75 ± 5.08 | 82.08 ± 2.54 | 79.08 ± 3.06 | 0.10 |
| Corsi memory span | 4.08 ± 1.51 | 4.08 ± 1.68 | 4.33 ± 1.78 | 4.50 ± 1.31 | 0.90 |
| Digit span: forward | 4.67 ± 1.15 | 4.33 ± 1.15 | 4.00 ± 1.48 | 4.42 ± 1.44 | 0.67 |
| Digit span: backward | 3.67 ± 1.23 | 3.83 ± 1.03 | 3.17 ± 0.94 | 3.50 ± 1.09 | 0.48 |
| Medication (n)rowhead | | | | | |
| Yes | 1 | 2 | 4 | 2 | |
| No | 11 | 10 | 8 | 10 | |

modified to 8 feet (i.e., 2.43 m) and 10 feet (i.e., 3.05 m) respectively to suit children's shooting performance (Chase, Ewing, Lirgg, & George, 1994). The setup is presented in Fig. 1. Statistical analyses were carried out using IBM SPSS Statistics Version 24.

### 2.3. Design and procedure

The study was taken place in an university's indoor gymnasium. It consisted of two phases: the learning and the assessment phase. The learning phase started one week after screening. It consisted of 6 blocks of 15 trials separated by 3 min of rest. Each participant was asked to shoot the basketball into the hoop as accurately as possible. Performance was assessed using the scoring system developed by Hardy and Parfitt (1991), p. 5 was awarded for a 'clean' basket; 4 for rim and in; 3 for backboard and in; 2 for rim and out; 1 for backboard and out; and 0 for a complete miss (Hardy & Parfitt, 1991). The experimenter recorded each shot and the performance of each block was measured by adding the scores of the 15 shots (i.e., the full score was 75). Before each learning block, the experimenter demonstrated a standard stance position (e.g., stand before the position line, feet are shoulder width apart, bend knees slightly for every shot) and a standard grip (e.g., place the air hole between the middle and index fingers of the shooting hand, holding the side of the ball with the other hand). Participants assigned to the instruction groups were then instructed to shoot the basketball to the hoop using the respective instructions. Participants in the control group received no instruction and were simply told to shoot using their own methods (Lam et al., 2009). To minimize differences in the way in which instructions were provided, instructions were solely provided by one experimenter, who used the same presentation mode on all occasions. Considering the variability on IQ and communication ability of the participants, the experimenter would use different wordings to instruct the participants to ensure they all understand the instructions. Nevertheless, the content and the presentation mode remained the same across all participants within group. Each instruction were given twice at the beginning of each block of the learning phase. No instruction were given in the assessment phase (i.e retention and transfer). The assessment phase started one day after the learning phase, during which retention and transfer tests were conducted. During the retention test, participants were required to perform 15 shots for the same distance from the hoop. Three minutes after the retention test, participants engaged in a transfer test in which the distance from the hoop was increased by 20%.

### 2.4. Measures and statistics

SPSS software (Version 24.0; SPSS, Inc., 2018) was used for statistical analysis. Preliminary tests of the assumptions of the statistical tests, including data normality using Shapiro-Wilk tests (all $ps > .05$) and homogeneity of variance (Levene's tests: all $ps > .05$), were met. Shooting performance was measured by the experimenter using the scoring system applied by Hardy & Parfitt, 1991). To allow more accurate measurement of the scores, recorded video clips were evaluated by a research assistant blinded to the study groups and conditions. Intra-class coefficients (ICCs) were used to assess inter-rater reliabilities (Shrout & Fleiss, 1979). Inter-rater reliability was analyzed with ICC (2, 1), a two-way random model. A mean inter-rater reliability of 0.99 was obtained for the scores. Pearson correlation was used to analyze the relationship between shooting scores and participant's attributes including age, IQ, WMI, SRS and results revealed that the shooting scores were not correlated with any of attribute within each group. Thus, we did not use participants' attributes as a covariate in any statistical analysis. A 4 (Instruction Group) × 6 (Block: 1 to 6) ANOVA with repeated measures was used to analyze performance during the learning phase. Shooting performance in the retention and transfer tests was analyzed using one-way ANOVA. Post hoc tests with Bonferroni adjustments were performed if there was any significant effect.

