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Effects of attentional focus on motor learning in children with autism spectrum disorder

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Abstract

Inability to acquire a new motor skill is a common motor difficulty in children with autism spectrum disorder. The purpose of this study is to examine whether the motor learning benefits of an external focus of attention for typically developing children and children with intellectual disabilities could also be applied to children with autism spectrum disorder. Children ($N = 65$; mean age = 10.01 years) diagnosed with high-functioning autism spectrum disorder were randomly assigned into one of the three groups: external focus ($n = 22$), internal focus ($n = 22$), and control ($n = 21$). They were required to throw beanbags at a static target for 50 acquisition trials, 10 retention trials, and 10 transfer trials. While all three groups learnt the skills in a similar manner during the acquisition phase, the internal focus group demonstrated more robust motor performance than the external focus group and the control group in both retention and transfer tests, while there was no difference between the external focus group and the control group in both retention and transfer tests. The findings provide evidence that internal focus of attention may be more effective for facilitating motor learning in children with autism spectrum disorder. However, further study is needed to determine the factors contributing to this finding.

Keywords

attentional focus, autism spectrum disorder, children, motor learning

Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental condition characterized by difficulties with social communication, social reciprocity, inflexibility of behavior and thoughts, and atypical sensory processing (*Diagnostic and Statistical Manual of Mental Disorder* (5th ed.; DSM-V; American Psychiatric Association, 2013). Motor impairment is also prominent (Bhat et al., 2011; Cossu et al., 2012; Gidley Larson and Mostofsky, 2008; Smith and Bryson, 1994) and has recently been recognized as a core feature of ASD (Bo et al., 2016; Cossu et al., 2012). Children with ASD often exhibit non-functional movements (Loh et al., 2007) and delayed achievement of motor development milestones (Lloyd et al., 2013; Ozonoff et al., 2008). For example, young children with ASD have been found to experience difficulty in accurately moving their limbs (Bhat et al., 2011; Ming et al., 2007) and performing common fundamental movements (Pan et al., 2009; Staples and Reid, 2010). Crawling and walking skills have been found to develop more slowly in children with ASD compared with typically developing (TD) children (Lloyd et al., 2013). Researchers have proposed that these motor deficits may be linked to the inability of children with ASD to acquire new motor skills (Bo et al., 2016; Gidley Larson et al., 2008; Ming et al., 2007). Indeed, children with ASD very often display difficulty acquiring novel motor skills, for example, pedaling a tricycle or pumping their legs on a swing (Gidley Larson et al., 2008). These difficulties appear to significantly disturb the typical development of motor skill competence. According to the conceptual theory of motor skill competence proposed by

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Stodden et al. (2008), proper development of motor skill competence is a primary factor that modulates future participation in physical activities (Stodden et al., 2008). Therefore, poor development of motor skill competence in children with ASD may explain subsequent demotivation regarding participation in physical activities. Meanwhile, motor learning difficulties have been suggested to be closely related to a variety of functional problems such as limited social communication and interaction, restricted interests, and stereotypic behaviors (Bhat et al., 2011; Dziuk et al., 2007; Whittingham et al., 2010) that inevitably affect the long-term physical, mental, and psychological development of children with ASD.

