EXTENSION OF FITTS' LAW IN THREE-DIMENSIONAL SPACE WITH COORDINATED HAND MOVEMENTS

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ABSTRACT

Fitts' Law is a powerful model of human movements that predicts the time that it takes to move to targets of different widths and at different distances. It has been widely used in the field of human-computer interaction and in the design of the Graphical User Interface (GUI), and it is often a measure of the ergonomic acceptability of a cursor-positioning device. When first proposed in 1954 it was applied to one-dimensional (1D) and two-dimensional (2D) pointing tasks. Since that time numerous researchers have verified and extended Fitts' law to include three-dimensional (3D) tasks. Various modifications have been proposed for a variety of situations. Factors that might have an effect on the model have also been studied. The extension of Fitts' law to 2D space has been well documented, however research on the extension to 3D space has been restricted due to limitations of input device designs. The recent development of 3D input devices, such as the Kinect system launched in 2010, allow accurate gesture recognition and 3D gesture control of a computer interface.

This research was conducted to test the application of Fitts' law to coordinated hand movements in a 3D response space. A laboratory experiment was conducted in which 20 participants performed pointing tasks involving varying target distances, target sizes and approach angles using both Left Hand Move and Right Hand Click (LMRC) and Right Hand Move and Left Hand Click (RMLC).

Quantitative measures of movement time and qualitative measures of fatigue etc. were gathered. Video recordings of the participants' movements from three directions were used to analyze posture.

Results confirmed that Fitts' law applies to coordinated hand movements in 3D space. No significant gender difference was found for either the movement time or the response postures. Participants mainly reported that the tasks were fatiguing.

The main limitation of this study was that the software used in the experiment caused noticeable cursor vibration. Software that can provide a more stable display might be an improvement. In the future, more appropriate gestures and tasks could be found for testing the usability of 3D gesture control of computer interfaces.

BIOGRAPHICAL SKETCH

Xiaolu Zeng grew up in Chengdu of China where she completed her high school education at Chengdu Foreign Languages School. She received her Bachelor of Science degree, with honors, for the study of Psychology at Zhejiang University in 2010. Xiaolu came to Cornell to continue her work in human factors toward a Master degree. This thesis was completed as part of the requirement for the Masters of Science Xiaolu will receive in May, 2012.

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Chapter 1 INTRODUCTION

Since Paul Fitts proposed Fitts' law as a model based on information theory in 1954 (Fitts, 1954), it has been widely used in the interface design and human-computer interaction fields. Because of its importance, the extension of Fitts' law to two-dimensional space (2D) has been well developed. Various models have been proposed and their advantages and disadvantages have been thoroughly discussed. Research on the extension of Fitts' law to three-dimensional space (3D) is still limited though, partly because commercial use of computers is restricted to the desktop system (computer, keyboard and mouse) or laptops. However, this situation is gradually changing. More and more input devices have started to incorporate 2D and 3D gesture control. For example, the Kinect system, launched in 2010, can provide accurate gesture recognition in 3D space. Coordinated hand movement is very common while using this system. It makes truly free-hand gesture control possible.

Researchers are also interested in the postures people adopt during their computer interactions. Various factors, such as awkward posture and extended duration of operation may result in musculoskeletal disorders (MSDs) (Turhan, Akat, Akyuz and Cakci, 2008). Research on possible gender differences in this field has been done and showed that women usually have a higher prevalence than men for MSDs (Dahlberg, Karlqvist, Bildt and Nykvist, 2004), even after controlling age or work factors (Treaster and Burr, 2004).

The purpose of this research was to extend Fitts' law into three-dimensional space with coordinated hand movements, and to take a look at the posture of participants when interacting with the Kinect system. Any possible gender difference in posture was also taken into consideration. The following questions were explored:

1. Can Fitts' law be applied in 3D space with coordinated hand movements?
2. Is there a gender difference on posture when making 3D coordinated hand movements?

Chapter 2 BACKGROUND

2.1 Information Theory

Information theory, a branch of applied mathematics and electrical engineering, is about the quantification of information and was developed by Claude E. Shannon (Shannon, 1948). The theory is based on a general communication model: the information source produces a message or sequences of messages; the transmitter operates on the message to make it transmissible through a medium called the channel; a transmitted message reaches the receiver, which reconstructs the message at the destination (Shannon, 1948). In which information has been defined as a reduction in uncertainty (Shannon and Weaver, 1949) and quantified in units of bit.

It has been applied to many areas, including statistical inference (Jaynes, 1957), the construction of decision trees (Hartmann, Varshney, Mehrotra and Gerberich, 1982), and psychology (Hick, 1952) (Fitts, 1954). Entropy is the key measure of information based on information theory, which quantifies the uncertainty involved in predicting the value of a variable.

Hick's law (Hick, 1952) and Fitts' law (Fitts, 1954) are two well-known models developed from information theory in the field of psychology. The distinctive difference between the classical information theory and the psychological one is that engineers are capable of knowing the channel capacity through the physical hardware (bandwidth, type of cable, distance, etc.). Experimental psychologists can only determine capacity by measuring the information processing performance of a sensory, cognitive or motor system to obtain an inference of that psychological system (Seow, 2005). This is what Hick's law and Fitts' law try to do.

Hick's law is based on the rate of gain of information (Hick, 1952), describing the time needed for a participant to make a decision as a result of the possible choices available, in which the average reaction time $T = b*\log_2(n+1)$. Here, n refers to the number of equally probable choices while b is a constant determined from the observed data. The logarithmic term was developed from the definition of entropy (the uncertainty in predicting a value) described in information theory, which is similar to that in the Fitts' law model. Hick's law described cognitive information capacity, and, similarly, Fitts' law described the human motor system (Seow, 2005).

2.2 Fitts' Law Model

Fitts' law is a fundamental model widely used in interface design and human-computer interaction to test the design of computer products such as the stylus, trackball and mouse, and it describes the relationship between human movement time and the target's physical characteristics in a pointing task. It is a testing requirement for input devices that conform to ISO 9241. Because of the accuracy of prediction of movement times, extensions of Fitts' law to 2D space and 3D space have been done (see below). Various factors that might affect movement time, such as target width, distance, approach angle, age and gender have been taken into consideration.

2.2.1 The Original Fitts' Law Model

Fitts' law extends information theory to the human motor system, making predicting movement time based on target physical characteristics possible. The original task (also known as "Fitts' paradigm" (MacKenzie, 1992)) was a 1D task. Participants moved laterally from side to side between two strips to click the center of the targets with width constraints only in the movement direction on a flat metal plate with various target widths (W) and amplitudes (A) using a stylus (Figure 2.1). The task mainly involved the lower arm muscles (Fitts, 1954). Indices of difficulty (ID) and performance (IP) were proposed based on information theory and its conventional notation, where ID = $-\log_2 (W/2A)$ bits/response and IP = $-(1/t) \log_2 (W/2A)$ bits/sec (Fitts, 1954). ID reflects how difficult the combination of W and A is to a user, while IP is independent of the particular targets involved, reflecting how quickly the pointing task can be completed.

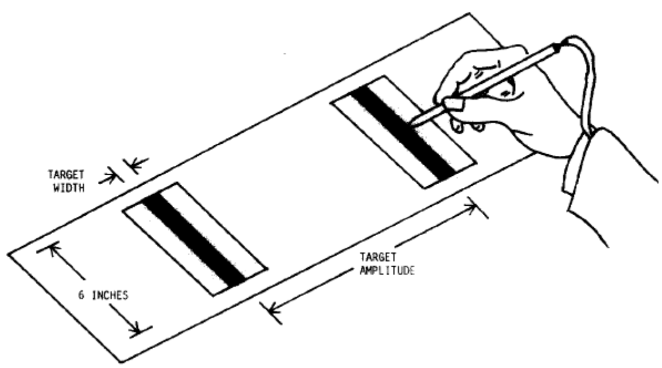


Figure 2.1 Fitts' original Reciprocal tapping task (Fitts, 1954)

According to Fitts' law (Fitts, 1954), the movement time (MT) to select a specific target is a function of the target width (W) and the distance from the starting point to the target (A), which can be derived from

$$MT = a + b \log_2 (\frac{2A}{W})$$

(in his original publication a=0).

In this equation, a and b are constants determined by linear regression, and they depend on the specific pointing product, the environment in which the product is used, the sensory channel being used and the person who is using the product. To calculate the ID, A and W were always measured in the same plane on the same axis.

As a fundamental law that predicts movement time very well, Fitts' law has been tested by many researchers. It has been widely used in testing input devices, and some revisions of the original formula have been proposed to better fit the observations. Welford (1968), modified the equation into

$$MT = a + b\log_2(\frac{A}{W} + 0.5)$$

while MacKenzie (1989) changed the equation into

$$MT = a + b\log_2(\frac{A}{W} + 1)$$

(also known as the Shannon formulation).

The main difference between these equations is the manner of calculating the index of difficulty (ID). Welford's revision was based on observed data and this equation avoids giving ID a value of zero or infinite (when A/W = 0), which would make no sense. The Shannon formulation was proposed by MacKenzie (1989) and was based on an adaptation of Shannon's equation. This formulation also avoids giving ID a value of zero and also can make ID always be positive ((A/W +1)>=1, thus $\log_2$ (A/W+1) >=0). Observations also show that the Shannon formulation provides a slightly better fit with the observed data (MacKenzie, 1989).

2.2.2 Extension of Fitts' Law in Two-dimensional Space

Because of the accuracy with which Fitts' law has to predict movement time, an extension of Fitts' law to 2D movements has been developed. The main difference between 1D movement and 2D movements is that in 2D movements it is now in 2 axes (left/right, forwards/backwards). The pointing task now can be taken as controlling both amplitude (defined by W) and directional error (defined by H) (Accot and Zhai, 2003). The method to define the index of difficulty for 1D tasks needs to be modified to apply to 2D tasks.