**Table 2**
Visual analogy, verbal analogy and explicit instruction protocols.

| Visual analogy protocol | Verbal analogy protocol | Explicit instruction protocol |
|---|---|---|
| Starting position | Starting position | Starting position |
| Stand with feet side by side | Stand with feet side by side | Stand with feet side by side |
| Eyes on the hoop | Eyes on the hoop | Eyes on the hoop |
| Carry the ball with your strong hand bottom and the other hand on the side of the ball | Carry the ball with your strong hand at the bottom and the other hand on the side of the ball | Carry the ball with your strong hand at the bottom and the other hand on the side of the ball |
| Shooting | Shooting | Shooting |
| Look at this picture (Fig. 2) | Shoot the ball as if you are trying to put cookies into a cookie jar on a high shelf | Move the ball upward and release the ball when your strong arm becomes vertical |
| | | When releasing the ball, your strong hand is facing downward |

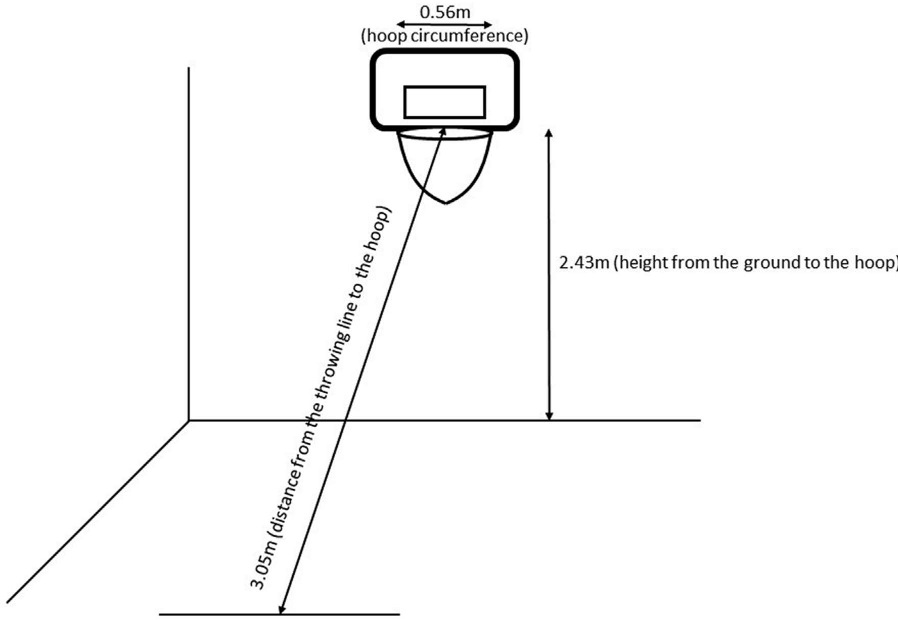


**Fig. 1.** Task setting.

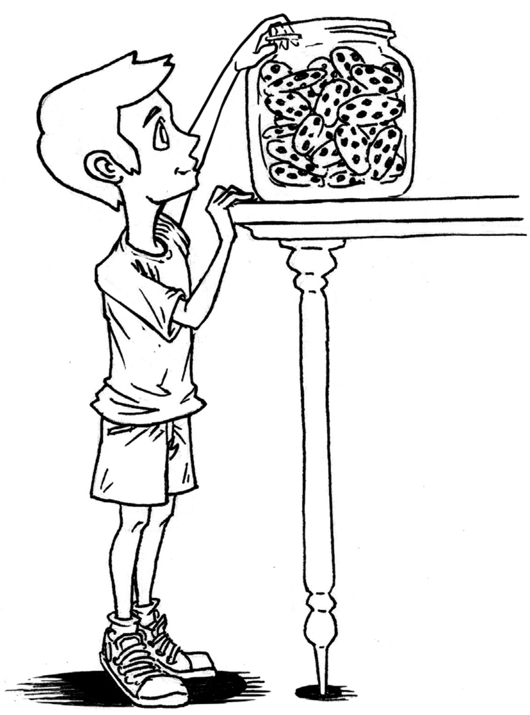

**Fig. 2.** Illustration for the visual analogy protocol.

## 3. Results

### 3.1. Basketball shooting performance

Shooting accuracy measured by scores of all four groups throughout learning and assessment phases are shown in Table 3 and Fig. 3.

### 3.2. Learning phase

The two-way ANOVA with repeated measures revealed a significant block effect [$F$(2.90, 127.64) = 23.64, $p < .001$, partial η2 = 0.35], a significant group effect [$F$(3, 44) = 10.26, $p < .001$, partial η2 = 0.41] and a significant interaction effect [$F$(8.70, 127.64) = 6.84, $p < .001$, partial η2 = 0.32] during the learning phase. Post-hoc multiple comparisons with Bonferroni adjustments showed that the three instruction groups scored significantly higher than the control group between Blocks 2 and 6 (all *ps* < .001). Separate two-way ANOVAs with repeated measures were conducted to examine the linear trend across block for each group. Results showed that all three instruction groups scored significantly higher across the learning blocks (i.e., Block 1 to Block 6) (all *ps* < .001) whereas the control group did not ($p$ = .51).

