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Which Factors Affect Hand Selection in Adults? Combined Effects of Ocular Dominance, Task Demand and Object Location

by
Meysam Rezaee[1], Masomeh Shojaee[2], Abdullah Ghasemi[3], Amir Moghaddam[4], Maryam Momeni[5]

Eighty-five right-handed subjects (39 female and 46 male, 47 being right-eye dominant and 38 being left-eye dominant) were tested on three tasks of different levels of difficulty, performed in five locations. In the current study, participants were required to pick up the tool, pick up and pantomime how to use it and pick up and actual use on the materials provided. Our goal was to evaluate how the effect of object location interacts with task difficulty on adult hand selection. We also tried to evaluate the effect of eye dominance as a biological factor on hand selection. The result showed that the frequency of preferred hand reaches was greater for pantomime and real use than the pick up condition. This effect was mediated by the position of the object in hemispace, with more right hand reaches occurring for the use and pantomime task than the pick up task. The result also revealed that there is no difference between frequency of preferred hand reaches in left- and right-eye dominant. Based on results of this study, it can be suggested that limb selection depends on task and environmental constraints, rather than a biological factor like eye dominance.

Key words: limb selection, reaching, task demand, eye dominance

Introduction

Movement and motor behavior in humans begins before one's birth. One of these behaviors is reaching movements, which appear in early times. Humans achieve different capabilities in reaching movements at different ages and even during the infant stage, for example, reaching in different regions of hemispace (contralateral, midline and ipsilateral) and using one or both hands to carry out various actions (Van Hof.et al., 2002).

Thus, it seems that reaching is an inseparable component of human actions (actions related to the hand). However, people prefer to perform most reaching actions with their preferred hand. They use their preferred hand in reaching to most objects in their peripheral environment. Therefore, it was concluded that repetition and frequency of reaching with the preferred hand occurs much more frequently than reaching with the non-preferred hand (Gabbard et al., 2003; Gabbard et al., 1997; Helbig & Gabbard, 2004; Pryde et al., 2000; Doyen et al., 2008). According to the kinesthetic perspective, performing actions on each side of body with the ipsilateral hand is defined as hemispheric bias or kinesthetic proficiency. Hence, hemispheric bias means that using the ipsilateral hand for reaching can limit biomechanical constraint effects bearing on the movement. In other words, using the

[1] - *Science and Research Branch/ Islamic Azad University/ Tehran/ Iran*
[2] - *University of Alzahra/ Tehran/ Iran*
[3] - *Science and Research Branch of Islamic Azad University/Tehran/ Iran*
[4] - *Mashhad Branch/ Islamic Azad University/ Tehran/ Iran*
[5] - *University of Rehabilitation and Welfare Science, Tehran*

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contralateral hand for doing such actions requires longer trajectory and body midline crossing, which leads to action efficiency reduction (Gabbard et al., 1997). Recently, some studies suggest other various factors that affect limb selection. For example, studies performed on adults imply that doing actions in contralateral hemispace reduces probability of using preferred hand considerably (Helbig and Gabbard, 2004), while most subjects prefer the use non-preferred hand for doing and ipsilateral action. According to Gabbard et al.(1997) and Gabbard et al. (2003), motor dominance (hand dominance) is the first determining factor in selection of hand in the ipsilateral hemispace. Nevertheless, attentional information related to object location can influence limb selection in the contralateral hemispace.

Task demand or skill demand is another variable that may have effect on limb selection (Bryden et al., 2003; Mamolo et al., 2004; Leconte and Fagard, 2004, 2006; Hill and Khanem, 2009). For instance, using an object or even presenting it (pantomime) can lead to more recalling of the preferred hand in contralateral hemispace; while in lifting an object this does not occur (Mamolo et al., 2006).