Target shape and approach angle bring new questions to the application of Fitts' law in 2D space. For example, with circular targets, target width is always the radius and keeps constant throughout all approach angles. However, for rectangular targets, to take the height or width of the rectangle as the target width depends on the approach angle. If the target width is defined as the length along the approach angle, the rectangle's width would be taken as target width while moving along the rectangle's width. However, the height would be taken as target width while moving along the height. The role of width and height of the rectangle changes as the approach angle varies. Taking a look at the specific rectangular target in two-dimensional tasks is meaningful. Most buttons have a rectangular shape, and tasks such as text selection can also be seen as rectangular target selection (Card, English, & Burr, 1978). Target width has been redefined in various models to make ID still applicable to Fitts' law (see below).

Different Fitts' Law Models in Two-dimensional Space

For all of the models described below, participants conducted 2D movement through the mouse to control the cursor on the computer screen. The 2D targets were displayed on orthogonal surface (the computer screen).

Many models have been proposed for determining ID. One of them is the W' model. In this model, for a rectangular target, the target width refers to the width along the approach axis. The height, width, and the approach angle are needed to get the target width (W'). MacKenzie (1992) thought this model valuable because it allows a one-dimensional interpretation of a two-dimensional task.

Another model is the "SMALLER-OF" model in which the target width refers to the smaller of Height (H) and Width (W). This model is appealing because it is easy to apply (MacKenzie, 1995). Users don't need to know the approach angle to get ID, unlike the W' model.

In the "STATUS QUO" model, target width always refers to the length of the horizontal axis of the target.

Another two models, W+H and W*H, were assessed by Gillian, Holden, Adam, Rudisill and Magee (1990) to see whether they can be substitutions for target width. In these two models target width is substituted with W+H or W*H. Gillian et al. (1990) justified W+H because it is "the border of the text object closest to the start button", and thought the W*H model was appealing because it ignored the limitation of target shape.

All of the models mentioned above focused on rectangular targets. The definition of target width was different among these models. Since the effect of rectangle's height and width would be different considering the different approach angle. However for circular targets, the difficulty to define the target width can be avoided. No matter what the approach angle is, the target width is always the radius.

MacKenzie (1992) tested the fit of each model for a given condition (a rectangular target was used in the experiments). Both the W' model and the "SMALLER-OF" model performed better than the others (no significant performance difference between them), and these two models have no differences in calculating target width for circular targets. However the validity of his results is questionable since he only tested the model when the approach angle is 0, 45 or 90 degrees. And more importantly, the W' model doesn't take account of the limit tasks properly (Amplitude pointing task v.s. Directional pointing task: Accot and Zhai, 2003). Here, an amplitude-pointing task refers to a pointing task when H tends to infinity, while a directional pointing task refers to a pointing task when W tends to infinity. One model was found to provide a better fit (Accot and Zhai, 2003)

$$MT = a + b \log_2 \left(\sqrt{\left(\frac{D}{W}\right)^2 + \eta \left(\frac{D}{H}\right)^2} + 1 \right)$$

Where 'a' varies in the range of [-50, 200], b in [100,170], γ in [1/7, 1/3]. The impact of amplitude and directional constraints was found to be unequal, with the former dominating the latter (Accot and Zhai, 2003).

In recent years, a new probabilistic model has been proposed (Grossman & Balakrishnan, 2005). In this model, a function to map the probability of hitting a target to an ID value was used. The probability of pointing inside the region defined by the target, based on the spread of hits was calculated. Thus the region of the target was taken into consideration instead of the exact target shape. This model gives a good fit to the observed data (R^2=0.952) and also can be generalized to targets of any shape, which avoids the problem of target width. The idea of effective target width in a 1D pointing task was extended to effective target width in a 2D pointing task using a 2D joint probability density function which can reach a better fit than the conventional model (Murata, 2009). The approach angle in this experiment was fixed to 45°, which might be a limitation.

Considering the focus of my study was not to compare different 2D Fitts' models, circular targets were used in the present research.

Another research area for the extension of Fitts' law in 2D space is the effect of approach angle. Different muscle groups got involved with different approach angle thus might have an effect on the movement time. Boritz (1991) conducted an experiment to study directional mouse movement and found there is a relationship between the approach angle and the time required to move the cursor to a target. More rapid mouse-driven cursor movements at 0°, in comparison with 270°, was found. Whisenand and Emurian (1996) found moving along two vertical and two horizontal directions was generally faster than moving along four diagonal directions.

2.2.3 Extension of Fitts' Law in Three-dimensional Space

Several factors that might impact the movement time need to be addressed and controlled when discussing 3D tasks. In 3D tasks participants move in 3D space (left/right, forward/backward, up/down). Differences exist in the target characteristics. Participants might move in 3D space while seeing the targets in 2D space. If this is the situation, with all of the targets on the same plane, the angle of the plane needs to be addressed (horizontal, vertical or at an angle). The participants might also be presented with targets in 3D.

Movement in 3D space can be quite complicated and different from 1D or 2D movements. One of the main differences is that for 1D or 2D movements, the weight of the arm can usually be supported. While for 3D movements, there is often a lack of support. The weight of the arm and the hand becomes a load, which often leads to fatigue.

Another difference is that 3D movement involves more movements of the shoulder. Usually it includes scapular movements and humeral movements (Jenkins, 2009). The scapular movements includes elevation of the scapula (muscle group: trapezius, levator scapulae and the two rhomboids), the depression of the scapula (muscle group: pectoralis minor, subclavius, latissimus dorsi, lower trapezius, serratus anterior and pectoralis major), upward rotation of the scapula (muscle group: trapezius and the serratus anterior), downward rotation of the scapula (muscle group: rhomboids, levator scapulae, pectoralis minor, the pectoralis major and the latissimus dorsi) and the protraction of the scapula (muscle group: serratus anterior and pectoralis major and minor) (Jenkins, 2009). The humeral movements includes flexion of the arm (muscle group: anterior deltoid, clavicular of the pectoralis major, the coracobrachialis and the biceps brachii), extension of the arm (muscle group: posterior deltoid, latissimus dorsi, sternocostal of the pectoralis major, teres major and the long head of the triceps brachii), abduction of the arm (muscle group: supraspinatus), adduction of the arm (muscle group: pectoralis major, latissimus dorsi and teres major), medial rotation (muscle group: subscapularis) and lateral rotation (muscle group: infraspinatus, teres minor and posterior deltoid).

Considering the differences between two-dimensional and three-dimensional movement, there is a need to look at the extension of Fitts' law to three-dimensional space. Past research on 3D space is limited, due partly to traditional input devices only allowing movement in 2D space, and these devices (computer with mouse, touchpad etc.) are still the main options in today's human computer interaction system.

Researchers have started to look at the extension of Fitts' law in three-dimensional space. Murata and Iwase (2001), looked at the extension of Fitts' law to a 3D pointing task but they didn't truly address a 3D task in their experiment (movement is limited to the display plane). Participants were asked to interact on a vertical plane (all of the targets were 2D and were on the same plane), though proximal muscles, less accurate muscles, did get involved during the movement. A receiver (sensor) was tightly attached to the right index fingernail of the participant who used this as a mouse. The whole pointing task was some thing like using a "Wii" controller. The definition of "click" or "select" the target was different from that of the traditional pointing task. For the study, when the coordinate of the fingertip (the receiver) reached the target, it was defined as a click, thus there was no real movement for clicking or selecting the target. The task was only to point with this receiver to the target. The results showed that the conventional Fitts' model did not fit very well with the observations unless one additional factor was added. The extended Fitts' model had to contain the approach angle to "provide better fit, both in terms of r^2 and the standard error of the residual between the measured movement time and the value predicted by model fit".

The ID in the conventional Fitts' law was modified (Murata & Iwase, 2001) into

$$ID = \log_2(\frac{A}{W} + 1.0) + c \sin \theta$$

The optimal value of c was found to be 0.5.

Grossman and Balakrishnan (2004) studied Fitts' law with 3D targets created by a volumetric virtual display and extended the Fitts' model by defining MT as a function of target width (width along the movement axis), target height, amplitude and angle. The volumetric virtual display created a realistic image as it was in 3D environment. Cha and Myung (2010) created a real 3D pointing environment to study the extension of Fitts law. Electronic touch sensors in three axes were set to collect the movement data. However, in that research participants accessed 2D targets.

For all of the experiments mentioned above, the participants used a tracker or simply moved their right index finger to point. No coordinated hand movement was involved.

2.3 Applications of Fitts' Law

Fitts' law is useful for Graphical User Interface (GUI) design. It provides an effective quantitative method to model user performance for rapid, aimed movements, such as moving to a screen area and clicking on it. This is not limited to hand movement but also to other parts of the body such as the head (Jagacinski and Monk, 1985), chin (Andres and Hartung, 1989), thumb (Trudeau, 2011) and elbow (Corcos, Gottlieb and Agarwal, 1988). It is also not limited to clicking tasks but also applies to tap and drag tasks that involve pointing movements (Cockburn, Ahlstrom and Gutwin, 2011). It can be used to assist in the design of user interfaces (e.g., the layout of the buttons), in the interface/input device evaluation and in predicting the performance of operators in a human-computer interaction system. Recent researches on mobile interface keyboard proposed a better design called ATOMIK (Alphabetically Tuned and Optimized Mobile Interface Keyboard) (Zhai, Hunter and Smith,2002). Fitts' law was used as a quantitative design method in the research. Various pointing methods can be proposed based on Fitts' law to facilitate pointing tasks such as temporarily bringing potential targets to the cursor or removing empty space between the cursor and targets (Balakrishnan, 2004). For example, the bubble cursor method can enhance target acquisition by dynamic resizing of the cursor activation area (Grossman and Balakrishnan, 2005).

The general idea behind the application of Fitts' law in interface design can be summarized into three principles (AskTOG, 1999):

- Assign buttons that are more frequently used closer to the average cursor position
- Make those buttons larger
- Make full use of the boundary created by the edges of the screen (Farris et al., 2001)

Fitts' law can also be used for allocating tasks to operators and predicting movement time for assembly line work (MacKenzie, 1991). Another prevalent use of Fitts' law is as an indicator when comparing different input devices. Fitts' law is a testing requirement for input devices that conform to ISO 9241. It has been verified that Fitts' law can model both pointing and dragging tasks (Gillian etc., 1990) and the index of performance based on this law is often used as an indicator to compare various input devices (mouse, trackball or stylus with tablet) (MacKenzie, Sellen and Buxton, 1991). Ergonomic evaluation of various computer input devices (joysticks, track balls, mice) can be made based on Fitts' law (Zoller and Konheisner, 1999).

