An Investigation into the Relative Importance of Vision Whilst Making Bimanual Reaching Movements, in the Preferred and Non Preferred Hands of Adults

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Abstract

It is widely agreed that visual feedback contributes to the coupling between the two upper limbs found at the end of a bimanual movement (e.g. Riek et al, 2003; Kelso et al, 1979; Marteniuk et al, 1984), however, another contributing factor, proprioception, has also been identified (Jackson et al, 2000). One could argued that the two factors need to work together in order to control a bimanual movement. 12 right-handed participants took part in an experiment to identify how ones preferred and non preferred limbs use both of these feedback methods. Visual information was manipulated resulting in four vision conditions and further combined with four distance conditions, giving a total of 16 unique trails. The results concluded that amount of visual feedback available can make a significant difference on the asynchrony at the end of a movement.

Introduction

Kelso, Southard and Goodman (1979) aimed to investigate the possible coordination between the two upper limbs. In this study, two movement conditions were created, 'easy' and 'difficult'. These were based upon combinations of target size and the distance the limb had to travel to make the movement. Kelso et al state that using the principles of Fitts' Law (developed by Fitts, 1954), movement time for a one-handed movement in the easy condition (a large target and a short distance), would be quicker than that of the difficult condition (a small target and long distance). It was then considered if when performing a two-handed movement, would the hand with the easier task reach the target quicker than the hand with the more difficult task, or would both hands begin and end their movements at the same time? This was investigated in a pilot study (Kelso et al, 1979) and it was concluded that during bimanual movement tasks where the two hands individual movements were of different difficulties (e.g. when one hand moves to an easy target, and the other to a difficult target) the hands acted as a single unit, and were closely coupled. After conducting three separate experiments using similar designs, Kelso et al concluded that unimanual movement times for difficult tasks were longer, and that this was the same for bimanual congruent movements with equal difficulty for each hand, however that when bimanual incongruent movements were made the differences in the overall movement time for each hand were not found, indicating again that the hands were coupled during these movements.

The 1984 paper by Marteniuk, MacKenzie and Baba described similar results to those found by Kelso et al (1979). However, results from experiments conducted by Marteniuk et al (1984) showed that although there does appear to be coordination between the two limbs when making a bimanual movement, they are not always carried out in the synchronous manner described by Kelso et al.

Further investigation has been conducted by Riek, Tresillian and Mon-Williams (2003). After conducting three experiments, Riek et al found similar asynchronies to those found by Marteniuk et al, one of these being named as a 'hover phase'. Riek at al found this tendency for a temporal asynchrony at the end of a movement compensated for the asynchronies at the start of a movement, allowing movements to start and end at approximately the same time. Riek et al argue that this phase of hovering by one hand, allows the other to find its spatial position before both limbs terminate the movement together. It was also argued that as one cannot use vision to monitor the position of two hands at one time, a limitation of the human visual system, each hand is monitored individually, resulting in this temporal asynchrony.

Although the role of visual feedback has been widely studied and it is agreed that visual feedback does contribute to the coupling between the two upper limbs found at the end of a bimanual movement (e.g. Kelso et al 1979; Marteniuk et al 1984; Riek et al 2003), others have argued that it may not only be feedback from the visual system that aids a bimanual movement. Researchers such as Jackson, Jackson, Husain, Harvey, Kramer and Dow (2000) outlined evidence displaying that proprioception also aids these movements and that the two feedback systems may work together, with information from the visual system ensuring the accuracy of one's proprioceptive knowledge. A study conducted by Jackson et al (2000) examined the effects of proprioceptive signals in bimanual movements, comparing the performance of an individual, named D.B., whom had no sense of one limb, with the performance of normal individuals. Both D.B. and the control participants had full vision of the required targets. Jackson et al found that the level of coupling in the bimanual movements made by D.B. were impaired when compared to the control individuals. This evidence would support the argument that proprioception also aids a bimanual movement.

The following research aims to identify how ones preferred and non preferred limbs use both of these feedback methods. The main objective is to identify whether the asynchrony of the two hands at the end of a bimanual movement is affected by the amount of visual feedback the limbs receive.

Method

Participants:

A total of 12 participants took part in the experiment on a voluntary basis. There were 3 male and 9 female participants, with a mean age of 26.83years (SD 4.26). All participants were right-handed, assessed by using the Edinburgh Handedness Inventory (Oldfield, 1971) and had normal or corrected-to-normal vision. The experiment had full approval from the School of Psychology ethics board.

Equipment and Data Recording:

The MIRAGE VR system (as described by Preston and Newport, 2010) was used in the experiment. This showed participants real-time video images of their hands captured via specifically placed cameras, and reflected onto a mirror above the table top, from a computer monitor (as detailed in figure 1). Participants were seated on a height adjustable chair to ensure an accurate and full view of the video images displayed on the mirror. The equipment enabled the manipulation of the visual information available to the participant of one or both hands. The required start positions were clearly marked on the table top. Along with the image of the participant's hand/s, targets were reflected onto the mirror. There were four possible target positions which can be seen in figure 1. The participants always had full view of the necessary targets, despite any manipulation of the visual information of the hand/s.