### 3.3. Assessment phase

Retention test: One-way ANOVA revealed a significant group effect during the retention test [$F$(3, 44) = 14.52, $p < .001$]. Post hoc multiple comparisons with Bonferroni adjustments indicated that the visual analogy group performed with higher scores ($M$ = 19.92, $SD$ = 3.03) than the verbal analogy group ($M$ = 14.25, $SD$ = 4.05) ($p < .001$, 95% $CI$ = [1.57, 9.77]), the explicit instruction group ($M$ = 14.75, $SD$ = 3.25) ($p < .001$, 95% $CI$ = [1.07, 9.27]) or the control group ($M$ = 10.17, $SD$ = 4.09) ($p < .001$, 95% $CI$ = [5.65, 13.85]). Moreover, both the verbal analogy and explicit instruction group scored higher than the control group (verbal analogy vs control: $p$ = .03, *95% CI* = [−0.02, 8.18]; explicit instruction vs control: $p < .05$, 95% $CI$ = [0.48, 8.68]). No significant score difference was found between the verbal analogy group and the explicit instruction group ($p$ = .74, 95% $CI$ = [−4.60, 3.60]).

Transfer test: One-way ANOVA revealed a significant group effect during the transfer test [$F$(3, 44) = 20.65, $p < .001$]. Post hoc multiple comparisons with Bonferroni adjustments indicated that the visual analogy group performed with higher scores ($M$ = 16.58, $SD$ = 2.84) than the verbal analogy group ($M$ = 10.83, $SD$ = 2.89) ($p < .001$, 95% $CI$ = [2.50, 9.00]), the explicit instruction group ($M$ = 11.92, $SD$ = 2.15) ($p < .001$, 95% $CI$ = [1.41, 7.92]) or the control group ($M$ = 7.42, $SD$ = 3.50) ($p < .001$, 95% $CI$ = [5.91, 12.42]). Meanwhile, both the verbal analogy and explicit instruction groups scored higher than the control group (verbal analogy vs control: $p < .05$, 95% $CI$ = [0.16, 6.67]; explicit instruction vs control: $p$ = .02, 95% $CI$ = [1.25, 7.75]). No significant score difference was found between the verbal analogy group and the explicit instruction group ($p$ = .39, *95% CI* = [-4.34, 2.17]).