The negative consequences of motor learning difficulties highlight the importance of developing effective techniques to enhance motor learning and motor performance among the ASD population. One possible technique that has received widespread attention is the manipulation of one's focus of attention. Instructions inducing an external focus of attention (directing a learner's attention to the effects of their movements on the environment; e.g. focus on the movement pathway of skateboard; look at the target carefully; focus on the weight and position of the dart) have consistently been found to be more effective than instructions inducing an internal focus of attention (directing a learner's attention to their own movements, e.g. concentrate on your finger movements; focus on your hand position; flex your elbow) (see Wulf, 2013 for a review) in enhancing motor learning in TD children. Recently, this strategy-based difference in motor learning outcome has also been evidenced in children with intellectual disabilities (ID; Chiviacowsky et al., 2013). In Chiviacowsky et al.'s (2013) study, children with ID were taught to throw beanbags at a specific target. One group of children was instructed to focus on the movement of their hands, while the other group was instructed to focus on the movement of the beanbag during the throws. Results showed that the performance of the external focus group was better than that of the internal focus group during practice, as indicated by a higher accuracy score. More importantly, the external focus group displayed more robust performance in retention (1 day after a practice session) and transfer (increasing throwing distance) tests (Chiviacowsky et al., 2013). These findings not only confirmed the benefits of an external focus of attention on motor learning, evidenced by numerous previous studies (e.g. Wulf et al., 1998, 2010; Zachry et al., 2005), but also demonstrated the feasibility of applying an attentional focus effect for motor learning in children with ID—a population that, along with children with ASD, also exhibits developmental delays and difficulties in motor learning (e.g. Connor-Kuntz and Dummer, 1996; Hartman et al., 2010;Westendorp et al., 2011).

Considering the efficacy of the attentional focus effect in enhancing motor learning and motor performance, and the possibility of extending this effect to children with motor dysfunction, we speculated that children with ASD may also benefit from an attentional focus approach. The purpose of this study was to investigate this hypothesis. Similar to Chiviacowsky et al.'s (2013) study, this study comprised three phases: acquisition, a retention test, and a transfer test. All participants were asked to throw beanbags at a specific target without instructions (control) or with instructions that induced attentional focus (i.e. external or internal). Based on the previously reported motor learning benefits of approaches emphasizing an external focus of attention, it is hypothesized that participants receiving external focus instructions would perform better than those receiving internal focus instructions in all three phases (i.e. acquisition, retention test, and transfer test).

Methods

Participants

In relevant previous studies with children, the effect size ranged from $d = 0.30$ (Emanuel et al., 2008) to 1.78 (Tse and van Ginneken, 2017). In this study, the mean value ($d = 1.04$) of these was used to calculate the sample size required. With a 5% level of significance, a sample size of 27 participants (9 per group) was required to achieve a power of 90% for interaction effect using G*Power 3.1.9.2 software (Faul et al., 2007). We received an overwhelming response to our recruitment call, and were able to enroll 65 children from three local schools for children with ID in the study. Written consent was obtained from parents/guardians and the school of each participant. The study was approved by the ethics committee of the appropriate university. The inclusion criteria were as follows: (1) aged 9–12 years; (2) ASD diagnosis given by a physician based on the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed., text revision; DSM-V-TR); (3) nonverbal intelligence quotient (IQ) range over 70; (4) ability to follow instructions and perform requested motor tasks as indicated by a total raw score greater than 40 on the object control subtest of the Test of Gross Motor Development-2 (TGMD-2, Ulrich, 2000); (5) no formal training related to throwing beanbags toward a circular target board and no prior experience in similar experiments; and (6) no history of reading disabilities according to their parents. The participant exclusion criteria were as follows: (1) one or more co-morbid psychiatric disorders as established by a structured interview based on the *Diagnostic and Statistical Manual of Mental Disorder* (4th ed., text rev.; DSM-IV-TR); (2) a complex neurologic disorder (e.g. epilepsy, phenylketonuria, fragile X syndrome, tuberous sclerosis); and (3) visual and auditory deficits.

After screening, 65 participants (48 boys and 17 girls; mean age = 10.14 years; SD = 1.17 years) were successfully enrolled in the study. To ensure fair comparison between groups, participants were first categorized

Table 1. Demographic statistics of participants in internal focus group, external focus group, and control group.