2.4 Limitations of Fitts' Law

Various factors that might affect the movement time, thus affecting the application of Fitts' law, are discussed below. Fitts' law focuses on velocity as the kinematic variable for predicting movement variability or precision. Some researchers suggested: 1) this might lead to several inconsistencies, such as different predictions for temporal and spatial constraints, and 2) reliance on velocity does not provide a framework for addressing other important variables such as mass (Flach, Guisinger and Robison, 1996). The authors proposed a new model, which focused on acceleration and in which an acceleration-accuracy tradeoff account for the performance differences.

2.4.1 Fitts' Law with Different Task Characteristics

Movement and Task Paradigm

Fitts' law was designed for rapid and aimed movements. For tasks like steering, drawing curves or handwriting, a new method is needed to describe movement. The CLC (Curves, Line segments and Corners) model described single-stroke pen gestures within certain error constraints in terms of production time well (Cao and Zhai, 2007). Steering law predicts the movement time while steering in a 2D tunnel. Movements like radial selections should be modeled using Steering Law (where the tunnel width increases with movement distance) instead of Fitts' Law (Cockburn, Ahlstrom and Gutwin, 2011). Fitts' law mainly describes low-level tasks like pointing and moving. It does not address issues that might affect movement time such as system response time, mental preparation time or selection rules for alternative methods (MacKenzie, 1991). These issues have been addressed in the Keystroke-level Model and the CPM-GOMS model (John, 1988). The time required for each phase was determined and the task was decomposed of several sub-tasks. The total time needed for completing the task is the sum of completion time of sub-tasks.

Task paradigm, whether the task was accomplished alone or in conjunction with other tasks, might also affect movement time (Shehab and Schlegel, 1993). Research testing Fitts' law on a dual-task paradigm (Fitts' task along with a display monitoring task) showed that Fitts' law still holds but with a relatively low R^2 (0.66-0.82). Unlike the Fitts' law, in which a function of target size and amplitude was calculated (ID) first, then a linear regression based on ID was conducted. In this new model, a multiple linear regression involving target size and amplitude provided better predictions with R^2 values of 0.90 to 0.93 (Shehab and Schlegel, 1993).

Target Characteristics

The target status could be one of the influencing factors. If the target is moving instead of stationary, Fitts' law needs modifications through a steady-state position error, which reduces the effective target width thus increases the ID. This revised model provide excellent fit (Hoffmann, 1991).

Based on Fitts' law assumptions, target size and distance contribute equally to the movement time but this might not be true, since one study found that target size was a stronger contributor, thus the effective task difficulty with small targets was notably underestimated (Sutter and Ziefle, 2004).

An exception to Fitts' law occurs when the target appears in a structured, linear display with placeholders indicating the possible target locations. MT to the furthest target was shorter than that predicted by Fitts' law. "Fitts' law may be limited to egocentric (body-based) visuomotor action, and that the visual control of hand movements may use allocentric (environment-based), in addition to egocentric, spatial information" (Adam, Mol, Pratt and Fischer, 2006).

Display-Screen Size

The influence of display-screen size on the application of Fitts' law interests researchers due to the fact that the use of PDAs and smart phones has recently become quite popular. One comparison between a traditional tablet PC screen and a PDA's smaller touch screen showed that the traditional ID formulation cannot predict movement time well for the smaller screen (Okada, Akiba and Fujioka, 2009). Research on field of view (FOV) restricted displays showed that Fitts' law did not hold if the display FOV is restricted below a certain value (the critical size) and a refined Fitts' law model was proposed (Haitao, 2012). However it works well for scrolling (Hinckley, Cutrell, Bathiche and Muss, 2002). Research on the application of Fitts' law in multi-scale electronic worlds showed that Fitts' law did apply to a zoomable interface for ID up to and beyond 30 bits, whereas the classical Fitts' law was confined in the 2-10 bit range (Guiard and Beaudouin-Lafon, 2004). The research mentioned above mainly concluded that for smaller screens, the ID formulation should be revised (the revision varies across these researches) to provide a better fit. However, the traditional ID formulation can be applied to large touch-screens (Butzler, Vetter, Jochems and Schlick, 2012).

2.4.2 Fitts' Law with Different Participant Characteristics

Gender and Age Effect

Rohr (2006) tested the possible gender effects on reciprocal tapping tasks with upper and lower limbs based on Kimura's (2000) interpretation of the hunter-gatherer hypothesis, in which men are better at targeting tasks and women are better at fine-motor tasks because of their evolutionary experiences. She found that Fitts' law still holds for both men and women, although men and women preferentially adopt distinct strategies emphasizing speed for men and accuracy for women. Women's movement times were longer than men's for both upper and lower limb movements. This result is inconsistent Brogmus (1991), who tested the possible gender effects on hand movements and found females were faster than males.

It has been verified that age has an effect on the application of Fitts' law. Based on the research results (Brogmus, 1999), the young were generally faster than the old and the difference between the young and the old was especially significant for tasks with high-complexity (Pohl and Winstein, 1998). Bakaev (2008) found Fitts' law can still be applied to elder participants though with a lower R^2. It took the elder participants twice as much time to complete tasks but they were completed with higher accuracy. An extended Fitts' law model including factors of participants' ages and experience was proposed to provide a better fit of the observed data for older adults conducting rapid, aimed movement with a computer mouse.

Test Probe

The application of Fitts' law also depends on which part of the body would be used in a test, although the movement of most body parts conforms to Fitts' law; one exception is using the finger pad in a test. People's finger pads change gradually with age. Using a finger in a test may lead to misleading results, since the target tolerance may vary due to the difference in the width of the finger pad (Hoffmann and Sheikh, 1991). An revision of the target width was made when calculating the ID thus to provide a better fit. Fitts' law is also limited when considering some newly developed pointing methods, such as eye-gaze pointing. Eye-movement time was significantly related to target size and the distance between targets, but the speed-accuracy trade-off was significantly different from what would be predicted by Fitts' Law (Chi and Lin, 1997).

One Hand Movement and Coordinated Hand Movement

Past research on Fitts' law has almost exclusively focused on the use of the dominant hand, though some researches have mentioned the effect of the non-dominant hand. Kabbash et al, (1993) found that the non-preferred hand is more than a poor approximation of the preferred hand. The hands are complementary, each having its own strength and weakness. One design implication is that the non-preferred hand is well suited for tasks that do not require precise action, such as scrolling. Research on both right-handed and left-handed participants showed that there is no significant difference in their Fitts' task performance (Hoffmann, 1994). But this is only for one hand movement instead of coordinated hand movement. Another research study, on a pen-based user interface, found that pressing a button with the non-dominant hand produces better performance compared with other switching techniques such as pressing the barrel button on a stylus or press and hold to switch between ink mode and gesture mode (Li, Hinckley, Guan & Landay, 2005).

Similarly, research on the applicability of Fitts' law to tasks requiring coordinated hand movements was limited. One study considered a type of two-handed Fitts' task in which participants used their left hand to move the target while using their right hand to move the pointer (Mottet, Guiard, Ferrand and Bootsma, 2001). Results showed that Fitts' law still holds in this situation. The amplitude concept at work in the Fitts' aimed movement paradigm is more general and abstract than has been traditionally assumed (Mottet et al., 2001). Another study (Chen, Guimbretiere and Lockenhoff, 2008) examined the influence of merging and two-handed operation method on command selection speed. Results showed that the one-handed technique (Bimanual Marking Menu <Odell, Davis, Smith and Wright, 2004>) could be as fast as the two-handed technique (ToolGlass <Kabbash, Buxton and Sellen, 1994>). Possible reason was due to a split in visual attention for two-handed technique. However, this result depends on the task characteristic.

For a gestural input system, coordinated hand movement is defined as participants moving one of their hands to point while clicking with the other. Coordinated hand movement can be quite different from one-handed movement, which makes this a good topic for study.

2.5 Input Devices

An input device is any equipment, which is used to provide data and control signals to an information processing system such as a computer or other information appliance. Graphical User Interface is widely used in today's computer interaction system. The key feature of a GUI is a pointing device and 'point and click' interaction. The pointing device most common in desktop systems is the mouse, although others are also available, such as trackballs, joysticks, and touchpads (MacKenzie,Kauppinen, and Silferberg, 2001). Although this situation continues and the mouse is still the most common input device in desktop systems, with the development of technology, computer input devices have started to incorporate 2D and 3D hand gestures.

2.5.1 Traditional Input Devices

The most common input device in present desktop systems are the mouse and touchpad. The mouse is an input device providing indirect pointing (some of them can provide absolute pointing though), the movement does not coincide with the display space and the positional information provided by the mouse is relative. A mouse currently has advantages compared to other input devices. It can be used in either hand, especially if the design is symmetrical; it can cause relatively little fatigue; it is physically robust; and in a good design, it has convenient selection buttons (Shanis, 2002).

A poorly designed mouse might also cause problems. A musculoskeletal disorder (MSD) called "Mousitis" refers to pain in the forearm due to the overuse of a computer mouse possibly caused by prolonged exposure to postures involving wrist extension and ulnar deviation (Burgess-Limerick et al, 1999). Wrist extension and the pinch forces associated with mouse tasks may be more culpable, as they are more prevalent than flexion when using a mouse, (Damann and Kroemer, 1995). Carpal tunnel syndrome is an entrapment median neuropathy causing paresthesia, pain, numbness and other symptoms in the distribution of the median nerve due to its compression at the wrist in the carpal tunnel (Phalen, 1966). Research has found that the risk of carpal tunnel syndrome is increased with the use of a computer, especially when using a mouse for more than 20 hours per week (Village, Rempel and Teschke, 2005). Although the causal relationship between mouse use and this syndrome remains controversial based on recent research (Andersen et al, 2007), it is worthwhile thinking about wrist deviation while using a mouse.

Using a mouse requires a flat surface and an open area with a keyboard and a screen, conditions that are not easy to satisfy everywhere. The poor performance on free hand drawing with a mouse is another disadvantage of this device (Douglas and Mithal, 1997).

