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Full Length Article

Training compliance control yields improved drawing in 5–11 year old children with motor difficulties

Winona Snapp-Childs [a,*], Katy Shire [b], Liam Hill [b], Mark Mon-Williams [b], Geoffrey P. Bingham [a]

[a] *Department of Psychological & Brain Sciences, Indiana University, United States*
[b] *School of Psychology, University of Leeds, UK*

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ABSTRACT

There are a large number of children with motor difficulties including those that have difficulty producing movements qualitatively well enough to improve in perceptuo-motor learning without intervention. We have developed a training method that supports active movement generation to allow improvement in a 3D tracing task requiring good compliance control. Previously, we tested a limited age range of children and found that training improved performance on the 3D tracing task and that the training transferred to a 2D drawing test. In the present study, school children (5–11 years old) with motor difficulties were trained in the 3D tracing task and transfer to a 2D drawing task was tested. We used a cross-over design where half of the children received training on the 3D tracing task during the first training period and the other half of the children received training during the second training period. Given previous results, we predicted that younger children would initially show reduced performance relative to the older children, and that performance at all ages would improve with training. We also predicted that training would transfer to the 2D drawing task. However, the pre-training performance of both younger and older children was equally poor. Nevertheless, post-training performance on the 3D task was dramatically improved for both age groups and the training transferred to the 2D drawing task. Overall, this work contributes to a growing body of literature that demonstrates relatively preserved motor learning in children with motor difficulties and further demonstrates the importance of games in therapeutic interventions.

1. Introduction

Children have to learn to perform skilled movements from walking to throwing to handwriting. There are many routes that a child can take to achieve motor goals, but it seems that most children converge on a common solution set and behaviors of different children appear very similar (i.e. see Snapp-Childs & Corbetta, 2009). Nevertheless, there is a segment of the childhood population that, for one reason or another, does not follow the expected trajectory of motor development. The issue for teachers, therapists, parents and the like is how to intervene to help these children to improve their motor skills and potentially "catch-up" to their peers. A traditional approach has been to model desired movement skills for the child with the hope that the child will acquire the correct form of the required skill and then improve with subsequent practice.

* Corresponding author at: Indiana University, Department of Psychological and Brain Sciences, 1101 East Tenth Street (A326), Bloomington, IN 47405-7007, United States.

E-mail address: wsnappch@indiana.edu (W. Snapp-Childs).

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This approach has taken several forms. For instance, an adult expert (teacher, movement therapist) will physically move the child's limbs through the desired form of movement (called "active assist"). Likewise, robotic approaches have been developed to do the same (for reviews, see Kwakkel, Kollen, & Krebs, 2008; Marchal-Crespo & Reinkensmeyer 2009). Generally, however, passive robotic approaches to therapy are ineffective (Lo, Guarino, Richards, Haselkorn, Wittenberg, et al., 2010; Reinkensmeyer & Patton, 2009; Wong, Kistemaker, Chin, and Gribble, 2012) and do not lead to robust learning (for examples, see Beets, Macé, Meesen, Cuypers, Levin, et al. 2012; Goodwin, 1976; Snapp-Childs, Casserley, Mon-Williams, & Bingham, 2013). However, recent efforts to develop active robotic and/or virtual reality based training systems have shown great promise to be effective tools for intervention for children with motor difficulties (for examples see Golomb et al., 2010; Meyer-Heim et al., 2009).

With the aforementioned findings in mind, we developed a method to train children to attain better manual control (Snapp-Childs, Mon-Wiliams, & Bingham, 2013). Children are required to perform a complex 3D tracing task actively while being supported. The child holds a stylus in the hand and uses it to control a virtual stylus with which they are to push a virtual bead around a complex 3D shaped path. One of the features of this task is that keeping the stylus in contact with the path can be made easier or more difficult. The robotic arm was modeled as a virtual spring that acted on the stylus so as to hold it onto the path giving the phenomenological impression of a 'magnetic attraction' between the stylus and the path. In this context, the best way to perform the task is to be compliant to the path, that is, to let the path to which the stylus is magnetically held lead the movement. This enables users to acquire better compliance control gradually because the level of attraction can be gradually reduced. The hope is that the improved compliance control positively transfers to other tasks, such as 2D tracing or drawing tasks, that require good compliance control (for discussion, see Snapp-Childs, Mon-Wiliams, et al., 2013).