	Internal focus group (n = 22)	External focus group (n = 22)	Control group (n = 21)	p
Gender	14 boys and 8 girls	15 boys and 7 girls	15 boys and 6 girls	0.87
Age (years)	10.14 ± 1.17	10.04 ± 0.89	10.09 ± 0.99	0.96
Weight (kg)	35.68 ± 3.43	37.22 ± 3.57	35.81 ± 4.04	0.31
Height (m)	1.37 ± 2.56	1.39 ± 1.06	1.37 ± 2.64	0.76
BMI (kg/m^2)	18.86 ± 1.25	19.31 ± 0.89	± 18.84 ± 1.93	0.24
SRS-2 T-scores	82.09 ± 4.43	79.24 ± 4.19	80.57 ± 3.94	0.71
TGMD-2 (object control) total raw score	42.31 ± 1.97	41.72 ± 2.47	41.85 ± 2.06	0.41
TGMD-2 overhand throw raw score	0.24 ± 0.44	0.27 ± 0.46	0.28 ± 0.46	0.94
Type of ASD (n)				
Autism	7	6	7	
Asperger's syndrome	15	16	14	
Medication (n)				
Yes	6	9	7	
No	15	13	14	

according to disability type (i.e. Autism and Asperger's syndrome), and within each disability type, further divided into two age groups (age 9–10 years and age 11–12 years). They were then randomly assigned to one of the three groups using a computer program (Microsoft Excel). We collected information about each participant's autistic behaviors by asking parents to complete the Social Responsiveness Scale (Second Edition; SRS-2; Constantino and Gruber, 2012). We also collected information about medication usage and records of after-school therapy (e.g. speech therapy, occupational therapy) from the parents of the participants. Demographic data for the three groups are given in Table 1.

Apparatus. For administration of the TGMD-2, a 4-in lightweight ball and a plastic bat were used for a test of striking skill, a 9-in playgroup ball was used for tests of stationary dribbling and kicking skill, and a tennis ball was used to test overhand throwing and underhand rolling ability. For the beanbag experiment, 10 beanbags weighing 100 g and a vertical black target board (circular with a diameter of 453 mm) were used (Figure 1). The height and distance of the board were adjusted according to each child's height (Eoff, 1985). Statistical analyses were carried out using IBM SPSS Statistics Version 18.

Procedure. Prior to the beanbag experiment, the TGMD-2 (Ulrich, 2000) was conducted to serve as a measurement of motor proficiency. To avoid a potential fatigue effect and to address solely throwing skill in this study, each participant was only required to complete the object control subtests in the TGMD-2 (i.e. strike the stationary ball, stationary dribble, catch, kick, overhand throw, and underhand roll). Test performance was measured by the total raw subtest score. After administration of the

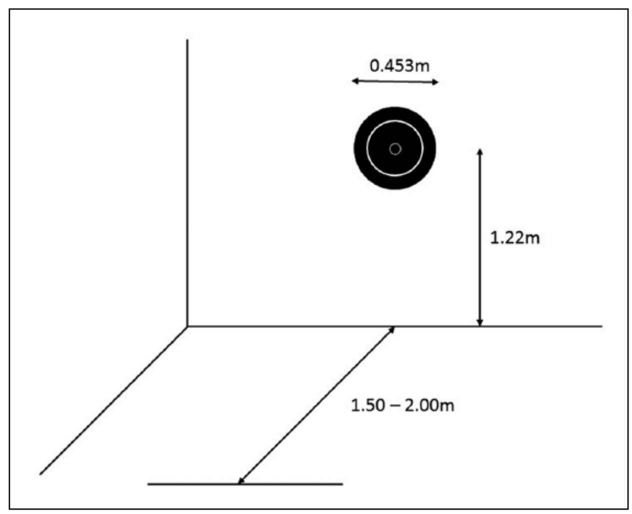

Figure 1. The task setting.

TGMD-2 (object control), each participant received a 15-min resting period.

The beanbag experiment had three phases: acquisition, a retention test, and a transfer test. Each participant was asked to throw a beanbag, aiming to hit the center of the target board as closely as possible. Prior to acquisition, each participant received instructions regarding beanbag grasp and standing position (e.g. "stand behind the position line," "grasp the beanbag with five fingers"). The experimenter also demonstrated the basic overarm throwing movement as an example of the desired action. Participants then received either no instructions (control) or internal or external attentional focus instructions. The instructions were similar to those given in Chiviacowsky et al.'s (2013) study, but had been translated into Chinese (see Appendix 1 for detailed instructions). Participants in the external focus group were

Table 2. Means and standard deviations of ANOVA of MRE for the instruction groups during the acquisition and test sessions.