Touchpads are pointing devices featuring a tactile sensor, a specialized surface that can translate the motion and position of a finger to a relative position on a screen. They are widely integrated into laptop computers because they are convenient and save space. Similar to the mouse, the touchpad provides indirect pointing and the positional information provided by it is relative. Compared with the mouse, the biggest advantages of the touchpad are saving space and reducing the number of exchanges between the keyboard and mouse when doing text-editing tasks. Another outstanding advantage is its directness, in that the user manipulates the target directly, instead of through a cursor. It is even easier to learn to use the touchpad.

Potential problem of using the touchpad is the possible awkward posture of the hands, arms and shoulders (Kelaher, Nay, Lawrence, Lamar and Sommerich, 2001). This can be improved by providing the appropriate location for the touchpad. Location of the touchpad with regard to the location of the keyboard has a significant influence on wrist flexion/extension, radial/ulnar deviation, shoulder flexion, elbow flexion and the discomfort ratings (Kelaher et al, 2001). Based on Cakir and Muller's (1995) research, the use of a touchpad for everyday tasks did not cause postural discomfort or fatigue to participant based on both subjective and electromyography (EMG) measurements (no indication of progressive fatigue or increased muscular load). In some respects the touch pad may even be preferable to the mouse if the user can achieve the same level of performance.

Different operational techniques for touchpads, such as pressing a physical button or the lift and tap motion, might result in a difference in performance (MacKenzie and Oniszczak, 1998).

Multi-touch refers to a class of devices that can recognize the presence of two or more points of contact with the surface. This plural-point awareness is often used to implement advanced functionality such as pinch to zoom or activating predefined programs. It has become more widely used recently. Some device that can support multi-touch (e.g., iPad and some KIOSK) is a combination of an input device and a display device. It provides direct pointing and the positional information provided by it is absolute. The advantage of multi-touch is that it is more portable and lighter, and it frees the constraint of the need for a keyboard (Shanis, 2002). Two-handed operation like this has both manual advantages and cognitive advantages, involving speed and coordination processing, as well (Shanis, 2002). Leganchuk, Zhai and Buxton (1999) have also verified the manual and cognitive benefits of two-handed input. The two-handed input techniques have been around for a while. Multi-touch providing a more natural interaction method and requires little learning, make those two-handed input techniques easier to use. However, there is also a cost to multi-hand interaction (Chen, Guimbretiere and Lockenhoff, 2008), due to a possible split in visual attention. Graphical manipulation seems a better use of chords in today's computing environment (Westerman, Elias and Hedge, 2001). However, to manipulate targets using multi-touch one still needs to physically touch the screen, thus the gestures used to operate it are confined to 2D space.

2.5.2 Gesture Input

Hand gestures play an integral role in human communication (Westerman et al., 2001). People have incorporated 2D hand gestures in the use of computer input devices with tools such as the touchpad. Commands can be expressed with 2D hand gestures instead of typing on the keyboard or clicking with a mouse.

Three dimensional gesture interfaces are being developed to capture hand movement with techniques such as a finger working as a 3D pointer, hand gestures for manipulating 3D displays (Pavlovic, Sharma and Huang, 2000), gloves wired to a computer, or a system with two video cameras to recognize gestures. However, the application of these input devices is limited and they are less practical for typical tasks like typing or pointing due to the lack of tactile feedback and a surface to support the hands (as with a conventional keyboard or mouse) (Westerman, Elias, and Hedge, 2001). And from a designer perspective, it is difficult to set the correspondent relationship between certain gestures and the operations.

The inaccuracy of recognizing gestures in 3D space has also been one of the disadvantages until recently.

Wii, Kinect and the Wireless Face Interaction Method

Recent improvements in input technology now allow for more accurate gesture control. The Wii, released by Nintendo on November 19, 2006, is a video game console. A distinguishing feature of the console is its wireless controller, the Wii Remote, which can be used as a handheld pointing device that detects movement in three dimensions. Research showed that Fitts' law still holds and can predict the pointing time for participants conducting pointing tasks with a Wii (Campbell, O'Brien, Byrne and Bachman, 2008).

The Kinect for Xbox 360 or simply Kinect enables users to control and interact with the Xbox without the need to touch a game controller, like the Wii Remote or a screen, through a more natural user interface using gestures and spoken commands. Control is not really precise and there can be a long lag. Research has shown that relatively small lags could cause considerable degradation in performance if the targets are small (Ware and Balakrishnan, 1994). A model was proposed based on the multiplicative effect the lag has on the ID (MacKenzie and Ware, 1993). Coordinated hand movement is very common in the Kinect system. Research has shown that a two-handed input technique has significant motor (faster performance) and cognitive advantages (Leganchuk, Zhai and Buxton, 1998). Contradicted result of two-handed input technique also exists (Chen et al., 2008).

This new gestural interface allows the application of Fitts' law to coordinated hand movements in 3D space to be tested, and the result of the application of Fitts' law in 3D space may also provide suggestions for gestural user-interface design guidelines. Recent developments in input devices have allowed researchers to develop wireless face interaction, using gaze direction and facial muscle activations for input, which creates more interesting topics for research in the interface design field (Tuisku et al., 2012).

2.6 Musculoskeletal Disorders

Musculoskeletal disorders (MSDs) can affect the body's muscles, joints, tendons, ligaments and nerves. Most work-related MSDs develop over time and are caused either by the work itself or by the work environment (Bernard, 1997). Typically, MSDs affect the back, neck, shoulders and upper limbs; less often they affect the lower limbs. Upper extremity MSD's are associated with the following risk factors: repeated loading, awkward postures, mechanical pressure, force exertion and duration of loading (Chany, Marras and Burr, 2007). Among these, awkward posture, the extended duration of loading and repeated loading might be associated with a 3D gestural input system use. To collect upper body discomfort information the electromyography (EMG) method is usually used (Chany, Marras and Burr, 2007). The EMG information for the trapezius, deltoid, flexor digitorum superficialis (FDS) and thenar muscles is usually recorded. Subjective discomfort surveys and fatigue surveys are usually used as indicators of MSDs. Gender differences are also interesting. One study found women have significantly higher chances than men to get upper extremity musculoskeletal disorders (UEMSDs) (Treaster and Burr, 2004). Depending on the specific posture analysis, the gender difference is not always significant (Gold, Driban, Thomas, Chakravarty, Channell and Komaroff, 2012).

2.6.1 Wrist Posture

Muscles originating in the forearm stretch long distances to control flexion and extension of the wrist. The most common wrist deviations that might result in MSDs are dorsi flexion and palmar flexion (see Fig 2.2). Neutral (zero) wrist angles (i.e. zero position for pronation, extension/flexion and radial/ulnar deviation, as defined by the American Academy of Orthopedic Surgeons) produce the least postural risk for developing cumulative trauma disorders (Zecevic, Miller and Harburn, 2000). Considering the possible effect carpal tunnel pressure has on carpal tunnel syndrome (Rempel, Bach, Levinsohn and Gordon, 1996), it is worthwhile measuring the wrist angle while assessing the operation of an input device.

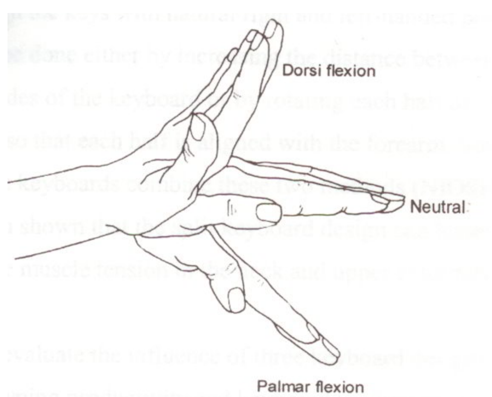


Fig 2.2 Wrist Posture (Sanders and McCormick, 1993)

2.6.2 Elbow Posture

Flexion and extension were the main movements while interacting with a gestural interface, and are controlled by two muscle groups: extensors and flexors. The triceps control elbow extension allowing participants to straighten the arms. Biceps are the primary flexors of the elbow and the brachialis, brachioradialis, and pronator teres might also be involved in elbow movement.

2.6.3 Upper Arm and Shoulder Posture

The humerus is the bone connecting the lower arm and the shoulder. Muscles from the shoulder, chest and back connect with this bone. Abduction and adduction were the main movements of the shoulder during the experiment. Posture with 0^0 flexion and 0^0 abduction of the shoulder is regarded as the neutral position (Chany, Marras and Burr, 2007). Research showed that the risk of getting localized muscle fatigue (LMF) was significantly increased by posturing the hands above shoulder level, and this posture will cause significant discomfort even in light-weight conditions (Wiker, Chaffin and Langolf, 1989).

2.7 Research Rationale and Hypotheses

The present research was designed to test the application of Fitts' law in 3D space (the movements are in 3D space, while the movement controlling the cursor on the screen is 2D) with coordinated hand movements. Three-dimensional gesture control was provided by the Kinect system. Both quantitative and qualitative information regarding the Fitts' tasks and posture were collected. Subjective measures of discomfort, enjoyment, fatigue and ease of use were also gathered. Pointing tasks, with varied "amplitude", "radius" and "approach angle" combinations, were completed by participants through the Kinect system (used as a tracking device). Movement time for each session was recorded and 3 video cameras from three directions (left, right, rear) were set to record the whole process during the experiment for each participant. Hypotheses were formulated based on past research and are as follows:

1. Fitts' law can be applied in 3D response space with coordinated hand movements.
2. There is a gender difference in postures while interacting with the 3D gesture input system to complete a pointing task.

Chapter 3. MATERIALS and METHODS

3.1 Apparatus

A MacBook connected with a Smart Board (SMART Board™ PX352 Interactive Whiteboard, 140cm*89.5cm with a resolution of 1280*800) and a Kinect (Microsoft) was used for the experiment. The Fitts' law program was written in Java (http://dl.dropbox.com/u/238738/FittsLawradial/FittsLaw.html) and it was run in a web browser (Google Chrome). The MacBook was used for running the Fitts' law program, while the Smart Board was used as the output display. The Kinect system was used to recognize the participant's gestures (with the code appropriately modified using software developed by USC researchers, called FAAST, http://projects.ict.usc.edu/mxr/faast/). The location of all of the apparatus was fixed. The height of the Kinect was 1.12m above floor level. The Smart Board was placed vertically on the wall, 1.45m above floor level. Three video cameras were set, from the rear, left and right of the participant, 2.9m away and 1.1m above floor level, to record the whole experimental process (see Figure 3.1). A survey was administered at the end of the study. It was a 5-point scale survey asking for participant feedback as to the ease of use, comfort, enjoyment and fatigue experienced conducting the task. Higher scores reflected a more positive feedback. Questions about which hand was more tired under LMRC and RMLC conditions were also asked.

