Human Movement Science 27 (2008) 551–576

Contents lists available at ScienceDirect

Human Movement Science

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

Manual asymmetries in the temporal and spatial control of aimed movements

Robert R.A. van Doorn *

Faculty of Psychology, Maastricht University, P.O. Box 616, 6200 MD Maastricht, The Netherlands

ARTICLE INFO

Article history:
Available online 17 July 2008

PsycINFO classification:
2330

Keywords:
Manual asymmetries
Aimed movements
Programming and feedback mechanisms
Kinematic measures

ABSTRACT

Right-handed participants performed aimed, left- and right-hand movements toward a fixed target in speed and precision conditions. The purpose was to determine detailed hand differences in the temporal and spatial control during the course of a movement. The results showed that hand differences pertaining to spatial control of movement direction occurred throughout movement execution, and that these differences were stronger in the high speed and low precision conditions. Furthermore, the left hand took more time to execute a movement than the right hand, especially in conditions of low speed and high precision. Detailed time analysis revealed that slowing down of the left hand specifically happened prior to peak acceleration and beyond peak deceleration. These detailed temporal hand differences reoccurred as additional discontinuities in the acceleration profile. These results suggest that the left hand has more difficulty at movement start than the right hand, possibly in overcoming initial inertia. It is discussed whether time-based manual asymmetries located near the end of movement execution should be explained in terms of increased feedback use, or should be related to hand differences regarding the possible active dissipation of mechanical energy at movement completion.

1. Introduction

Most people prefer one hand above the other to perform everyday motor skills. With a few exceptions, the preferred hand appears to be dominant when it comes to accurate and swift performance of

* Tel.: +31 433881926; fax: +31 433884211.
E-mail address: r.vandoorn@psychology.unimaas.nl

0167-9457/$ - see front matter
doi:10.1016/j.humov.2007.11.006

motor sequences (Hausmann, Kirk, & Corballis, 2004). Even though handedness of both left- and right-handers (Boulinguez, Nougier, & Velay, 2001; Boulinguez, Velay, & Nougier, 2001) can be demonstrated by self-report and performance, there is no unified explanation of how aimed motor performance of the dominant and non-dominant hands differ and how manual asymmetries originate in the brain (Beaton, 2004; Bryden, 2002; Bryden & Kay, 2002; Carson, 1996; Elliott & Chua, 1996; Elliott, Lyons, Chua, Goodman, & Carson, 1995). The present study aims to contribute to further insights into hand-dominance by focusing on detailed analysis of motor performance of right-handers. The purpose is to localize manual asymmetries during the course of single aimed movements with respect to spatial and temporal characteristics.

It is relatively easy to identify the preferred hand by asking participants a number of questions about manual preference in regard to everyday motor skills such as writing, drawing, lighting a match, or using a tooth brush (Bryden, 1977; Oldfield, 1971). Subsequent behavioral appraisal mostly confirms the preferred hand to be dominant when it comes to skilled movement sequences (Bryden, Pryde, & Roy, 2000; Hausmann et al., 2004). It has been shown that the preferred hand takes less time to complete motor sequences such as a reciprocal tapping series (Bryden et al., 2000; Bryden & Kay, 2002; Carson, Goodman, & Elliott, 1992; Elliott, Chua, & Pollock, 1994; Flowers, 1975; Todor & Doane, 1978; Woodworth, 1899) or the successive re-locating of a number of wooden pegs (Annett, Annett, Hudson, & Turner, 1979; Bryden & Allard, 1998; Westwood, Bryden, Roy, & Kalbfleisch, 1999; Westwood, Roy, Bryden, Bryden, & Roy, 1998). The difference between hands in performing movement sequences typically increases with the number of movement elements (Bryden et al., 2000; Carson, 1992; Elliott et al., 1994). This suggests that manual asymmetries may still be found in the execution of discrete movements. A large body of research on single aimed movements has indeed shown that the dominant hand often takes less time to hit a target and is frequently more precise at movement completion (Bagesteiro & Sainburg, 2002; Boulinguez, Nougier et al., 2001; Boulinguez, Velay et al., 2001; Bryden, 2002; Bryden & Kay, 2002; Carson, Chua, Elliott, & Goodman, 1990; Carson, Elliott, Goodman, & Thyer, 1993; Carson, Goodman, Chua, & Elliott, 1993; Elliott et al., 1995, 1999; Hausmann et al., 2004; Heath & Roy, 2000; Maruff et al., 1999; Roy & Elliott, 1989; Roy, Kalbfleisch, & Elliott, 1994; Roy, Kalbfleisch, & Silcher, 1999).

The most prevalent explanation of observed manual asymmetries is that a movement with the non-dominant hand, hereafter also referred to as the left hand, is often reported to be less precise and more time-consuming, because it is more susceptible to inherent noise in the motor system (Annett et al., 1979; Carson, 1992; Carson et al., 1990, 1992; Carson, Elliott et al., 1993; Carson, Goodman et al., 1993). The classic idea is that the execution of the non-dominant hand is preceded by motor instructions that contain more noise (Annett et al., 1979). This notion may explain why left hand movements are often less precise than movements with the right hand, but it does not explain why the left hand frequently takes more time to execute a movement. One possible explanation is that noise inherent to programming will have direct motor consequences during execution. It has been suggested that noisy instructions incorporate inefficient and more time-consuming online coordination of the involved muscle groups in the left arm (Barthelemy & Boulinguez, 2002). The same logic applies to less efficient coordination of online torques underlying the control of separate segments of the left arm (Bagesteiro & Sainburg, 2002, 2003). However, these occurrences may not be entirely due to noisy motor instructions. Muscle and inter-segment coordination may work less efficiently for the non-dominant limb due to influences during movement execution. In this respect, there may be limb-specific biomechanical differences (Carey, Hargreaves, & Goodale, 1996; Carey & Otto de Haart, 2001) that make it more difficult to coordinate muscle groups and limb segments in the left arm. These specific hand differences may be more apparent in situations where the left limb has to overcome initial inertia at movement start (Gordon, Ghilardi, Cooper, & Ghez, 1994; Tseng & Sholz, 2005) or has to establish a complete standstill at movement completion (Dounskaia, Wisleder, & Johnson, 2005; Wisleder & Dounskaia, 2007).

All possible influences pertaining to manual asymmetries described above assume that the left arm is passively undergoing the influence of noise originating before and concurrent with movement execution. This assumption implies that the left arm is more prone to error, and it typically excludes the possibility of online error compensation and reduction. However, it makes sense that the left hand is capable of at least partly compensating possibly anticipated error. The classic mechanism by which