Attentional focus instruction	Acquisition					Tests	
	1	2	3	4	5	Retention	Transfer
Internal	14.24 (1.57)	13.69 (1.66)	11.73 (1.68)	10.92 (2.01)	10.28 (1.23)	10.27 (1.64)	11.01 (3.07)
External	13.69 (1.25)	13.50 (1.92)	12.16 (3.02)	11.86 (1.93)	10.99 (1.47)	13.99 (2.39)	14.10 (2.20)
Control	13.56 (1.87)	12.63 (2.00)	12.44 (1.99)	11.73 (1.55)	10.65 (1.65)	13.26 (3.00)	14.51 (1.96)

$$\mathrm{MRE} = \frac{1}{m}\sum_{i=1}^{m} \mathrm{REi}$$

$$\mathrm{RE} = \sqrt{x^2 + y^2}$$

where MRE is the mean radial error, RE is the radial error (distance in centimeters between the throw and the center), *m* is the number of trials, and *i* is a particular trial.

instructed to focus on the beanbag's flight path, while those in the internal focus group were instructed to focus on the movement of their throwing arm. The focus instructions were repeated prior to each block of trials. Control group participants did not receive any attentional focus instructions. Instructions were provided to all participants in a similar manner (e.g. same volume, same tone, and same "natural" speaking style).

The participants were given five warm-up throws, after which they performed five blocks of 10 trials separated by 3 min of rest. One day after the acquisition phase, participants completed the retention and the transfer tests wherein they performed 10 beanbags throws from the same distance as that used during acquisition. However, they received no instructions before or during this retention test. After the retention test, participants engaged in a transfer test in which the distance was increased by 30%. Similar to Emanuel et al.'s study (2008), we checked whether participants adhered to the instructions regarding focus of attention by verbally asking them what they focused on while performing the task. We asked this open-ended question at the end of each block in each phase (i.e. acquisition, retention, and transfer). The verbal data were audio-recorded by an experimenter for later analysis.

Measures and statistics. We conducted a one-way analysis of variance (ANOVA) to analyze performance on the object control subtests of the TGMD-2 for each group, as measured by the total raw score. We measured throwing performance in a similar fashion to that in a dart throw study by Emanuel et al. (2008), where mean radial error (MRE) indicated the average deviation of the dart from the center of the target. To ensure accurate measurement, the beanbags were covered with white chalk powder by the experimenter prior to each block of trials so that a white print would be left on the black target board after the throw. A research assistant measured the radial error (i.e. distance between the center of the print and the center of the target board) immediately after each throw. The white print was erased afterward to prevent it from interfering with the attentional focus of the participant during the next trial. We used a 3 (Instruction Group) × 5 (Blocks: 1–5) ANOVA with repeated measures to analyze performance during acquisition. Throwing performance in the retention and transfer tests was analyzed using a one-way ANOVA. We used the chi-square test to assess adherence to instructions. Post hoc tests with Bonferroni adjustments were performed if we found any significant effects. Preliminary tests of the assumptions of the statistical tests, including data normality using Shapiro–Wilk tests (all $ps > 0.05$) and homogeneity of variance (Levene's tests: all $ps > 0.05$), for the ANOVAs were met.

Results

TGMD-2

The motor proficiency of each group measured by the total raw score of TGMD-2 object control subtests is shown in Table 1. There was no significant difference between groups ($F(2, 62) = 3.29, p > 05$), which implied that all three groups had similar baseline motor proficiencies in object control.

Throwing performance

Throwing accuracy measured by MRE of all three groups throughout acquisition, retention, and transfers is shown in Table 2 and Figure 2.

