Human Movement Science 32 (2013) 1070–1081

Contents lists available at SciVerse ScienceDirect

Human Movement Science

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

The direction of bilateral transfer depends on the performance parameter

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ARTICLE INFO

Article history:
Available online 1 April 2013

PsycINFO Classification:
2330
2343

Keywords:
Drawing
Aiming
Hand
Fingers
Visuo-motor skills

ABSTRACT

To acquire a more comprehensive understanding of the learning benefits associated with bilateral transfer and to gain knowledge of possible mechanisms behind bilateral transfer, we investigated the transfer direction of several parameters which are assumed to represent important features of movement control in a visuo-motor task. During the study, participants learned a multidirectional point-to-point drawing task in which the visual feedback was rotated 45° and the gain was increased. Performance changes of the untrained hand in movement time, trajectory length, normalized jerk, initial direction error, ratio of the primary sub-movement time to the total movement time, and the accuracy of the aiming movement after the primary sub-movement were investigated as indices of learning from bilateral transfer. The results showed that performance parameters related to the initial production of the movement, such as the initial direction, ratio of primary sub-movement to the total movement time, and movement accuracy after the primary sub-movement, only transferred to the non-dominant, while hand performance variables related to the overall outcome, such as movement duration, movement smoothness, and trajectory length, transferred in both directions. The findings of the current study support the basic principle of the "dynamic dominance model" because it is suggested that overall improvements in the non-dominant system are controlled by trajectory parameters in visuo-motor tasks, which resulted in transference of the afore mentioned production parameters to rather occur to the non-dominant hand as opposed to transference to the dominant hand.

Published by Elsevier B.V.

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0167-9457/$ - see front matter Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.humov.2012.02.013

1. Introduction

The transfer of learning that occurs between the two limbs has been referred to as the bilateral transfer of learning (Magill, 2011). Thus after training a motor task with one limb, the performance of the untrained contra-lateral limb will show improvements on the same motor task. The phenomenon of bilateral transfer has been investigated in tasks such as writing inversed and reversed letters (Hicks, 1974; Parlow & Kinsbourne, 1989), reaching targets when visual feedback is displaced or dynamics are disturbed (Imamizu & Shimojo, 1995; Sainburg & Wang, 2002; Thompson & Henriques, 2010; Wang & Sainburg, 2004), pursuing a target (Hicks, Gualtieri, & Schroeder, 1983), sequence learning (Kirsch & Hoffmann, 2010), maze learning (van Mier & Petersen, 2006), mirror drawing (Kumar & Mandal, 2005), anticipatory timing and force control (Teixeira, 2000). Often bilateral transfer shows an asymmetry, in which there is a greater amount of transfer from one limb to the other limb than vice versa (Hicks, 1974; Parlow & Kinsbourne, 1989), but the underlying mechanism of the asymmetry in bilateral transfer is uncertain.

1.1. Models for bilateral transfer

Three models have been proposed to explain the asymmetry of bilateral transfer. In the "access model", it is stated that that one single "engram" is stored in the dominant hemisphere regardless of the limb trained. Thus the dominant limb has always direct access to the "engram" to get information of the task, while the non-dominant limb has only indirect access (Hicks, 1974; Taylor & Heilman, 1980). Based on this model, bilateral transfer should only occur from the non-dominant limb to the dominant limb, because of superior access of the dominant limb to the information. In the "cross-activation model", it is proposed that training of the dominant limb results in the creation of a dual "engram" in both the dominant and non-dominant hemisphere (although a weaker one) which then provides information for the non-dominant limb, while training of the non-dominant limb results in the creation of only one "engram" in the non-dominant hemisphere (Parlow & Kinsbourne, 1989). Therefore, bilateral transfer always occurs from the dominant limb to the non-dominant limb because of the lack of an engram being created in the dominant hemisphere if the non-dominant limb is trained. One limitation of the two models above is that they both predict that bilateral transfer only occurs in one direction. Therefore, they cannot explain the complex observations of studies which measured several performance measures in detail. The majority of studies suggest a complex directional distribution of each movement parameter of bilateral transfer rather than a simplified overall transfer direction.

The "dynamic dominance model" solved this problem by suggesting that the asymmetry of bilateral transfer is caused by the asymmetry of the hemispheres (Sainburg & Wang, 2002; Wang & Sainburg, 2004, 2006). Each arm controller has access to all information learned by the opposite hand, but the controllers select and use the information differently based on its own proficiency of movement control to make the whole system work efficiently. Specifically, the dominant hand is proficient in trajectory control, so it tends to use the directional information from the opposite hand and inhibit utilizing other information. In contrast, the non-dominant hand is skillful at tuning final position, so it tends to use the information about final position and inhibit utilizing final position information from the opposite hand (Sainburg, 2002; Sainburg & Wang, 2002). The choice of parameters of initial direction and final position in the "dynamic dominance model" of bilateral transfer were associated with studies of Lackner and DiZio (1994) and Sainburg (2002). Lackner and DiZio (1994) showed that adaptation of movement end point and trajectory are independent from each other in a reaching task during body rotation, while Sainburg (2002) showed in a handedness study that the dominant hand is more proficient in controlling intersegment dynamics which is the basis of trajectory control, while the non-dominant hand is more advanced in the control of final position. Trajectory and endpoint position are important parameters of goal aimed movements, but focusing on just these two parameters may not be sufficient to comprehensively describe the characteristics of bilateral transfer in visuo-motor tasks.