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The ability to mentally represent action is associated with low motor ability in children: a preliminary investigation

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Abstract

Background Theory and anatomical research suggest that the ability to mentally represent intended actions affect level of execution. This study presents preliminary data examining the association between children's ability to mentally represent action and general motor ability.

Methods Children aged 7- to 10 years were assessed for motor imagery ability using a simulation of reach task and motor ability via the Movement ABC-2. Motor ability values, based on percentile rank, ranged from 2 to 91, with a mean of 36.

Results The overall correlation between mental representation and motor ability yielded a moderately positive relationship (r = .39). Interestingly, when looking at motor ability subcategories, only Balance was significant in the model, explaining 20% of the variance.

Conclusions These results provide preliminary evidence that children's motor ability and the ability to mentally represent action are associated in a positive direction. Furthermore, given the results for Balance, we speculate that there are clinical implications regarding work with potentially at-risk children.

Introduction

Motor programming theory suggests that an integral component in an effective outcome is an adequate action representation of the movements. These representations are frequently associated with the notion of internal (forward) models and are hypothesized to be an integral part of action planning (Miall & Wolpert 1996; Skoura *et al*. 2005). It has been proposed that internal models make predictions about actions (Kunz *et al*. 2009; Pelgrims *et al*. 2009; Lorey *et al*. 2010), including limb kinematics and parameters of the external world (Wolpert 1997). Complementing the internal model idea and central to the present study is the suggestion that motor imagery provides a window into the process of action representation; that is, it reflects an internal action representation (Jeannerod 2001; Munzert *et al*. 2009). Furthermore, Jeannerod contends that mental imagery is the keystone to cognition, with simulation being the offline recruitment of the same neural networks involved in perception and action. Often referred to as the 'equivalence hypothesis' (e.g. Jeannerod 2001), this idea suggests that motor simulation and motor control processes are functionally equivalent (Munzert & Zentgraf 2009; Ramsey *et al*. 2010). For example, several studies report a high correlation between real and simulated movements (e.g. Heremans *et al*. 2007; Nikulin *et al*. 2007; Sharma *et al*. 2008; Young *et al*. 2009).

Regarding the ability to mentally represent action, one line of research indicates quite convincingly that children with developmental co-ordination disorder (DCD) have difficulties which underscore poor motor planning and performance (e.g. Deconinck *et al*. 2008; Lewis *et al*. 2008; Williams *et al*. 2008). One of the few studies that addressed this issue in typically developing children aged 7–12 years found a significant relation between general motor ability and motor imagery (Caeyenberghs *et al*. 2009). The researchers used a pointing task and mental hand rotation task to assess imagery and the McCarron

Assessment of Neuromuscular Development for evaluating motor ability.

Here, we present preliminary (pilot) data examining the association between general motor ability and a relatively unreported form of action representation – estimation of reachability. That is, using motor imagery to judge (estimate) whether an object is within or out of reach. As a form of motor imagery, the estimation of reach paradigm has drawn the interest of contemporary researchers for examining the processes involved in action representation with adults (Lamm *et al.* 2007; Coello *et al.* 2008) and children (Gabbard *et al.* 2007, 2009a,b).

Methods

The sample consisted of 29 right-handed children (17 male and 12 female), aged 7–10 years (mean 8.52); all participants had normal or optically corrected-to-normal vision. The university human subjects committee approved all procedures. During recruitment, which took place at a summer camp, instructors were asked to identify those that were not as co-ordinated as others; this action provided a prescreening for those with low motor ability.