**Table 3**
Means and standard deviations of basketball shooting scores for the instruction groups during the acquisition and assessment sessions.

| Instruction | Acquisition | | | | | | Assessment | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | Retention | Transfer |
| Visual analogy | 13.25 (3.11) | 14.83 (3.07) | 16.50 (3.21) | 17.50 (3.48) | 19.67 (3.47) | 21.75 (3.25) | 19.92 (3.03) | 16.58 (2.84) |
| Verbal analogy | 12.67 (3.03) | 14.17 (2.72) | 15.25 (2.63) | 16.25 (3.11) | 17.92 (4.10) | 19.50 (3.83) | 14.25 (4.05) | 10.83 (2.89) |
| Explicit instruction | 13.58 (4.91) | 14.25 (4.47) | 15.75 (5.21) | 16.33 (4.83) | 18.42 (5.12) | 20.17 (4.88) | 14.75 (3.25) | 11.92 (2.15) |
| Control | 13.00 (4.47) | 11.17 (3.46) | 10.42 (3.92) | 10.00 (3.79) | 10.75 (4.18) | 9.42 (4.03) | 10.17 (4.09) | 7.42 (3.50) |

## 4. Discussion

The present study examined the use of analogy with different presentation modalities on motor skill acquisition in children with ASD. It was hypothesized that analogy learning would induce improved motor performance in children with ASD. The findings supported this hypothesis. Results showed that the shooting accuracy of both analogy groups increased throughout the learning phase, which implies that analogy learning is feasible for children with ASD when acquiring a novel motor skill. However, contrary to our hypothesis about the motor learning benefits of analogy learning, only the visual analogy group displayed more robust motor performance during transfer and retention while there was no difference in motor performance between the verbal analogy, explicit instruction and control groups.

One possible explanation for the results may lie in the visual learning tendency displayed by children with ASD. It has consistently been shown that children with ASD show better abilities in nonverbal problem solving than in verbal reasoning and that they are superior in their encoding of visuospatial rather than auditory information (Caron, Mottron, Berthiaume, & Dawson, 2006; Hermelin & O'Connor, 1970; Quill, 1997; Tissot & Evans, 2003). For example, Hermelin and O'Connor (1970) showed that children with ASD completed a puzzle task faster than TD children when a visual cue (a line drawn across pieces) was presented. Joseph, Keehn, Connolly, Wolfe, and Horowitz (2009) demonstrated that children with ASD exhibited an overall faster reaction time in a visual search task compared with age- and IQ-matched TD children (R. M. Joseph et al., 2009). Given this cognitive profile, participants in the visual analogy group may therefore have interpreted the information about the key movement component of the basketball shoot (arm high with the wrist being relaxed) more easily than those in the verbal analogy and explicit instruction groups, resulting in more robust motor performance.

Compared with previous analogy motor learning studies (e.g., Lam et al., 2009; Liao & Masters, 2001; Tse et al., 2016), which indicated superior performance of verbal analogy over explicit instruction, the present study did not show any performance differences between verbal analogy and explicit instruction groups in the assessment phase (i.e., retention and transfer tests). This finding suggests that analogy may not be sufficient to induce motor learning benefits (e.g., robust performance in retention and transfer) for children with ASD given its verbal nature. Although verbal analogy is thought to encourage implicit motor learning (i.e., requires less conscious processing - Liao & Masters, 2001; Poolton, Masters, & Maxwell, 2006), processing of the verbal instruction itself still requires phonological resources from working memory. Previous studies showed that verbal working memory capacity in children with ASD was generally low to maintain and monitor goal-related information (Robert M. Joseph, Steele, Meyer, & Tager-Flusberg, 2005). The verbal analogy group in the present study may not have been able to fully grasp the motor concept of the analogy or to hold the task information in mind during the assessment phase when cognitive demands were high (i.e., retention and transfer tests). This argument is supported by findings from the working memory assessment prior to the experiment. In the present study, the Corsi memory span of participants ranged from 4.08 to 4.50 (see Table 1), which was similar to the norm (ranged from 4.04 to 4.53) of the age-matched TD children reported (Piccardi et al., 2014). However, when comparing the findings of the digit span tests (both forward and backward) in the present study with the previous norms reported for TD children (Brito, Alfradique, Pereira, Porto, & Santos, 1998), discrepancies were noted. For instance, the digit forward spans reported in the present study ranged from 4.0 to 4.67 while norms for the age-matched TD children were from 2.9 to 4.8. For the digit backward span, the range in the present study was 3.17–3.83, while norms for age-matched TD counterparts ranged from 2.9 to 4.8 (Brito et al., 1998). With limited verbal working memory in children with ASD, verbal analogy may not be sufficient to induce the motor learning benefits shown in TD children. However, since comparisons were made across three different studies, there may be factors such as gender and experimental conditions that