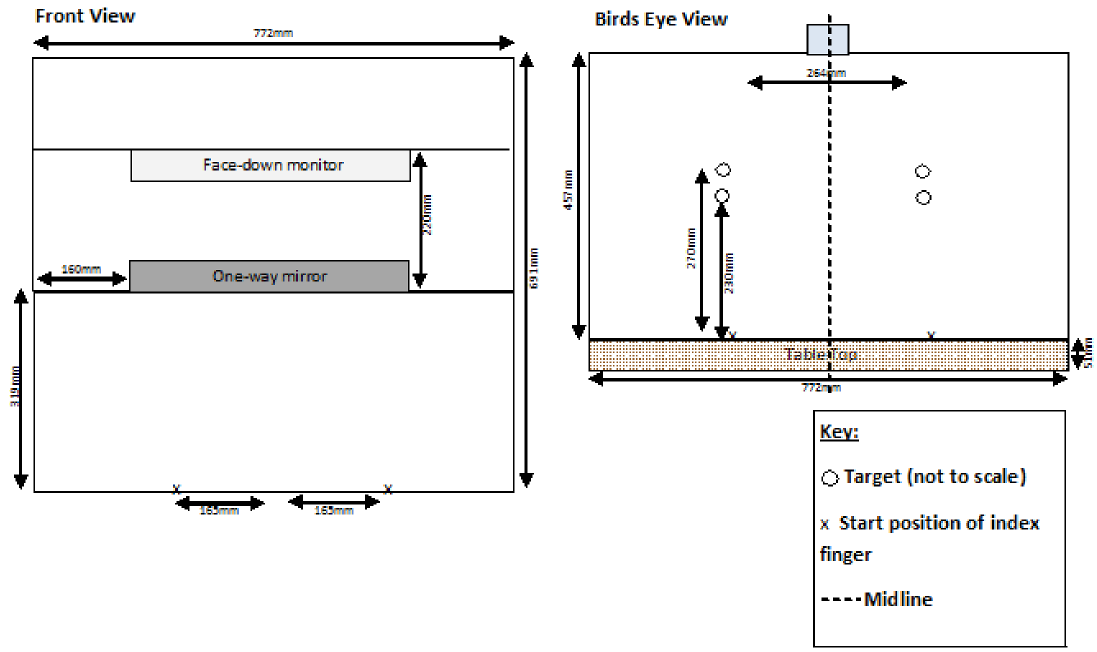

Fig.1. Simplified diagram of the MIRAGE VR system, displaying measurements and distances. All to scale (except target size).

The participants' hand movements were recorded using a MiniBIRD position and orientation measurement system (Ascension Technology, Inc., Burlington, VT) at a sampling rate of 94.7 Hz. A total of two sensors were attached to the participant's index fingernails, one on each hand and the receiver was positioned 508mm from the start position along the midline.

The raw movement data received from the MiniBIRDs was analysed using a custom analysis programme written with the LabVIEW programming environment (National Instruments Corp., Austin, TX).

Design and Procedure:

Each participant completed a total of 128 bimanual trials within the experiment. Visual information was manipulated resulting in four vision conditions:

- full vision (FV, participants were able to see both hands)

- no vision (NV, participants were unable to see either hand)
- left vision (LV, participants were able to see the left hand only)
- right vision (RV, participants were only able to see the right hand)

The order of the vision conditions was counterbalanced across participants. Within each of the four vision conditions were a further four distance combinations:

- left hand near – right hand near (NN)
- left hand near – right hand far (NF)
- left hand far – right hand far (FF)
- left hand far – right hand near (FN)

The combination of vision and distance conditions gave a total of 16 unique trials, each repeated eight times. The order in which the trials were presented to the participants was quasi-randomised to ensure no more than two identical trials occurred sequentially.

The participants were required to sit at the table and place their index fingers on the start positions. Participants were instructed that when the target appeared they must reach towards the target and touch the tabletop (below the mirror where the target appeared), as accurately as possible, then return to the start position. Participants were given the opportunity of a short break after every block of trials.

Data Handling and Analysis:

The dependent measure for the research was the time difference between the points at which each hand completed its movement (end lag). This was examined in terms of both signed and absolute data.

A 4 x 4 analysis of variance (ANOVA) was carried out with repeated measures over visual and target condition.

Results

Signed Lag:

The ANOVA showed no main or interaction effects. This would suggest that there was an equal lag across all of the conditions. The average level of asynchrony was -7.436325, suggesting a slightly dominant left hand lead.

Absolute Lag:

The ANOVA showed a main effect of vision [$F(2.623) = 3.096$, $p<0.05$]. There were no other significant main or interaction effects.

Figure 2 indicates that overall, the greatest asynchrony occurs when visual feedback is received from the non preferred limb (LV). The visual condition showing the most synchronised movements is that of no vision. The lag in the full vision and right vision conditions is very similar (approximately 79ms).