For estimation of reachability, actual maximum reach (used as the comparison) and imaged reach responses were collected via short-throw projection system (*Sanyo Model PLC-XL50*) linked to a computer programmed with Java and Visual Basic. Table and seat pan positioning were modified from Carello and colleagues (1989) and Choi and Mark (2004) and used to scale individual reach. Visual images were projected onto a table surface at midline. After the measurement of maximum actual reach (1-d.f. reach), participants were provided seven imagery targets (2 cm circles) with '4' being the actual reach, complemented with three targets above and three below touching at the rims. For imaged reaches, participants were asked to kinaesthetically 'feel' themselves executing the movement ('feel your arm extending . . .'), therefore being more sensitive to the biomechanical constraints of the task. Participants were asked to make judgments relative to whether the target was within ('yes') or out of reach ('no'). For imaged trials, data collection began with a 5-s 'Ready!' signal –immediately followed by a central fixation point lasting 3 s, at the end of which was a tone. The image appeared immediately thereafter and lasted 500 ms with another tone at the end – which required an immediate (after imaging) verbal response. Target presentation was given in random order with three trials at each of the seven targets. No feedback was available to participants about the accuracy of performance. A second experimenter served to reinforce instructions regarding imagery technique and refocusing to the central fixation point with each trial. We wish to note that prior to data collection participants were trained in motor imagery (effector focus, kinaesthetic imagery) and a few children were dropped due to immaturity in understanding task instructions, or by virtue of answering 'yes' with all practice trials with some being beyond reach. This paradigm has been used and reported with children as young as 5 years of age (Gabbard *et al.* 2007, 2009a,b). Children were assessed for general motor ability using the Movement Assessment Battery for Children – Second Edition (Movement ABC-2; Henderson *et al.* 2007), which is a standardized motor ability assessment for children between 3 and 16 years of age. The test is known as a reliable and valid instrument (Chow & Henderson 2003; van Waelvelde *et al.* 2006) for identifying children with motor co-ordination problems and was chosen with the goal of identifying children that may be in the lower quartile of percentile ranking. The test consists of eight items categorized into three subtests of manual dexterity, aiming & catching and balance (static and dynamic).

Individual testing was conducted in an isolated room and consisted of two sessions of approximately 25 min each. On the first session, all participants performed the estimation of reach task, and on the second session, they were tested for motor ability.

Results

For reach estimation, total score was defined as the amount of right answers out of 21 trials; mean score was 16.38 (SD = 2.59), ranging from 11 to 20. Distribution of error results via frequency data analyses showed significantly less error in peripersonal (targets 1–4) compared with extrapersonal space (targets 5–7). Most errors occurred around target 5, revealing a greater tendency to overestimate.

Mean score for the Movement ABC-2 percentiles was 36.1 (SD = 26.37), ranging from 2 to 91. Of the total number of participants, four scored below the 15th percentile (2nd – $n = 1$; 5th – $n = 2$, 9th – $n = 1$). This test is widely used to identify children with DCD, ≤15 percentile and having no neurological or cognitive impairments.

Spearman's correlation analyses for Reach and Movement ABC-2 total indicated that there was a moderately positive relationship ($r = 0.39$, $P = 0.03$). Correlation analysis for Reach and percentiles for Movement ABC-2 subcategories revealed significance for Balance skills ($r = 0.41$, $P = 0.02$). Stepwise linear regression analysis indicated that the Movement ABC-2 explained 14% of the variability in the data. When looking specifically at the subcategories, only Balance was significant in the model, explaining 20% of the variance for the total score in Reach.

Discussion

This study presents preliminary data examining the association between the ability to mentally represent action via estimation of reach and general motor ability in children. Our initial expectation was that there would be a positive relation between higher levels of mental representation and general motor ability. Although factors other than mental representation could be involved, as noted earlier, studies of children with DCD report those children having significant difficulty using motor imagery to mentally represent action.

The key finding was that there was a moderately positive relationship ($r = 0.39$, $P = 0.03$) between mental representation and motor ability. That is, better estimation accuracy for reach was associated with higher motor ability scores. As a general observation, this result complements our prediction and is consistent with ideas related to development of forward (internal) models, action planning and concomitant gains in movement skill (Wilson *et al.* 2004; Choudhury *et al.* 2007; Molina *et al.* 2008; Caeyenberghs *et al.* 2009).

Another finding of interest was that, among the motor ability subcategories, Balance accounted for the only significant predictive factor ($r = 0.41$, $P = 0.02$). Although this finding is preliminary, due to sample size, if it holds with larger numbers, there are implications for identifying and intervening with children potentially at risk for low motor ability. Interestingly, the brain literature supports a common link between postural control (balance) and mental representation via the cerebellum (Barlow 2002; Blakemore & Sirigu 2003; Jahn *et al.* 2008).

In summary, these preliminary findings support the idea that there is a positive association between the ability to mentally represent action and motor ability. Furthermore, there is also a hint that the relationship may have significant implications for tasks requiring postural control in the context of balance. Obviously more data that includes greater sample size, especially those with low motor ability, and a greater variety of motor imagery tasks are needed. However, one of the merits of this study is the fact that, even with a small sample, it was possible to detect an association between movement representation and motor ability. Certainly, another area that merits further investigation is the role of cerebellar processing in movement representation.

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