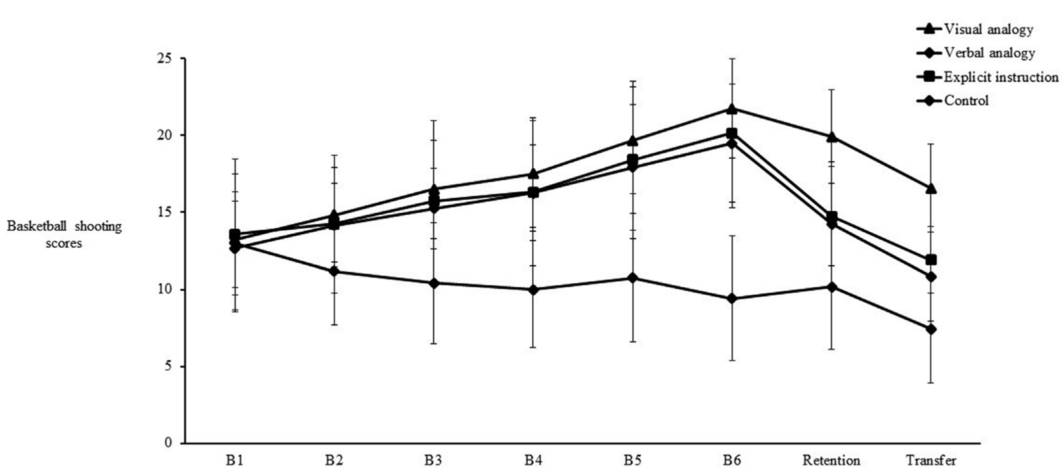


**Fig. 3.** Interaction effect among groups (visual analogy versus verbal analogy versus explicit instruction versus control) and blocks during the acquisition and assessment phases.

confound results. Future studies of motor learning in children with ASD should therefore consider recruiting TD control groups for direct working memory comparison.

It is also worth noting that number of instruction given to the verbal analogy group is fewer than that to the explicit instruction group. With less working memory demand for fewer instructional information, the performance of verbal analogy group should be better than that of the explicit instruction group. However, the present study shows an equivalent performance of both groups during the test phases. This finding has illustrated a property of analogy, where it depends on the way of information being chunked by the participant rather than the amount of instructional information. In the present study, it may be the way of chunking in children with ASD is different from TD children, which results in no difference between verbal instruction and explicit instruction. Nevertheless, no previous study has been done to explore the way of how information is interpreted between analogy and explicit instruction from a neural perspective. Future studies exploring this aspect is warranted.

Several limitations should be considered in the present study. First, the sample size was small with only 12 participants in each group. Future studies may consider using a larger sample size. Second, there was no TD comparison group. Our justification based on the working memory theoretical framework for the between-group performance during the assessment phase cannot be verified. Moreover, without a TD comparison group, it is unclear whether visual analogy works the best specifically for children with ASD, or whether visual analogy actually works the best for both ASC and TD child population. Future studies are needed to compare the motor learning difference between ASD and TD children groups. Third, there was a lack of comprehensive working memory assessment (e.g. backward Corsi memory span test), it is recommended that future similar studies should incorporate a more comprehensive working memory assessment.