Acquisition

Figure 2 shows that MRE decreased during acquisition (i.e. blocks 1–5) for all three groups. A significant difference was evident between blocks ($F(3.15, 195.07) = 48.22, p < 0.001, \eta_p^2 = 0.44$). Although the internal focus group tended to perform better (i.e. had a smaller MRE value) than the external focus and control groups, no significant difference was shown between groups ($F(2, 62) = 2.60$, $p > 0.05$, $\eta_p^2 = 0.78$). In addition, no significant

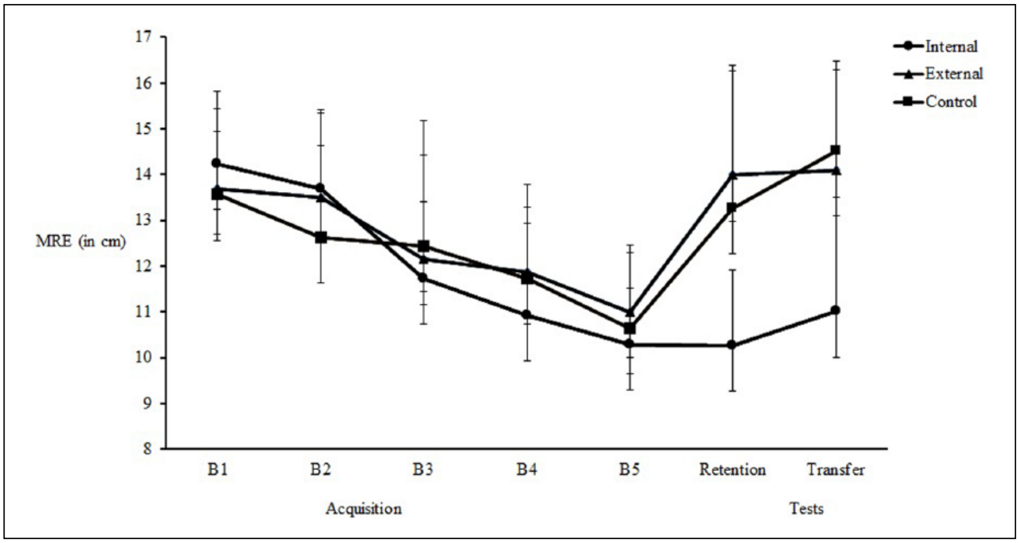

Figure 2. The interaction effect among instruction (internal focus vs external focus vs control) and block (B1–B5) during the acquisition, retention test, and transfer test.

interaction was revealed between groups and blocks ($F(6.29, 195.07) = 1.21, p > 0.05, \eta_p^2 = 0.03$).

Retention test

The retention test revealed a significant difference between groups ($F(2, 62) = 9.91$, $p < 0.05$). Post hoc multiple comparisons with Bonferroni adjustments indicated that the internal focus group performed with higher accuracy (i.e. lower MRE value; $M = 10.27$, $SD = 1.64$) than the external focus instruction group ($M = 13.99$, $SD = 2.39$; $p < 0.001$, 95% confidence interval (CI) = −3.69 to −0.81) and the control group ($M = 13.26$, $SD = 3.00$; $p < 0.001$, 95% CI = −3.74 to −0.82]), whereas no difference was found between the external focus and control groups ($p > 0.05$, 95% CI = 1.43 to −1.48).

Transfer test

The transfer test revealed a significant difference between groups ($F(2, 62) = 6.68$, $p < 0.05$). Post hoc multiple comparisons with Bonferroni adjustments indicated that the internal focus group performed with higher accuracy ($M = 11.01$, $SD = 3.07$) than the external focus instruction group ($M = 14.10$, $SD = 2.20$) ($p < 0.05$, 95% CI = −3.41 to −0.46) and the control group ($M = 14.51$, $SD = 1.96$) ($p < 0.05$, 95% CI = −3.35 to −0.37), whereas no difference was found between the external focus and control groups ($p > 0.05$, 95% CI = −1.42 to 1.56).