Based on the developmental perspective, some studies have examined task complexity in children as well and obtained inconsistent results. For example, in a study performed on children in third and fourth grade, using the preferred hand increased between 6-16 percent with regard to increasing task complexity (Steingrueber, 1975); but another study found no significant effect for task effect on hand selection in 3-10 years old children (Pryde et al., 2000). There is also another concept, which is one of the main aspects of this research; that is, eye dominance or ocular dominance. Dominant eye refers to the eye, which does purposeful tasks, for example, the eye which focuses on the camera, or the eye, which is determined in hole-in-the-card test (Rice et al., 2008; Cheng et al., 2004). Based on some evidence, the visual system and visual skills have strong effects in sport performance (Ghasemi et al., 2009). There are also different studies on ocular dominance that indicate the effects and the role of this variable in human behavior performance. Research findings indicate that golf stroke accuracy increases when using the dominant eye, and this condition does not differ significantly with binocular view condition (Hofeldt et al., 1996). In another study, Coren (1999) observed that speeded target striking task was related to handedness and ocular dominance, and following binocular view, the dominant eye view had the best executive score. Sugiyama & Lee (2005), in a research on Japanese college students, demonstrated that the dominant eye could partly influence the accuracy in a golfer's putt. In addition, Shneor & Hochstein (2006) concluded that using the dominant or non-dominant eye has considerable impact on performance, and results were significantly better when the dominant eye focused on the target. Review of the literature on ocular dominance indicated that this variable could have an essential role, as a biological concept, in performing most motor behaviors. Moreover, based on the dynamic system, different factors such as biological, environmental and task constrains have important roles in movement and pattern formations, and every behavior is a product of interaction between these factors. Therefore, the question of this research can be expressed in a dynamic system as: What are the effects of environmental (objects location), task (doing actions with different level of difficulty) and biological constraints (ocular dominance) on hand selection for reaching behavior in adults?

Method

This research consisted of physical education students at Mashhad University in Iran. Following the eye and hand dominance tests, Aneet handedness questionnaire (Aneet, 1970) and hole-in-the-card test, 85 female and male subjects (39 female and 46 male, 47 being right-eye dominant and 38 being left-eye dominant) were evaluated among qualified people (strong right handed and healthy, age range= 18 to 25 yrs) as the study sample .

Design and data analysis

Implementation method and tools employed in this research were extracted from Mamlo et al., (2004). Five tools were placed in five positions with 45 intervals on a half circle with a 30cm diameter. Position 1 was far right, position 2 near right, position 3 midline and positions 4 and 5 in near left and far left, respectively. Used tools included pencil, paintbrush, small knife, small plastic saw, and a small hammer. According to Waterloo's handedness questionnaire, these tools require most recalling of dominant hand.

Each participant was seated at a table in front of the experimental apparatus with his/her hands resting on the table. Then experimenter randomly asked subjects to accomplish one of following tasks with the objects: 1. simple lifting of objects, 2. pantomime the use of the tool (first lifting the object and then its pan-

tomime, 3. Real use (first lifting and then performing the action). In this test, subjects were asked to perform the respective action naturally and quickly. In this case, experimenter stands before the subject and records data related to each effort. Efforts related to each tool and actions were recorded in combined form and randomly in a 15-effort set format. After finishing the first block, the tool's location was changed so that each tool was placed in a specified position. At the end of the task, each subject should accomplish 75 efforts. Regarding the fact that each variable has different aspects (task = 3, location = 5, ocular dominance = 2), the research design was an inter-group design and multifactor variance analysis (3.2.5) with repeated measures used for variable study. Furthermore, different tests such as t-dependent, ANOVA and MANOVA were used to determine the effect of each variable and their interactions on frequency of preferred hand use.

Results

Based on findings of this research, the task has significant effect on frequency of preferred hand usage ($p=0.000$, $F=23.351$); that is, by increasing level of task difficulty, preferred hand recalling also increased. According to statistical results, the preferred hand was most frequently used in real use tasks ($M= 24.99$) and next most commonly used in pantomime action ($M = 24.89$) and lastly in simple lifting ($M = 23.78$). Regarding Tukey's follow up test, it was found that there were significant differences between mean frequency of preferred hand reaches in lift tasks and the other two tasks (pantomime and real use) ($p = 0.001$) , while this difference was not observed in pantomime and real use tasks ($p = 0.873$).