## 5. Conclusion

To conclude, the present study is pioneering work that examined the feasibility of using analogy instructions with different presentation modalities in motor learning for children with ASD. Results only supported the hypothesis that the motor performance of children with ASD could be enhanced by visual analogy instruction. This finding has two important implications. First, given the visual learning tendency by the participants in the present study, it provides valuable insight for teachers and coaches who aim to help children with ASD to acquire new motor skills. Second, the study provides a new research direction when examining motor learning in children with ASD based on the working memory theoretical framework.

## Declaration of conflicting interests

The author declares no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## Funding

This work was supported by the ECS Support Grant (Grant number: RG45/2016-2017R) and the Departmental Research and Development Seed Money at the Department of Health and Physical Education, the Education University of Hong Kong (Grant number: 04218).

## Acknowledgments

The authors would like to thank Mr. Ivan Louey for drawing the visual analogy and Dr. W. H Lai for assessing the eligibility of the participants. He would also like to express their gratitude to all the children who participated in this study, teachers and parents for their support.

## References

American Psychiatric Association (2016). *Diagnostic and statistical manual of mental disorders: DSM-5.* Washington, DC: American Psychiatric Association.

Andersen, P. N., Hovik, K. T., Skogli, E. W., Egeland, J., & Øie, M. (2013). Symptoms of ADHD in children with high-functioning autism are related to impaired verbal working memory and verbal delayed recall. *PLoS One, 8*, e64842.

Baddeley, A. (1992). Working memory. *Science, 255*, 556–559.

Bhat, A. N., Landa, R. J., & Galloway, J. C. (2011). Current perspectives on motor functioning in infants, children, and adults with autism spectrum disorders. *Physical Therapy, 91*, 1116–1129.

Brito, G. N. O., Alfradique, G. M. N., Pereira, C. C. S., Porto, C. M. B., & Santos, T. R. (1998). Developmental norms for eight instruments used in the neuropsychological assessment of children: Studies in Brazil. *Brazilian Journal of Medical and Biological Research, 31*, 399–412.

Caron, M. J., Mottron, L., Berthiaume, C., & Dawson, M. (2006). Cognitive mechanisms, specificity and neural underpinnings of visuospatial peaks in autism. *Brain, 129*, 1789–1802.

Chase, M. A., Ewing, M. E., Lirgg, C. D., & George, T. R. (1994). The effects of equipment modification on children's self-I and basketball shooting performance. *Research Quarterly for Exercise and Sport, 65*, 159–168.

Clement, J. (1993). Using bridging analogies and anchoring intuitions to deal with students' preconceptions in physics. *Journal of Research in Science Teaching, 30*, 1241–1257.

Coll, R., France, B., & Taylor, I. (2005). The role of models/and analogies in science education: Implications from research. *International Journal of Science Education, 27*, 183–198.

Constantino, J., & Gruber, C. (2012). *Social responsiveness Scale, (SRS-2).* Torrance, CA: Western Psychological Services.

Corsi, P. M. (1972). Human memory and the medial temporal region of the brain. *Dissertation Abstracts International, 34*, 819B.

Donnelly, C. M., & McDaniel, M. A. (1993). Use of analogy in learning scientific concepts. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*, 975–987.

Downey, R., & Rapport, M. J. K. (2012). Motor activity in children with autism: A review of current literature. *Pediatric Physical Therapy, 24*, 2–20.

Fournier, K. A., Hass, C. J., Naik, S. K., Lodha, N., & Cauraugh, J. H. (2010). Motor coordination in autism spectrum disorders: A synthesis and meta-analysis. *Journal of Autism Developmental Disorders, 40*, 1227–1240.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science, 7*, 155–170.

Gentner, D., Anggoro, F. K., & Klibanoff, R. S. (2011). Structure mapping and relational language support children's learning of relational categories. *Child Development, 82*, 1173–1188.

Glynn, S. M., & Takahashi, T. (1998). Learning from analogy-enhanced science text. *Journal of Research in Science Teaching, 35*, 1129–1149.