Focus adherence

Most children (90.7%) adhered to the focus instructions by providing verbal data that matched with their assigned focus groups. Three participants had inadvertently shifted from their instructed external focus to an internal focus of attention. Among participants who did not receive any attentional focus instruction, three reported having focused internally.

Discussion

In this study, we investigated whether the motor learning benefits of guidance emphasizing an external focus of attention in TD children (e.g. Hadler et al., 2014; Perreault and French, 2016) could also be applied to children with ASD. We hypothesized that children who received external focus instructions would throw the beanbag with greater accuracy compared with those who received internal focus instructions and those who received no attentional focus instructions throughout all three phases: acquisition, a retention test, and a transfer test. The findings of this study, however, revealed no difference between the groups in the acquisition phase. More importantly, the results of the retention and transfer tests opposed those of previous studies in non-disabled children (Hadler et al., 2014) and in children with ID (Chiviacowsky et al., 2013). While all three groups showed equivalent learning effects during the acquisition phase, the internal focus group displayed more robust performance than the external focus and control groups in both the retention and transfer tests.

Although performance scores were similar during the acquisition phase in all three groups (i.e. the MRE of all three groups decreased across the learning blocks), only the internal focus group displayed a robust learning effect as evidenced in the delay tests. A possible explanation for the present findings may stem from the enhanced proprioception displayed by children with ASD (Blakemore et al., 2006; Glazebrook et al., 2009). Proprioception is the awareness of posture, movement, and knowledge of position in relation to the body. Previous studies have shown that children with ASD rely more strongly on their proprioception than their vision to guide their movements when learning a new motor task or adapting a skill to a new environment (Glazebrook et al., 2009; Marko et al., 2015). For example, Marko et al. (2015) asked a group of TD children and children with ASD to engage in a motor task where they were required to learn how to control a robotic manipulandum to move a cursor (on a computer screen) to a specific target. Later in the experiment, the movements were randomly perturbed and movement errors were sensed through proprioception and vision. The experimenters found that children with ASD outperformed TD children when the adapted movements were guided by proprioception, but underperformed TD children when errors were sensed through vision (Marko et al., 2015). Those children with ASD rely more strongly on proprioception may be particularly important when interpreting the results of this study, where they performed poorly in the overhand throw (Table 1). Many previous studies have suggested that proprioception is vital in improving motor function (see Aman et al., 2014 for a review). In this study, the internal focus instructions may have directed the learner's attention to the movement itself (i.e. focus on arm movements), which matched their sensorimotor experience. This would have allowed them to rely on proprioception to guide their movements in new situations (i.e. retention and transfer tests), thus benefitting motor performance. In contrast, the external focus instructions may have directed the learner's attention to the movement effect (i.e. the flight of the beanbag and the target itself), which required them to rely more on their vision to adjust their movements in the retention and transfer tests, therefore leading to poorer performance. For the participants in the control group, since they were not given any additional attentional focus instructions (i.e. including the internal focus instructions), they may not have been able to rely on their proprioception to the same degree as the participants in the internal focus group. This could have led to decreased performance compared with participants in the internal focus group.

This explanation regarding the usage of proprioception was also given by the authors of a similar study examining TD children (Emanuel et al., 2008). Emanuel et al. (2008) examined the efficacy of attentional focus (external vs internal) on dart-throwing performance in TD children. They found that internal focus instructions induced more accurate dart-throwing in the retention and transfer tests. Emanuel et al. (2008) observed that children tended to use a kinesthetic system as a feedback source to improve motor behavior and motor awareness. By directing the children's attention to their body movements, their kinesthetic system could be improved, leading to better motor performance (Emanuel et al., 2008). Conversely, when children's attention was directed to focus on movement effects (i.e. external focus of attention), they were required to rely more strongly on visual feedback to process information regarding a motor task, where they often collected irrelevant cues from visual fields (Geron and Reches, 1984). Thus, their motor performance was disturbed. To our knowledge, no studies have investigated the relationship between attentional focus and sensory feedback in children, while studies examining the effects of attentional focus in children are rare. Therefore, further studies are warranted to characterize attentional focus and sensory feedback in both TD children and children with ASD.