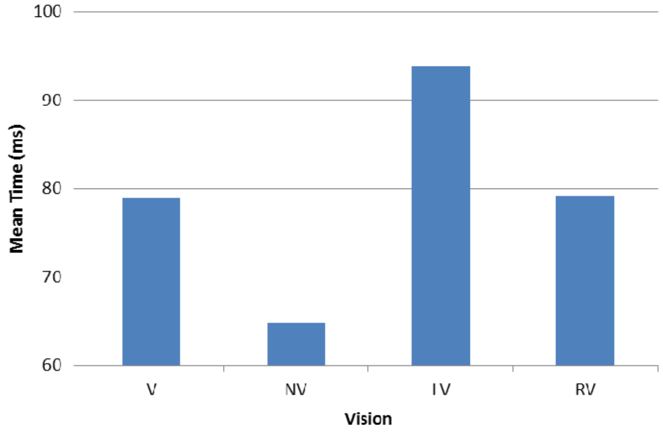

Fig.2. Mean lag for each of for each of the vision conditions (absolute data).

Figure 3 plots the mean lag for the four distance conditions. Although there is no significant effect of condition on end lag, this graph shows that the greatest asynchrony occurs when making incongruent movements (conditions NF and FN).

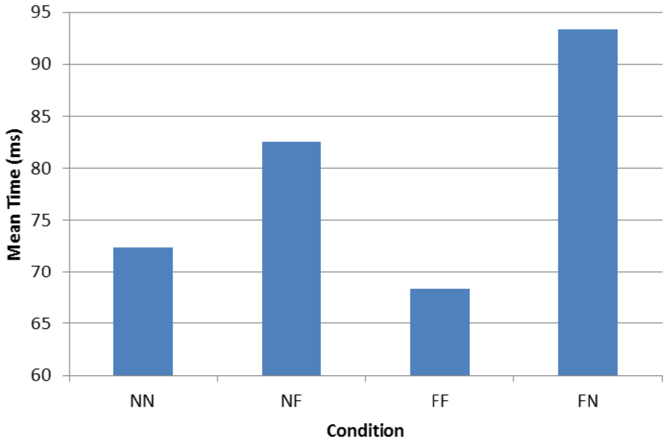

Fig.3. Mean lag for each of for each of the distance conditions (absolute data).

Discussion

This experiment aimed to identity how ones preferred and non preferred limbs use visual and proprioceptive feedback methods when making bimanual aiming movements, with focus on the asynchrony between the two hands at the end of the movement.

The results differ greatly when analysing the two different types of data, signed and absolute. The analysis of the signed data showed no significant main or interaction effects and would infer a tight coupling between the two upper limbs when making bimanual movements, and would therefore support the research findings of Kelso et al (1979), whose conclusions were drawn from analysing the signed data only. Conversely, if analysing the absolute data, very different results are found.

The first result to be discussed is that the greatest synchrony occurs when there is no visual feedback available (no vision condition). This supports the research findings of Riek et al (2003). They argued that a visual strategy is used for accurate target acquisition. Visual feedback is used to make corrections about the positioning of the limb, and temporal asynchronies occur as a result of not being able to monitor the two hands at the same time. In this research, when the visual feedback of the hands was removed, the hands displayed more synchrony than any of the conditions providing visual feedback. Due to the nature of the no vision condition, participants were able to use proprioception to match the positioning of their limbs with the visual information that was available – vision of the targets. This is a clear example of combining proprioceptive and visual feedback.

Another finding from this research that is supported by the previous findings of Riek et al (2003) is that a very similar asynchrony was found in the full vision and right vision conditions. Riek et al argued that when making bimanual movements, one's attentional focus will be on the preferred hand. This claim could be used to explain why such results occurred. It could be argued that because attention is focused on the right hand, the left maps itself, where possible, to the preferred hand. This leaves any visual feedback of the non preferred hand unrequired. When visual feedback was received from the non preferred limb only (in the left vision condition), the greatest asynchrony was found. This is further evidence to support the notion that the visual feedback of the preferred limb is more important when making a bimanual movement.

The final result to be discussed is the effect of the movement condition on the asynchrony of the hands. Incongruent movements (conditions NF and FN) produce the greatest asynchrony, with the longest lag between the hands being in the FN condition, where the non preferred hand has the more difficult task. This further highlights the point made previously, that the greatest asynchrony occurs when feedback is received from the non preferred limb and that the difficulty of the task also affects the synchronous manner in which the two limbs behave. The results also show that congruent movements (NN and FF) display the greatest synchrony between hands, indicating that when the two limbs are making identical movements they are able to used proprioceptive matching, regardless of the visual feedback available.

In conclusion, this research suggests that one's preferred and non preferred limbs utilise visual and proprioceptive feedback methods in different ways and that the amount of visual feedback available can make a significant difference on the asynchrony at the end of a movement. Further research could be done to examine the findings on congruent movements to determine whether the movements are guided by proprioceptive matching, rather than the visual feedback available.

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