Green, D., Charman, T., Pickles, A., Chandler, S., Loucas, T. O. M., Simonoff, E., & Baird, G. (2009). Impairment in movement skills of children with autistic spectrum disorders. *Developmental Medicine & Child Neurology, 51*, 311–316.

Hardy, L., & Parfitt, G. (1991). A catastrophe model of anxiety and performance. *British Journal of Psychology, 82*, 163–178.

Hermelin, B., & O'Connor, N. (1970). *Psychological experiments with autistic children.* London: Pergamon.

Jansiewicz, E. M., Goldberg, M. C., Newschaffer, C. J., Denckla, M. B., Landa, R., & Mostofsky, S. H. (2006). Motor signs distinguish children with high functioning autism and Asperger's syndrome from controls. *Journal of Autism Developmental Disorders, 36*, 613–621.

Jiang, Y. V., Capistrano, C. G., & Palm, B. E. (2014). Spatial working memory in children with high-functioning autism: Intact configural processing but impaired capacity. *Journal of Abnormal Psychology, 123*, 248.

Joseph, R. M., Keehn, B., Connolly, C., Wolfe, J. M., & Horowitz, T. S. (2009). Why is visual search superior in autism spectrum disorder? *Developmental Science, 12*, 1083–1096.

Joseph, R. M., Steele, S. D., Meyer, E., & Tager-Flusberg, H. (2005). Self-ordered pointing in children with autism: Failure to use verbal mediation in the service of working memory? *Neuropsychologia, 43*, 1400–1411.

Lam, W. K., Maxwell, J. P., & Masters, R. (2009). Analogy learning and the performance of motor skills under pressure. *Journal of Sport and Exercise Psychology, 31*, 337–357.

Law, J., Masters, R., Bray, S. R., Eves, F., & Bardswell, I. (2003). Motor performance as a function of audience affability and metaknowledge. *Journal of Sport and Exercise Psychology, 25*, 484–500.

Liao, C. M., & Masters, R. S. W. (2001). Analogy learning: A means to implicit motor learning. *Journal of Sports Sciences, 19*, 307–319.

Lord, C., Risi, S., Lambrecht, L., Cook, E. H., Leventhal, B. L., DiLavore, P. C., ... Rutter, M. (2000). The Autism Diagnostic Observation Schedule—Generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders, 30*, 205–223.

Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism Diagnostic Interview-Revised: a revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of autism and developmental disorders, 24*, 659–685.

MacDonald, M., Lord, C., & Ulrich, D. A. (2013). The relationship of motor skills and social communicative skills in school-aged children with autism spectrum disorder. *Adapted Physical Activity Quarterly, 30*, 271–282.

Masters, R. S. W. (1992). Knowledge, knerves and know-how: The role of explicit versus implicit knowledge in the breakdown of a complex motor skill under pressure. *British*

