Human Movement Science 46 (2016) 209–220

Contents lists available at ScienceDirect

Human Movement Science

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

Life span changes: Performing a continuous 1:2 bimanual coordination task

Peter Leinen [a], Solveig Vieluf [a,d], Deanna Kennedy [b], Gisa Aschersleben [c], Charles H. Shea [b], Stefan Panzer [a,*]

[a] Institute of Sport Science, Saarland University, Saarbrücken, Germany
[b] Human Performance Laboratory, College Station, Texas A&M University, USA
[c] Developmental Psychology Unit, Department of Psychology, Saarland University, Saarbrücken, Germany
[d] Aix-Marseille Université, CNRS, ISM UMR 7287, 13288 Marseille cedex 09, France

ARTICLE INFO

Article history:
Received 6 July 2015
Revised 4 January 2016
Accepted 5 January 2016

PsycINFO classification:
2330
2820

Keywords:
Motor development
Bimanual coordination
Neural crosstalk

ABSTRACT

The experiment was conducted to determine the influence of mirror movements in bimanual coordination during life span. Children, young adults, and older adults were instructed to perform a continuous 1:2 bimanual coordination task by performing flexion–extension wrist movements over 30 s where symmetrical and non-symmetrical coordination patterns alternate throughout the trial. The vision of the wrists was covered and Lissajous-feedback was provided online. All age groups had to perform 10 trials under three different load conditions (0 kg, .5 kg, 1.0 kg: order counterbalanced). Load was manipulated to determine if increased load increases the likelihood of mirror movements. The data indicated that the performance of the young adults was superior compared to the children and older adults. Children and older adults showed a stronger tendency to develop mirror movements and had particular difficulty in performing the non-symmetrical mode. This type of influence may be attributed to neural crosstalk.

1. Introduction

Research in lifelong motor learning and development has demonstrated that children and older adults tended to produce involuntary muscle co-activation with one body side when they have to perform an intended movement with the contralateral side (e.g., Addamo, Farrow, Bradshaw, & Georgiou-Karistianis, 2011; Cohen, Taft, Mahadeviah, & Birch, 1967; Conolly & Stratton, 1968; Walter & Swinnen, 1990b; Wolff, Gunnoe, & Cohen, 1983). This phenomenon has been referred to as mirror movements (see Cattaert, Semjen, & Summers, 1999). For children the tendency to produce mirror movements typically disappears after the first decade of life (Gooijers & Swinnen, 2014). This seemed to overlap with the completion of the myelination of the corpus callosum (e.g., Chicoine, Proteau, & Lassonde, 2000; Serrien, Sovijärvi-Spapé, & Rana, 2014; Yakovlev & Lecours, 1967). In contrast for older adults the tendency to produce mirror movements increases with aging (Baliz et al., 2005; Swinnen et al., 1998). These findings are associated with age-related degenerative processes of the callosal structures, i.e., demyelination of the callosal fibers (e.g., Pfefferbaum et al., 2000; Salat et al., 2005). Results based on neurophysiological methods proposed that in young adults without neural disorders the neural structure of the corpus callosum transmits inhibitory or excitatory commands between the two hemispheres (Meyer, Röricht, Gräfin von Einsiedel, Kruggel, & Weindl,

* Corresponding author at: Institute of Sport Science, Saarland University, Im Stadtwald B8.2, D-66041 Saarbrücken, Germany.
E-mail address: s.panzer@mx.uni-saarland.de (S. Panzer).

http://dx.doi.org/10.1016/j.humov.2016.01.004
0167-9457/

1995). Therefore, it is reasonable that the not yet completed myelination of the corpus callosum in children or the age-related degenerative process of the callosal structures results in problems with these inhibitory or excitatory influences. While this proposal offers a plausible explanation for a stronger tendency to produce mirror movements in children and older individuals, it is not the only potential explanation.

Another line of research interested in inter-limb coordination uses bimanual movements (Swinnen, 2002; Wiesendanger, Wicki, & Rouiller, 1994, for reviews). This research has argued that mirror movements are the preferred tendency of the corticospinal motor system (Duque et al., 2005; Galléa et al., 2011) and as such is the only inherently stable bimanual coordination pattern.

This assumption based on the results of a large number of experiments using cyclical 1:1 frequency ratio with 0° phase offset (typically termed in-phase movements) between the limbs has repeatedly demonstrated that the symmetrical mode, which involves the co-activation of homologous muscles, is more accurate and stable compared to non-symmetrical mode with 180° phase offset (typically termed anti-phase movements) which involved the activation of non-homologous muscles (Kelso, 1984).