According to results, object location has also an impact on frequency of reaching with the preferred hand ($F=17.113$, $p=0.000$). Thus, after positions 1 & 2 in the ipsilateral hemispace, more reaching was observed with the preferred hand in midline position ($M = 14.91$), compared to near ($M = 14.68$) and far left positions ($M = 14.12$). However, Tukey's follow up test did not show differences between far and near right, midline and near left positions. It was aslo found that mean reaching frequency with preferred hand in the far left position is significantly less than other positions ($p = 0.000$) (figure 1).

However, regarding combination and interaction of task and object location variables, it was found that there was a significant difference between different tasks in different positions ($p = 0.000$, $F = 0.059$). It also was found that mean frequency of using the preferred hand in far left position for lift task ($M = 4.2$) has significantly different in comparison with the other two tasks (pantomime mean=4.929 and real use mean=4.988) ($p = 0.000$) (figure 2).

Regarding the third variable of eye dominance, results indicated that there was no significant difference ($p = 0.223$) between mean frequency of using the preferred hand in right-eye dominant group ($M = 73.9$) and left-eye dominant group ($M = 73.39$). Interaction analysis of eye dominance with other variables, such as an object's location, showed that there was no significant difference between frequency of using the preferred hand in different positions in right- and left-eye dominant people ($p = 0.055$). Similar results were also observed for interaction between ocular dominance and task demand, which demonstrated no significant difference between using the preferred hand in different tasks in right- and left-eye dominant people ($p = 0.908$) (figure 3).

Interaction of all factors showed that there was no significant difference between mean frequency of using the preferred hand in different tasks in different locations between left- and right-eye dominance ($p = 0.0292$).

Discussion

The aim of this study was to evaluate factors affecting the usage of preferred hand for reaching in adults. In this research, interaction of three factors (dominant eye, object location, and task demand) was evaluated. According to some studies, handedness is only under influence of biological factors, with postnatal factors and environmental features having no influential affects (Geschwind et al., 2002; Van Strien, 2002). For example, Van Strien (2002) indicated that handedness is completely under the influence of genetic and inheritance factors. Geschwind et al. (2002) also concluded that hemispheric dominance can effectively influence handedness and indicated that in most people (adults and children), there are similar variables that incline people to use the right hand more frequently, and these variables originate from biological factors. However, other studies showed that limb selection was initially under influence of handedness and later was influenced by environmental factors. In fact, motor dominance and limb selection are flexible variables, which environmental factors have impact on (Gabbard et al., 2004). This research also studied other factors such as attentional information of an object's location and task demand, as well as ocular dominance. As mentioned earlier, factors related to an

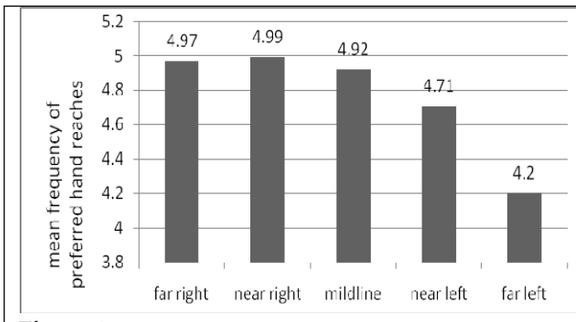

Figure 1

The mean of the frequency of preferred hand reaches at each position for right-handed participants

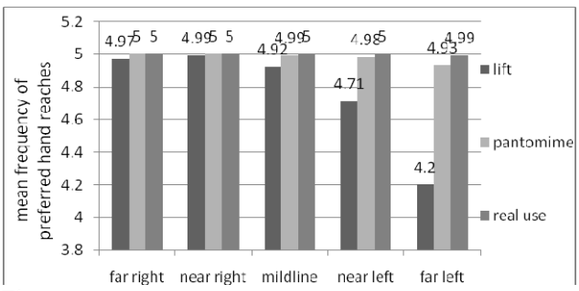

Figure 2

The mean of the frequency of preferred hand reaches at each position for right-handed participants. The frequency of preferred hand reaches was summed across the five tools to give a maximum possible score