Previously, we tested this method with 7–8 year old children diagnosed as having Developmental Coordination Disorder (DCD), comparing their learning and performance with age-matched typically developing children (Snapp-Childs, Mon-Wiliams, et al., 2013). We also tested and compared 7–8 and 10–12 year old school children. Prior to training, we found that the children with DCD were significantly worse at the 3D tracing task than the age-matched typically developing children. Likewise, the younger school children were worse relative to the older children. After training, the children with DCD performed as well as the typically developing children who had also trained. Similarly, younger children performed at the same level as older children after training. These results stand apart from those of other studies in two ways related to learning.

First, previous work has shown impaired learning for children with motor difficulties. For example, Zwicker and collaborators (Zwicker, Missiuna, Harris, & Boyd, 2011) had children (8–12 year old) with motor difficulties (specifically, children with DCD) and typically developing children practice a trail-tracing task and measured the brain activity associated with this practice. Overall, they found that the children with motor difficulties did not improve in the trail-tracing task as much as the typically developing children (and also had under-activation in certain brain regions that have been associated with visual-spatial learning). Likewise, Huau and collaborators (Huau, Velay, & Jover, 2015) showed that (8–10 year old) children with motor difficulties (specifically, children identified as having DCD) did not learn how to write a new letter as well as typically developing children. Second, previous work shows that when children with motor difficulties (specifically, children with suspected/probable Developmental Coordination Disorder or those identified as having DCD) exhibit learning, they are still impaired relative to typically developing children. For example, Missiuna (1994) trained children (6.5–8.5 years old) with and without DCD to perform aiming movements. All children learned the task but there were persistent differences between children with DCD and typically-developing children – training did not erase differences between the groups. Jelsma and collaborators (Jelsma, Geuze, Mombarg, & Smits-Engelsman, 2014) implemented an intervention for 6–12 year old children with motor difficulties (probable DCD). The intervention was successful in that training with the Wii Fit improved motor performance on the (Wii Fit) ski slalom game; however, because the typically-developing children participating in this study were not trained (or re-tested) it is not possible to determine if equal training resulted in similar or dissimilar gains.

In addition to examining learning of the task, we tested typically developing 7–8 and 10–12 year old school children to see whether training on the 3D tracing task would positively transfer to a 2D drawing task (Snapp-Childs, Flatters, Fath, Mon-Williams, & Bingham, 2014; Snapp-Childs et al., 2015). First, we found a direct relationship between the scale of the reproduced shapes and the amount of spatial error in reproducing the target shape (i.e. copied shapes that were too large had large amounts of spatial error). Second, we found small but significant reductions in the shape errors that the children generated after training – the training positively transferred to the drawing task. This is impressive given that many previous studies have failed to demonstrate transfer to drawing/handwriting tasks (for a review, see Hoy, Egan, & Feder, 2011).

1.1. Present study

The purpose of this study was to examine the efficacy of our training for children with motor difficulties over a range of ages from 5 to 11 years old. We previously tested children diagnosed with DCD, but only at ages 7–8 years of age and we had not tested transfer from the 3D training task to a 2D drawing task. Here we ask whether the training yields improvements in drawing for children with motor difficulties typical of DCD. Also, we previously found age differences (7–8 years old versus 10–12 years old) in pre-training performance in typically developing children and that age differences were eliminated by training. The question is whether we would now find such age differences in pre-training performance for children with motor difficulties typical of DCD. If so, would the training also eliminate such differences? In sum, we investigated whether