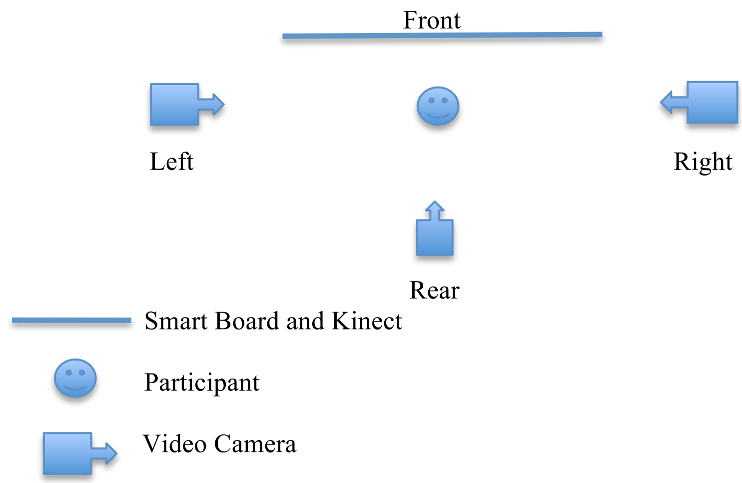


Figure 3.1 Experimental Arrangement

3.2 Participants

Twenty graduate students (age between 22~25) at Cornell University participated in this experiment. Ten were female and ten were male. All of the participants were right-handed and all of them had little or no experience using the Kinect system. Each participant received $10 as compensation for participating in this experiment.

3.3 Task

The starting point for the Fitts' task was a circle, with a diameter of 5.5cm, in the center of the screen. Targets (see figure 3.2) with different diameters (5.5cm and 11.5cm) were sequentially displayed around the starting point at different angles (0°, 45°, 90°, 135°, 180°, 235°, 280°, 325°) and at different distances (10cm and 22 cm) in a random sequence.

Considering the difficulty of defining the target dimension to calculate the ID (index of difficulty) if the targets were spherical, in this experiment 2D targets (circles) were used. All of the targets were displayed on a vertical plane. Users made 3D movements in response to 2D targets. Users acquired the 2D targets through upper limb movement and coordinated hand movements. Participants moved from the starting point to the inside of a target with one hand and selected the target by pushing their other hand. Once the target was selected it changed from blue to gray and the participant then had to move their moving hand back over the fixed central circle to start another trial. Each participant needed to complete two tasks, left hand move with right hand click and right hand move with left hand click. The order of these two tasks was balanced among all of the participants. For each task the coordinated movements for angle (8 trials) and distance (2 trials) were made 5 times for a total of 160 trials per task session.

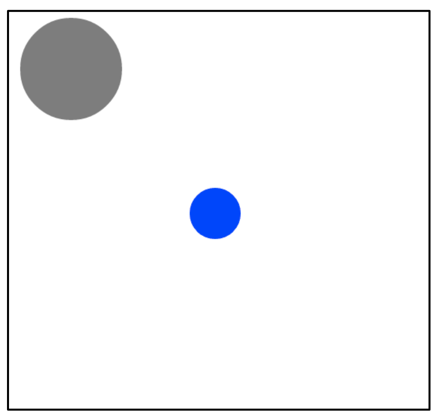


Figure 3.2 Screenshot of the task display

3.4 Procedure

A consent form was signed before participants started the experiment. The participant stood on a fixed point 2.9m in front of the Kinect and calibrated (by the software automatically) it. The participant then performed practice trials (about 15 trials) until they felt competent in performing the task. Each participant required some practice in order to become familiar with this new way of interacting using 3D gestures. The practice session lasted about 3 minutes, but the duration depended on how comfortable each participant felt about their ability to perform the gestures. During the practice session control of the cursor, what the task was going to involve and what to do if they made an error were all explained, then the participant moved as quickly and accurately as possible through the test trials. The goal of the coordinated movements was to move to the target with one hand and select it by pushing with the other hand. For the RMLC task participants used their dominant hand to move and their non-dominant hand to click. For the LMRC task participants used their non-dominant hand to move and their dominant hand to click. A monitor was present for all of the trials. The whole process was recorded with 3 video cameras from three directions (see Figure 3.1). The Cornell University Institutional Review Board approved the experimental protocol.

3.5 Experimental Design

A within-participant repeated-measures design was used. Three within-participant factors were varied in the experiment: target diameter (W: 5.5cm and 11.5cm), distance to the starting point (A: 10cm and 22cm) and target direction with respect to the horizontal (0°, 45°, 90°, 135°, 180°, 235°, 280°, 325°). Each participant performed a total of 160 trials (2*2*8*5). The order of each combination of trials was randomized among participants. The current combination of trials only changed when a participant had completed 5 correct trials in a random sequence for that combination. Otherwise, the specific combination repeated itself. Regarding the posture data, since each angle was measured both at the beginning and the end, the change of each angle was derived by subtracting the angle at the beginning from the angle at the end.

Because of the limitations of the Kinect and the experimental software, participants were required to maintain the same posture throughout the experiment (see Figure 3.3, screenshot of the video). Since different postural strategies might affect a participant's performance, each participant was instructed to do the pointing tasks as accurately and as quickly as possible.

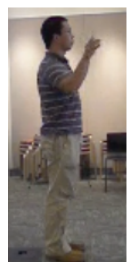
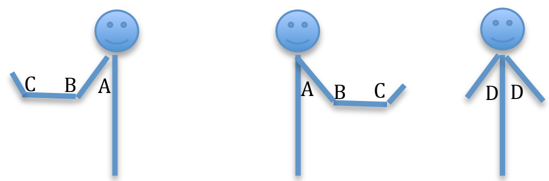


Figure 3.3 Standard Posture

3.6 Data Analysis

The program automatically recorded movement time in milliseconds, and the program generated a file containing MT and its corresponding session information.

All sessions were recorded on video for post-experimental postural analysis. Angles for left wrist flexion, left elbow flexion and left shoulder flexion were obtained from the video recording of the left video camera. Angles for right wrist flexion, right elbow flexion and right shoulder flexion were obtained from the video recording of the right video camera. The rear video camera recording was used to obtain the abduction of the trunk of both shoulders (See figure 3.4). Because of a technical problem, data for two participants were unavailable (Participant 1 and Participant 2). Each angle was measured twice, once at the beginning and once at the end of each movement. One single movement was defined as one coordinated hand movement (move to select and click). For example, for the LMRC task, three angles for the left arm and wrist were recorded when the participants started to move and when they stopped moving. Three angles for the right arm and wrist were recorded when the participants started to click and when they finished clicking. The same rule applied to the shoulder deviation angle recorded by the rear video camera.



A – Shoulder flexion
B – Elbow flexion
C – Wrist flexion
D – Shoulder abduction

Figure 3. 4 Arm Angles Measured

Sample images used to analyze posture for each participant were randomly picked from the video recordings. For each participant, 8 sample images in sequence about every 90 seconds from each side were chosen. Sample images were taken from the screenshots of the video recording. Angles on the sample images were measured through a goniometer. All data were input to a spreadsheet.

A 5 factor mixed model analysis of variance was used to test the MT data. A mixed model variance test was conducted on all of the beginning angles and the change of angles to see whether there was a significant difference between male and female participants' gestures. All other factors were controlled. Correlations between the gestures and the MT, comfort, ease of use, fatigue and enjoyment, as well as between the survey ratings and the MT, were done. SPSS, Version 18, and SAS 9.3 were the software used to conduct data analysis. The Statistical Consulting Service in the College of Human

Ecology at Cornell University was used to verify the appropriateness of the tests and their outcomes.

Chapter 4. RESULTS

4.1 Fitts' Law Model

4.1.1 Analysis of Movement Time

Results from the analysis of variance are shown in Table 1. There were significant effects on MT for the variables Condition, Distance and Target Size ($p<0.01$), and an interaction between Gender and Target Size ($p<0.01$) (see Table 4.1).

Table 4.1 Analysis of Variance Summary

Source	Df	F Value	P
Condition	1	7.07	0.0155
Gender	1	2.62	0.1226
Distance	1	70.72	<.0001
Target Size	1	102.74	<.0001
Angle	7	1.21	0.3037
Gender*Target Size	1	12.34	0.0025

4.1.2 Main Effects of Factors from Fitts' Law

For Condition, participants completed the task faster with RMLC than LMRC (LMRC = 2307 msec; RMLC = 2154 msec). MT increased when Distance increased (10cm = 1989 msec; 22cm = 2471 msec). Smaller Target Size required participants to take more time to acquire targets (5.5cm diameter = 2521 msec; 11.5cm diameter = 1940 msec).

The interaction of Gender*Target Size showed that women moved faster than men to acquire smaller targets (see Fig. 4.1).

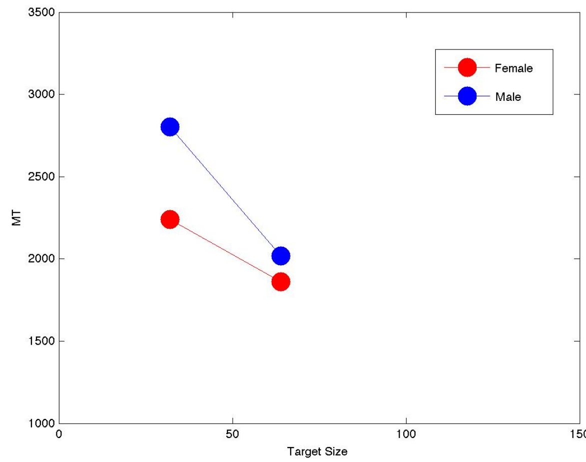


Fig. 4.1 Interaction between Gender and Target Size

4.1.3 Fitting the Data to the Revised Fitts' Model

First, the data were modeled using the following revised Fitts' formula for three-dimensional tasks (Murata & Iwase, 2001)

$$MT = a+b*ID,\ ID = \log_2 (A/W+1) +0.5*\sin \theta$$

MT refers to the time required to move one hand from the starting point to the target and then push to click with the other hand; A is the distance from the starting point to the target center; W refers to the diameter of the target circle; and θ is the target angle. The parameters 'a' and 'b' are constants determined from linear regression. All of the error trials (49%) were excluded from the analysis. For the remaining successful trials, the mean MT was calculated for each ID (2% of all responses were outliers and were excluded from the dataset). Based on the equation of ID, among 24 conditions, 15 ID levels can be derived.