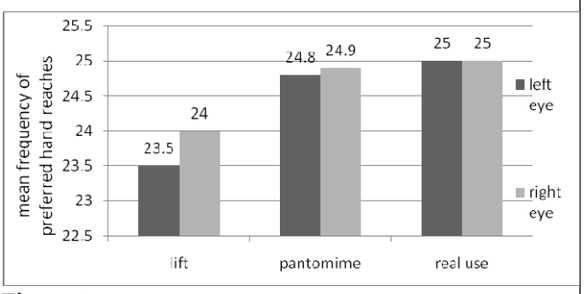

Figure 3

The mean of the frequency of preferred hand reaches for different skills in participants with left and right eye dominant

object's location have an effect in frequency of reaching with the preferred hand in adults. Thus, with almost all ipsilateral reaching efforts performed with the dominant hand, this changed significantly in contralateral hemispace, such that frequency of reaching with the preferred hand in far left position reduced significantly compared to other positions, especially positions related to ipsilateral hemispace and midline position; this finding is consistent with Mamolo et al. (2006) observations.

On the other hand, with regard to task demand effect, frequency of using preferred hand in different tasks changed significantly. This concept showed that people preferred to cross body midline for performing pantomime actions and in real use contralateral hemispace with regard to the biomechanical, non-efficiency of these movements. This indicates an increase of recalling the preferred hand with an increase in task difficulty level. Based on review of related literature, these results are not consistent with the Gabbard and Helbig (2004) and Gabbard et al. (1998) observations about body tendency of using each hand for performing task nearest it. These findings are also inconsistent with the hemispheric bias concept, which is about body tendency and convenience for responding actions on each side of the body with the ipsilateral hand (Gabbard et al., 1998).

A behavior may occur as the result of different factors interacting, or more accurately, as a result of interaction between environmental, biological constrains and task demand (Newell, 1986). Based on most researches in this field, hand dominance, or motor dominance, is related to biological constraint factors, the effect of which limb selection has been clearly defined (Gabbard and Helbig, 2004). According to this perspective, ocular dominance was regarded as a biological constraint in this study and its effect on limb selection was evaluated, among other factors. On the other hand, according to one suggestion based on hemispheric bias, using the ipsilateral hand for performing actions on each side of body causes referring to visual information of the same side that this feature provides more appropriate processing in one hemisphere (Bradshaw et al.,1994). Moreover, by definition, ocular dominance is a constant tendency for receiving input information from one eye which is more accurate and pictures seem clearer, larger, and more constant, and this eye can limit information from the less dominant eye (Porac & Coren, 1975, 1976). Therefore, the main question was whether the dominant eye, as a determining variable in visual information and as a biological constraint, has any effect on the organ . Based on results, frequency of preferred hand usage in people with left- and right-eye dominance did not have any significant difference, which suggests a lack of impact of this variable on limb selection. Even interaction of the ocular dominance variable with two other factors did not indicate any significance for this variable effect on limb selection. According to most studies, using the dominant eye leads to better performance (Shneor and Hochstein, 2006,

2009; Coren, 1999). For example, observations of Shneor and Hochstein (2006) indicated that the dominant eye has preference on binocular view processing, and using the dominant eye results in significant differences in performance, which may be due to the inhibitory role of the dominant eye against information from the less dominant eye. Unfortunately, the author did not find any research evaluating the effect of this factor on limb selection and it seems that this study is the first which evaluated dominant eye effect in limb selection. Based on results of this study and other studies on dominant eye, it can be suggested that although ocular dominance influences performance, this variable in adult limb selection is under influence of stronger factors such as motor dominance or handedness, object location and task demand. However, a possible question for future research is whether occular dominance is also ineffective in limb selection of children or infants whose preferred hand has not yet been determined, or if this factor, like other factors, such as handedness, may be under influence of the developmental process.

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Corresponding author

Meysam Rezaee
Science and Research Branch/ Islamic Azad University/ Tehran/ Iran.
Number 48, emamat14 Ave, vakilabad St, Mashhad, Iran.
Phone : +989157062015
Fax: +989157062015
E-mail: mysm_rez@yahoo.com