*Journal of Psychology, 83*, 343–358.
Masters, R. S. W. (2000). Theoretical aspects of implicit learning in sport. *International Journal of Sport Psychology, 31*, 530–541.
Masters, R. S. W., & Liao, C. M. (2003). Chunking as a characteristic of implicit motor learning. *Paper presented at the 6th European congress of sport psychology*.
Masters, R. S. W., & Poolton, J. M. (2012). *Advances in implicit motor learning.* London: Routledge.
Matson, J. L., & Shoemaker, M. (2009). Intellectual disability and its relationship to autism spectrum disorders. *Research in Developmental Disabilities, 30*, 1107–1114.
Maxwell, J. P., Masters, R. S. W., & Eves, F. F. (2003). The role of working memory in motor learning and performance. *Consciousness and Cognition, 12*, 376–402.
Mody, M., Shui, A. M., Nowinski, L. A., Golas, S. B., Ferrone, C., O'Rourke, J. A., & McDougle, C. J. (2017). Communication deficits and the motor system: Exploring patterns of associations in autism spectrum disorder (ASD). *Journal of Autism Developmental Disorders, 47*, 155–162.
Newton, D. P., & Newton, L. D. (1995). Using analogy to help young children understand. *Educational Studies, 21*, 379–393.
Pan, C.-Y., Tsai, C.-L., & Chu, C.-H. (2009). Fundamental movement skills in children diagnosed with autism spectrum disorders and attention deficit hyperactivity disorder. *Journal of Autism Developmental Disorders, 39*, 1694.
Pan, C.-Y., Chu, C.-H., Tsai, C.-L., Sung, M.-C., Huang, C.-Y., & Ma, W.-Y. (2017). The impacts of physical activity intervention on physical and cognitive outcomes in children with autism spectrum disorder. *Autism, 21*, 190–202.
Piccardi, L., Palermo, L., Leonzi, M., Risetti, M., Zompanti, L., Damico, S., & Guariglia, C. (2014). The walking corsi test (WalCT): A normative study of topographical working memory in a sample of 4-to 11-year-olds. *Clinical Neuropsychologist, 28*, 84–96.
Poolton, J. M., Masters, R. S. W., & Maxwell, J. P. (2006). The influence of analogy learning on decision-making in table tennis: Evidence from behavioural data. *Psychology of Sport and Exercise, 7*, 677–688.
Postorino, V., Fatta, L. M., Sanges, V., Giovagnoli, G., De Peppo, L., Vicari, S., & Mazzone, L. (2016). Intellectual disability in Autism Spectrum Disorder: Investigation of prevalence in an Italian sample of children and adolescents. *Research in Developmental Disabilities, 48*, 193–201.
Quill, K. A. (1997). Instructional considerations for young children with autism: The rationale for visually cued instruction. *Journal of Autism Developmental Disorders, 27*, 697–714.
Schellig, D. (1997). *Block-tapping-test.* Lisse: Swets & Zeitlinger.
Seifert, L., Button, C., & Brazier, T. (2010). *Interacting constraints and inter-limb coordination in swimming. Motor learning in practice: A constraints-led approach.* 83.
Shrout, P. E., & Fleiss, J. L. (1979). Intraclass correlations: Uses in assessing rater reliability. *Psychological Bulletin, 86*, 420.
Smit, J. J. A., & Finegold, M. (1995). Models in physics: Perceptions held by final-year prospective physical science teachers studying at South African universities. *International Journal of Science Education, 17*, 621–634.
Thorndike, R. L., Hagen, E. P., & Sattler, J. M. (1986). *Stanford-binet intelligence Scale* (4th ed.). Chicago: Riverside.
Tissot, C., & Evans, R. (2003). Visual teaching strategies for children with autism. *Early Child Development and Care, 173*, 425–433.
Trembath, D., Vivanti, G., Iacono, T., & Dissanayake, C. (2015). Accurate or assumed: Visual learning in children with ASD. *Journal of Autism Developmental Disorders, 45*, 3276–3287.
Tse, A. C. Y., Fong, S. S. M., Wong, T. W. L., & Masters, R. (2016). Analogy motor learning by young children: A study of rope skipping. *European Journal of Sport Science, 17*, 152–159.
Verté, S., Geurts, H. M., Roeyers, H., Oosterlaan, J., & Sergeant, J. A. (2006). The relationship of working memory, inhibition, and response variability in child psychopathology. *Journal of Neuroscience Methods, 151*, 5–14.
Vosniadou, S., & Schommer, M. (1988). Explanatory analogies can help children acquire information from expository text. *Journal of Educational Psychology, 80*, 524–536.
Wechsler, D. (2010). *Wechsler intelligence Scale for children* (4th ed.). China: King-May Psychological Assessment Hong Kong.
Williams, A. M., & Hodges, N. J. (2005). Practice, instruction and skill acquisition in soccer: Challenging tradition. *Journal of Sports Science, 23*, 637–650.
Wulf, G., & Schmidt, R. A. (1997). Variability of practice and implicit motor learning. *Journal of Experimental Psychology: Learning Memory and Cognition, 23*, 987–1006.