For the right hand move left hand click condition (RMLC), the R^2 of the linear regression between MT and ID was 0.53 (see Fig. 4.2).

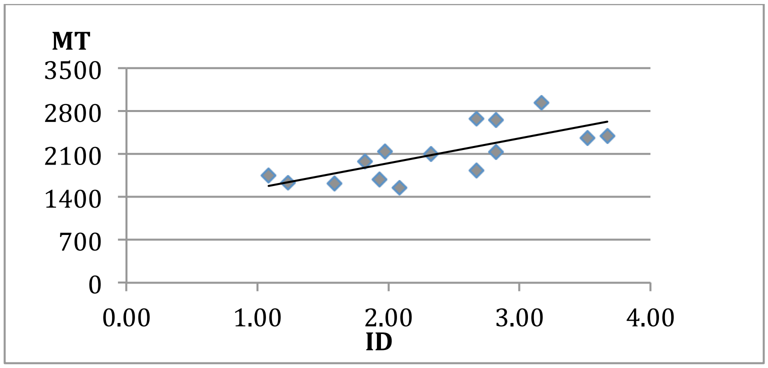


Fig. 4.2 Relationship between MT and ID (RMLC)

For the left hand move right hand click condition (LMRC), the R^2 of the linear regression between MT (movement time) and ID (index of difficulty) was 0.64 (see Fig. 4.3).

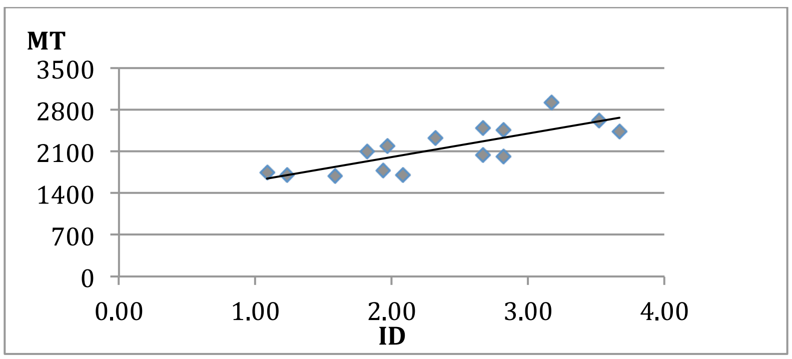


Fig. 4.3 Relationship between MT and ID (LMRC)

Further angle analysis for each condition (LMRC and RMLC) also showed a good fit of Fitts' law for each target angle (see Table 4.2 and Figure 4.4, Figure 4.8).

Table 4.2 Angle Analysis of Each Condition

LMRC		RMLC	
Angle	R^2	Angle	R^2
0	0.92	0	0.99
45	0.80	45	0.98
90	0.99	90	0.92
135	0.95	135	0.91
180	0.93	180	0.99
225	0.99	225	0.99
270	0.99	270	0.96
315	0.98	315	0.99

For the LMRC condition the analysis for each angle produced the following graphs

(Graphs below were given to show the good trend to Fitts' law for each angle, regression test was not based on these graphs), Figure 4.5 and 4.9 show the error analysis for each angle under LMRC and RMLC, Table 4.3 show the number of errors for each angle under two conditions:

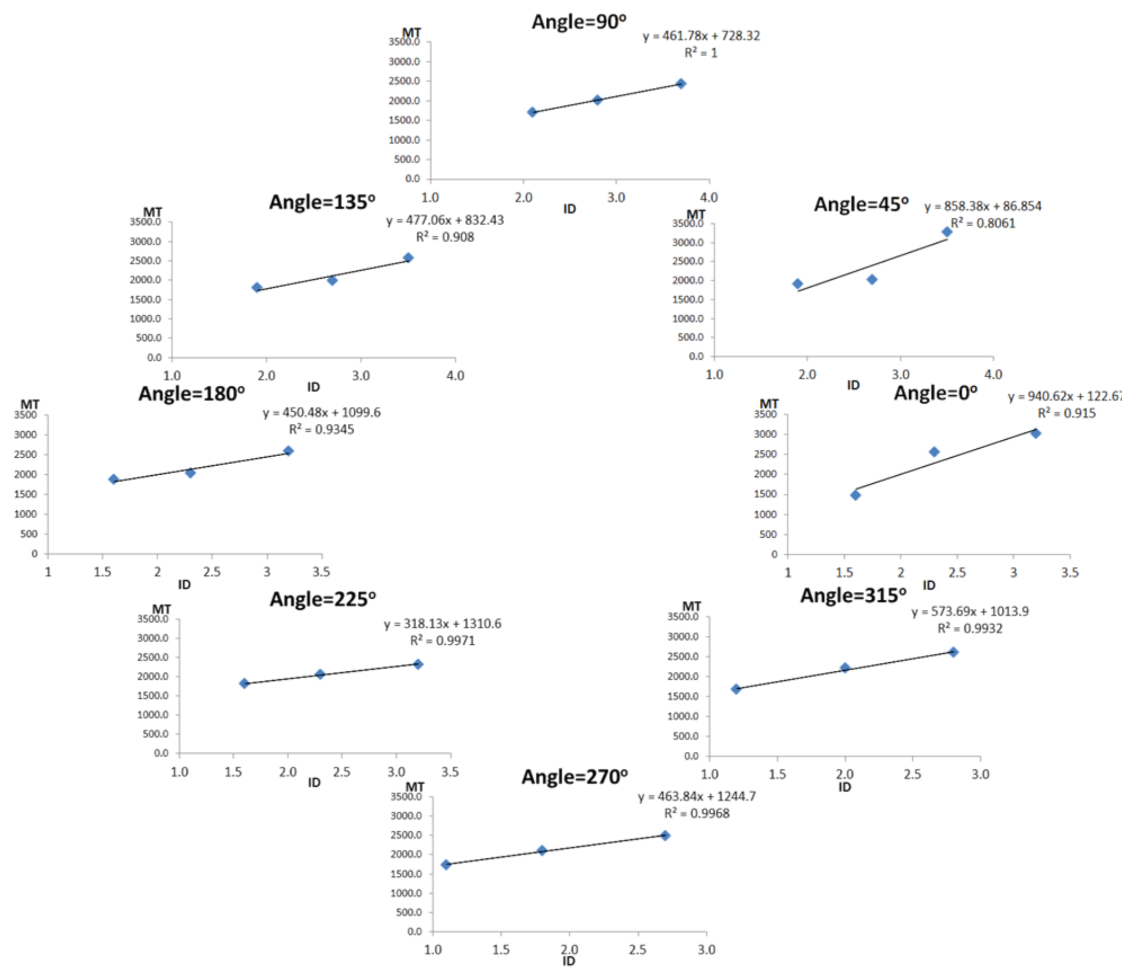


Fig. 4.4 Analysis of each angle under LMRC

Table 4.3 Error analysis for each angle under LMRC/RMLC conditions

Angle in degrees	LMRC Errors	RMLC Errors
0	280	148
45	225	229
90	147	168
135	177	175
180	196	293
225	170	227
270	144	166
315	255	200

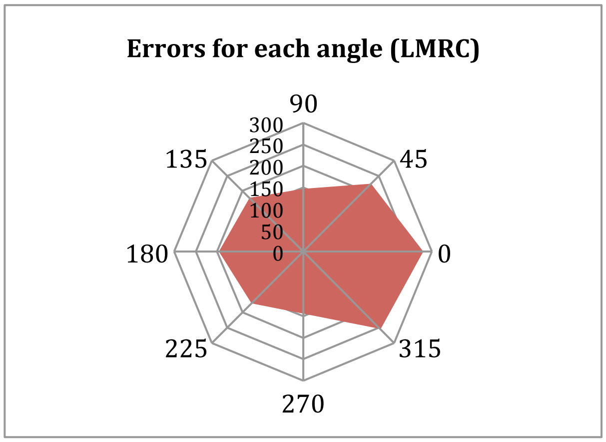


Figure 4.5 Radar plot of the total errors for each angle for the LMRC

Figure 4.6 shows the 'b' value for each angle under LMRC condition, for which the 'b' value reflects the rate of information being transmitted for a certain angle, in other words, the higher 'b' value is for a certain angle, the more information has been transmitted during the movement along the approach angle, the more difficult the task is:

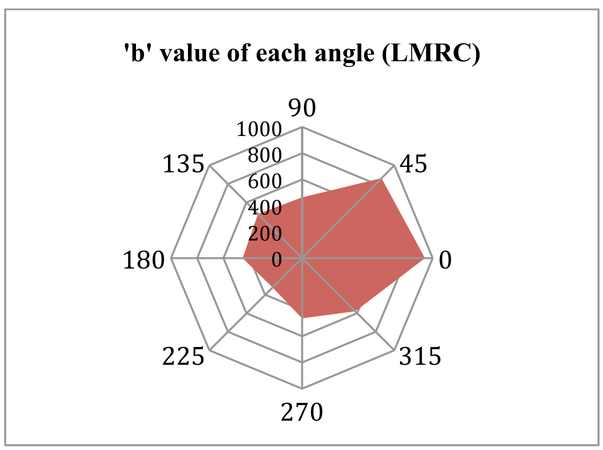


Figure 4.6 Radar plot of the 'b' values for each angle for the LMRC

Figure 4.7 shows the 'a' value for each angle under LMRC condition, with the 'a' value being the intercept of the regression for MT for each angle. This reflects the time it takes to initiate a movement.