One theoretical perspective argues that the tendency to prefer the mirror symmetrical mode in inter-limb coordination is based on the notion of neural crosstalk (Swinnen, 2002; Swinnen & Wenderoth, 2004). The basic assumption is that some portion of the signal controlling one hand is also sent as a mirror image command to the homologous muscles of the contralateral limb (Cattaert et al., 1999). Symmetrical bimanual movements are facilitated when contralateral and ipsilateral signals are integrated while non-symmetrical bimanual movements suffer from ongoing interference due to conflicting information or partial intermingling of signals controlling the two limbs simultaneously (Cardoso de Oliveira, 2002; Kagerer, Summers, & Semjen, 2003; Marteniuk, MacKenzie, & Baba, 1984). In addition, Swinnen, Walter, Serrien, and Vandendriesche (1992) provided evidence that neural crosstalk is directly related to the strength of innervation or to the actual forces produced by the motor system (Heuer, Spijkers, Kleinsorge, van der Loo, & Steglich, 1998; Walter & Swinnen, 1990a).

While the tendency to produce mirror movements in children (Wolff et al., 1983), in young adults (Shea, Buchanan, & Kennedy, 2015), and older adults (Addamo et al., 2011; Swinnen et al., 1998) has received some experimental attention (see Gooijers & Swinnen, 2014, for an review), little attention has been directed to compare directly within one experiment the three age groups using continuous bimanual movements. To the best of our knowledge there is only one experiment that compares the variability in force control in a unimanual and a bimanual coordination task throughout the lifespan (Smits-Engelsman, van Galen, & Duysens, 2004).

The primary purpose of the present experiment was to explore the accuracy and stability of limb movements in a continuous bimanual coordination task across the life span. Therefore, three different age groups were investigated: children (age $\leqslant$ 10 years), young adults (18–28 years) and older adults ($\geqslant$age of 65 years). To increase the likelihood of neural crosstalk impacting task performance the actual forces required to produce the task were systematically varied. As in Kovacs, Buchanan, and Shea (2010), we used a continuous 1:2 bimanual coordination task, because this task requires one limb to move twice as fast as the other limb, and there is a dynamical change between the symmetrical and the non-symmetrical mode of coordination while performing the task (Swinnen, Dounskaia, Walter, & Serrien, 1997). Attempts to produce the non-symmetrical mode are accompanied by the tendency to produce the more preferred symmetrical mode with mirror movements, resulting in inconsistencies and biases in the behavior. Therefore, excitatory and inhibitory influences have to be transmitted through the corpus callosum (Daffertshofer, Peper, & Beek, 2005; Swinnen, 2002). If neural crosstalk is a valid explanation for the tendency to preferred mirror symmetrical bimanual movement patterns mutual interference occurs between the limb motions, especially when children and older adults are asked to perform the task. To better observe the motor related constraints on bimanual coordination across the life span, online Lissajous feedback was provided to the participants to reduce attentional, perceptual and other cognitive constraints. Note, Lissajous display presents the integrated movement of the two limbs as a cursor in one plane, where the movement of the right limb, for example, moves the cursor to the right (extension) and left (flexion), while movement of the left limb moves the cursor up (extension) and down (flexion) in the display. This form of feedback has been shown to optimize perceptual information and reduce attentional demands resulting in effective performance after only a few minutes of practice (see Shea et al., 2015 for review). This setup increases the probability that the influence of the primarily motor constraints can be more clearly observed during the performance of the task. When the cognitive constraints are not effectively neutralized performance is so variable that it is difficult to isolate the effects resulting from motor constraints (see Kovacs et al., 2010).

Based on the assumption that neural crosstalk increases with higher force control (Heuer, 1993; Swinnen et al., 1992) we proposed that all three age groups will demonstrate higher interference when the force required to produce the task is increased. If age and higher force control levels interact, we predict that the interference will be stronger for children and older adults when force is increased compared to younger adults.

2. Method

2.1. Participants

Children ($N = 14$; 8–10 years, 7 females), younger adults ($N = 14$; 18–28 years, 7 females), and older adults ($N = 14$; 65–77 years, 7 females) with no history of neurological disease or musculoskeletal dysfunction participated in the experiment. All participants and the parents of the children completed an informed consent approved by the local ethics committee prior