Our result regarding focus adherence was consistent with that reported by Emanuel et al. (2008), who found that children in an external focus group reported focusing on their hand itself when dart-throwing (Emanuel et al., 2008). In this study, approximately 10% of the participants reported focusing internally despite being in either the external focus group (n = 3) or the control group (n = 3). However, none of the participants in the internal focus group or the control group reported focusing on the target or shifting their focus to the flight path of the beanbag. This suggests that children with ASD may spontaneously prefer to employ an internal attentional focus during the motor learning process. However, instructions or verbal feedback may involve mentioning body parts or movements, thus leading learners to inadvertently focus on their body movements (Chiviacowsky et al., 2013; Wulf et al., 1998).

Several limitations should be considered when interpreting the results of this study. First, we did not conduct process-oriented measurement. Such measurement is an important component in evaluating fundamental movement skill in children (Burton and Miller, 1998). Future studies should incorporate this type of measurement, for instance, by evaluating movement form and posture, to provide a more comprehensive assessment of motor skill in children. Second, with regard to task novelty and adherence to instructions, it is unlikely that the children had no prior experience with beanbags. Also, the participants had presumably accumulated some experience in throwing objects. Therefore, whether the results of this study can be applied to a completely novel motor task that is rarely learnt by children with ASD is unknown. Third, several children did not follow the attentional focus instructions and some focused in an opposing manner. Nevertheless, similar to Emanuel et al. (2008), the author did not exclude these participants due to the integrity of the randomized study design. Fourth, the voice used during the provision of instructions may have varied (e.g. pitch, volume), thus affecting the internal validity of the experiment. For example, the internal focus instructions may have been given in a way that enabled the participants to easily recall and complete the retention test. Future studies may consider using computers or audio recordings to provide instructions to minimize this "human difference." Finally, we did not collect a baseline measure, and therefore could not determine whether the baseline performance was equivalent among the groups. Moreover, the absence of a baseline measure may have produced a flaw in our statistical analysis because the starting point for each group (i.e. Block 1) could be influenced by the instructions (i.e. Group). Measurements of baseline performance should be incorporated in future studies.

To conclude, in this study, we examined the effects of attentional focus instructions on motor learning in children with ASD. The results of this study did not support the hypothesis that motor performance in children with ASD could be enhanced by external focus instructions. However, motor performance in children with ASD improved when attention was directed toward their body movements (internal focus of attention). This result has several important implications. First, it provides insight for the development of instructions used by teachers, athletic coaches, and physical therapists when guiding children with ASD to acquire new motor skills. Second, the participants in this study tended to emphasize internal focus during motor skill acquisition may be important for understanding motor learning behavior among children with ASD, with the ultimate goal of developing improved motor learning strategies for children in this population.

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Appendix 1

Instructions of two attentional focus groups

Internal Focus Group instructions:

1. Before throwing, concentrate on your arm position. Also, pay attention to your elbow movement.
   擲豆袋之前，請你留意下隻手仔唔係喺正確既位置, 同埋你擲豆袋時有無曲手肘。
2. Bring your hand backward until the beanbag touch your ear. At the end of the throw, your elbow is fully straightened.
   擲出去時， 首先我想你將手仔郁去後面，一直到貼到你隻耳仔; 當擲完飛鏢時， 你既手肘應該係直既。

External Focus Group instructions:

1. Look at the target attentively for a few seconds.
   擲豆袋之前， 我想你留心哋睇一睇牆上面既圈圈, 我要你睇幾秒鐘。
2. While throwing the beanbag, concentrate on its flight directly toward the target.
   擲豆袋時， 留意一下佢既飛行方向。