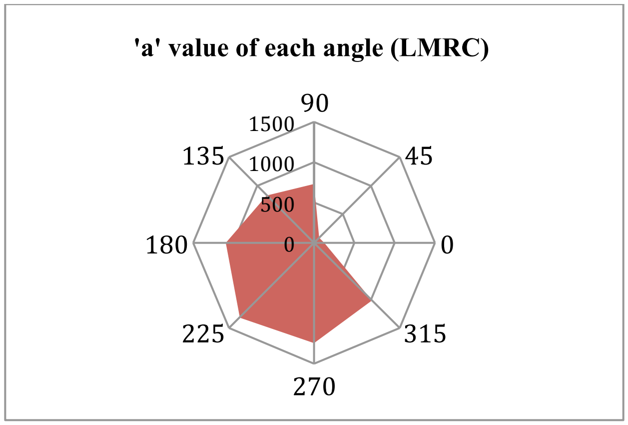


Figure 4.7 Radar plot of the 'a' values for each angle for the LMRC

For the RMLC condition the analysis for each angle produced the following graphs:

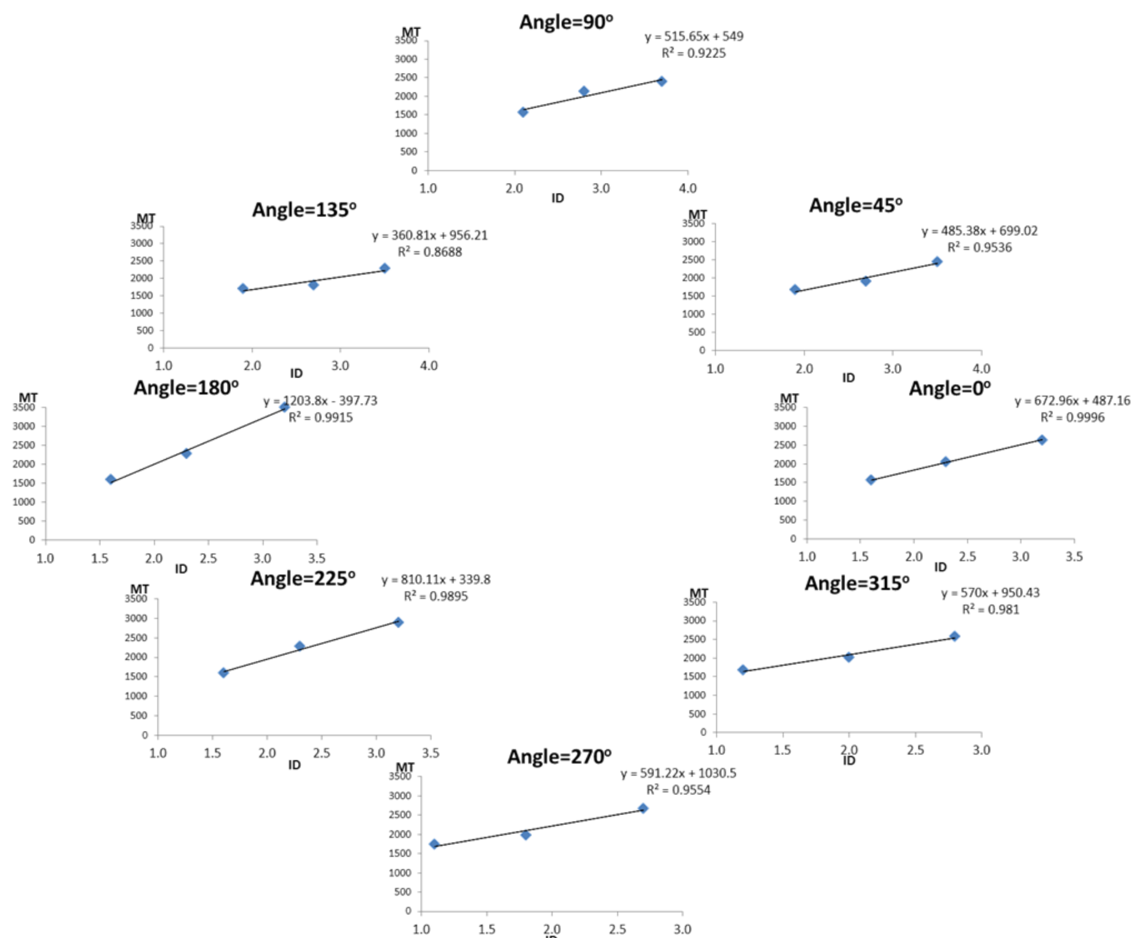


Fig. 4.8 Analysis of each angle under RMLC

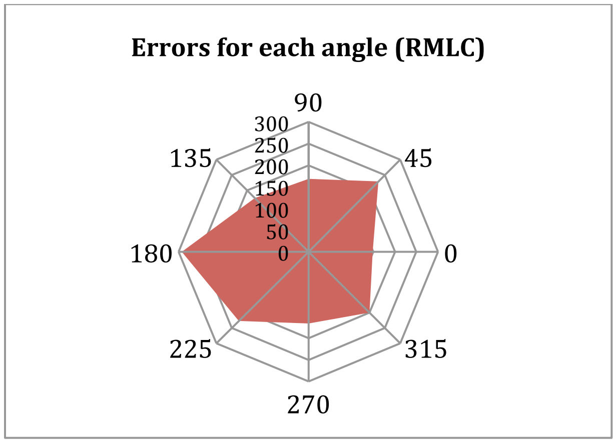


Figure 4.9 Radar plot of the total errors for each angle for the RMLC

Figure 4.10 shows the b value for each angle under RMLC condition:

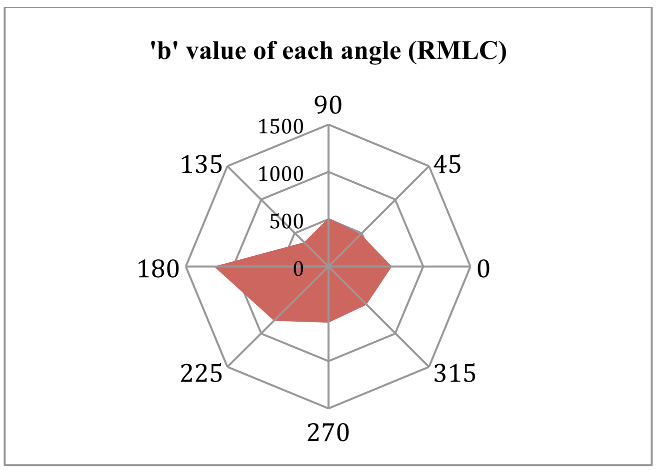


Figure 4.10 Radar plot of the 'b' valuesfor each angle for the RMLC

Figure 4.11 shows the *a* value for each angle under RMLC condition

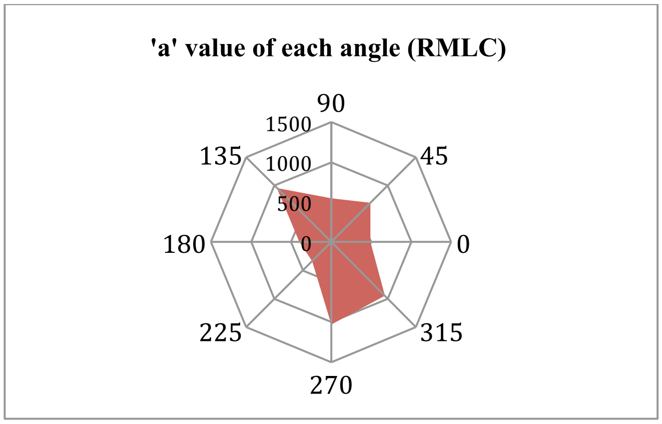


Figure 4.11 Radar plot of the 'a' valuesfor each angle for the RMLC

For each condition a Pearson correlation was computed between the average movement times and the total errors per participant. The results showed that there was a significant positive correlation (r=0.538) between movement time and errors under LMRC condition (r = 0.538, n=20, p<0.05), which shows that as the errors increased the participants slowed their movements as per the experimenter instructions, however, this correlation was not statistically significant for the RMLC condition .

4.2 Posture Results

The change and average of each measured angle under the LMRC and RMLC conditions are shown in Figures 4.13 to 4.16. In these figures, A refers to the angles for Left Shoulder Flexion, B refers to the angles for Left Elbow Flexion, C refers to the angles for Left Wrist Extension, D refers to the angles for Right Shoulder Flexion, E refers to the angles for Right Elbow Flexion, F refers to the angles for Right Wrist Extension, G refers to the angles for Left Shoulder Abduction, and H refers to the angles for Right Shoulder Abduction (see Figure 4.12). The sequence DA through DH refers to the change of these angles (absolute value) from the starting to finishing postures.

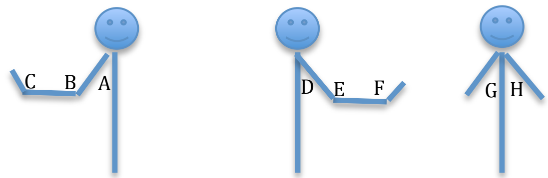


Figure 4.12 Angles in the statistical test

Average starting angles for the RMLC condition:

A= 24°, B = 60°, C = 144°, D = 43°, E = 84°, F = 143°, G = 25°, H = 31°.

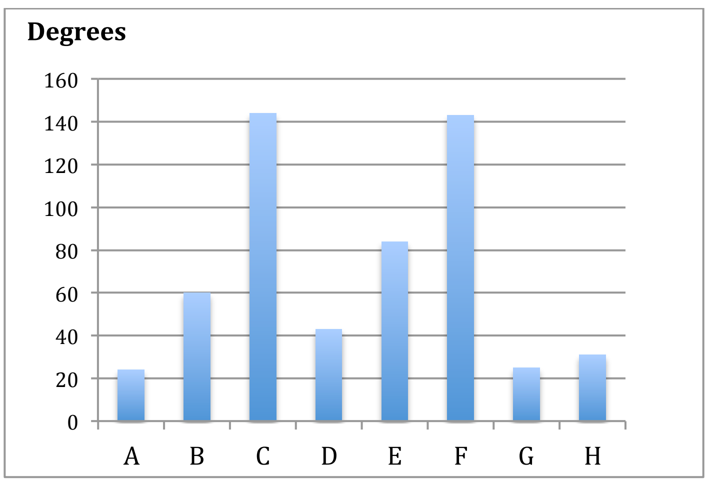


Figure 4.13 Average Starting Angles (RMLC)

Change in each angle between the starting and ending postures for the RMLC condition:

DA = 26°, DB = 57°, DC = 50°, DD = 21°, DE = 13°, DF = 6°, DG = 14°, DH = 12°.

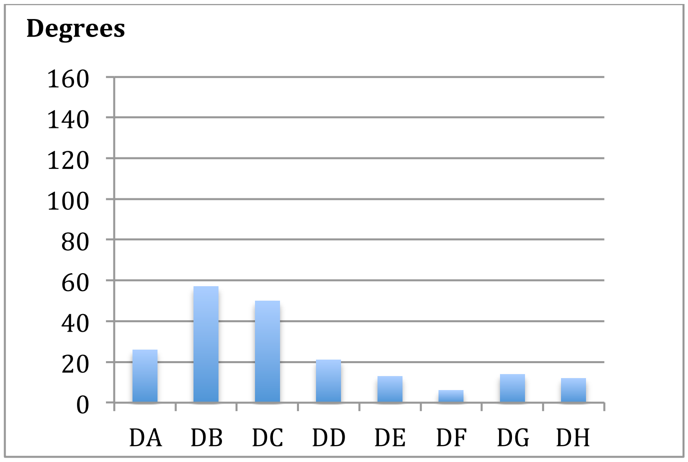


Figure 4.14 Change of the Angles (RMLC)

Average starting angles for the LMRC condition:

A= 40°, B = 81°, C = 146°, D = 28°, E = 66°, F = 139°, G = 27°, H = 27°.

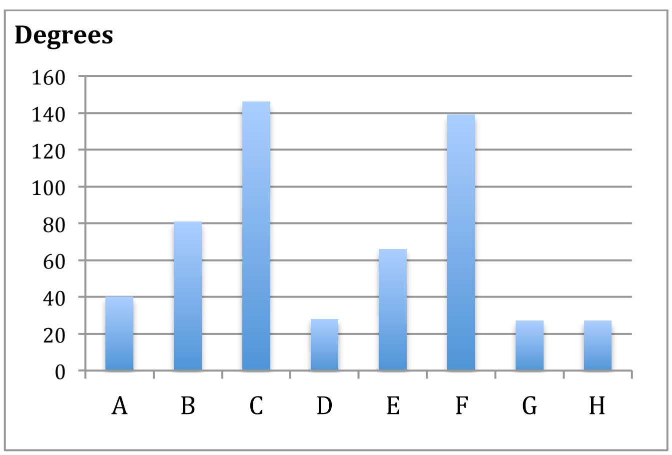


Figure 4.15 Average Starting Angles (LMRC)

Change in each angle between the starting and ending postures for the LMRC condition:

DA = 21°, DB = 11°, DC = 7°, DD = 33°, DE = 58°, DF = 40°, DG = 17°, DH = 15°.

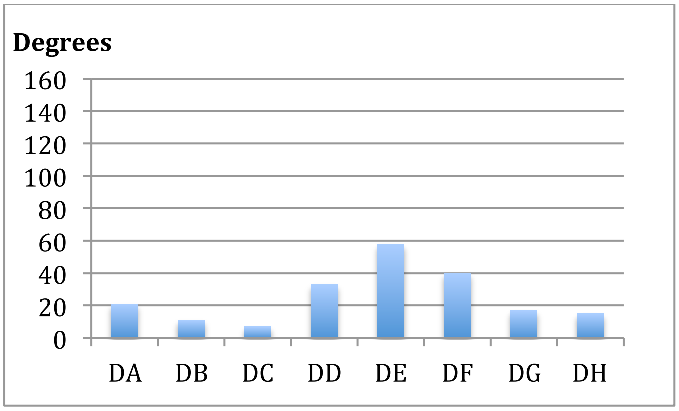


Figure 4.16 Change of the angles (LMRC)

Mixed model variance tests showed a significant difference between female and male participants but only for the LMRC condition. For the moving hand the starting wrist extension angle of male participants was significantly greater ($p = 0.015$) than that of female participants (Male: 42.2 degrees, Female: 25.7 degrees) (see Fig 4.17). For the clicking hand, the change of the wrist extension angle of male participants was greater ($p = 0.043$) than that of female participants (Male: 30.3 degrees, Female: 28 degrees). No other significant differences in gestural postures were found.

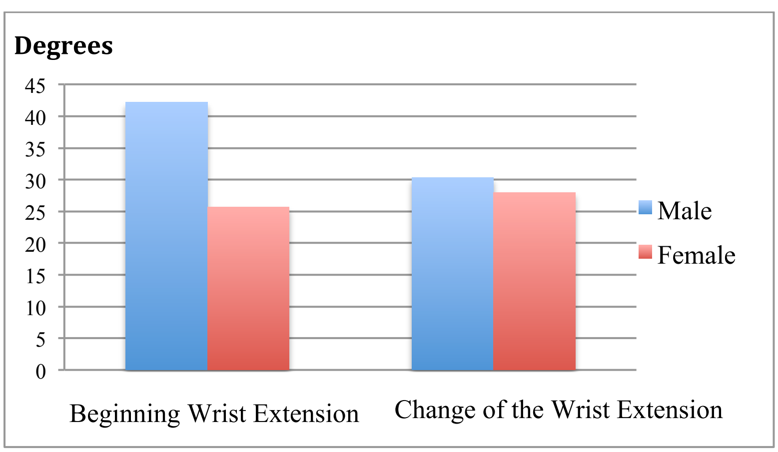


Figure 4.17 Gender Difference in Posture (LMRC)

Generally speaking, there were not many differences between the gestures of female and male subjects, after controlling for all of the other factors during the experiment. Both female and male subjectsmaintained a similar posture to perform the tasks.

4.3 Survey Result

Results from the correlations between posture and MT performed on the survey data showed that a positive correlation between comfort ratings and the change in right elbow angles under the RMLC condition. Participants with a greater change in their right elbow angle during the experiment reported a more comfortable experience. No other significant correlations between posture data and MT were found. No other significant correlation between the MT and the postures and between the postures and the subjective rating has been found.

The average ratings for all of the participants for ease of use, comfort, enjoyment and fatigue during the experiment were 2.8, 2.3, 3.1 and 2.0 respectively (Figure 4.18).

And Figure 4.18 showed the general feedback of the whole experiment, including both LMRC condition and the RMLC condition.

The higher the rating is, the better the feedback is. A higher rating on ease of use means the participant felt it is easy to use. A higher rating on comfort means the participant felt comfortable during the experiment. A higher rating on enjoyment means the participant did enjoy the experience. A higher rating on fatigue means the participant didn't feel significant fatigue during the whole process.

Correlations between the MT and the survey results showed that there was no correlation between any of these factors. Fatigue (average rating: 2.0) was the biggest problem, based on the results from this experiment.

For the LMRC condition, 17 participants reported their left hand was more tired than their right, while 3 participants reported the opposite. For the RMLC condition, 12 participants reported their right hand was more tired than their left hand while 7 participants reported the reverse, with 1 Participant reporting similar tiredness in both hands.

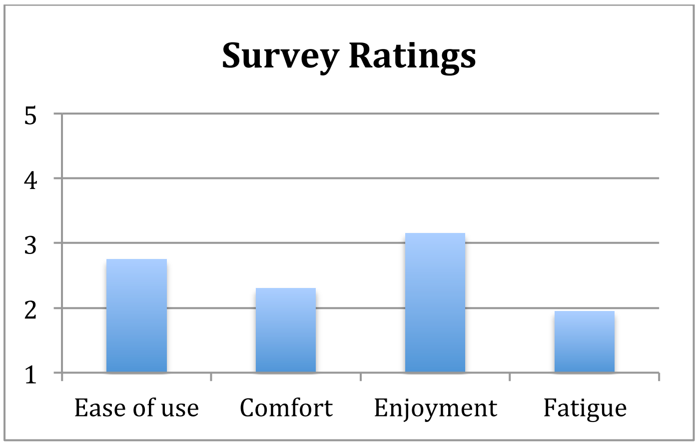


Figure 4.18 Mean Survey Ratings

Chapter 5. DISCUSSION

5.1 Discussion of the Results

5.1.1 Fit of the Revised Fitts' Law Model

In this study 2D targets were presented to participants who then made 3D responses that were quite different from 2D responses that would occur using a mouse because they involved the use of different muscles. Research on the effect of the approach angle on perceived width in 2D space has proposed a revised Fitts' model yields a better fit to the observation data (MacKenzie & Buxton, 1992). In this revised model, the effect of approach angle on perceived width is taken into consideration while calculating the Index of Difficulty (ID).

Another characteristic of the present experiment was that all participants conducted coordinated hand movements for the responses. For the LMRC condition participants moved their non-dominant hand to point and used their dominant hand to click, while for the RMLC condition participants moved their dominant hand to point and used their non-dominant hand to click. Each target acquisition involved hand coordination. Results showed that, based on the revised Fitts' model, Fitts' law still holds for coordinated hand movements made in 3D space in response to 2D targets (the movement is in 3D space while the movement controlling the cursor on the display is 2D), although the R^2 under each condition was relatively low ($R^2 = 0.53$ for the RMLC condition and $R^2 = 0.64$ for the LMRC condition). For each condition the specific analysis for each angle showed a goodness of fit to the Fitts' law trend ($R^2 > 0.8$). The revised model used in the current research calculated $ID = \log_2 (A/W+1) + c*\sin\theta$, with $MT = a + b*ID$ which will give $MT = a + b*c*\sin\theta + b*\log_2 (A/W+1)$. The revised model didn't change the slope of the equation but only changed the intercept. However considering the effect of different approach angles on the movement time is different, the revised model should have changed the slope instead of the intercept (the slope reflects the rate of information transmitted). This might be an explanation for the lower R^2 for the fit of the revised model. Thus it is possibility that the relationship between the movement angle and the movement time might better be described well by another model. Since the 'b' value is the slope, which reflects the difficulty of moving the arm at a certain angle, the higher the 'b' value the higher rate of information being transmitted during the movement, and the more difficult the task is. It can be expected that the approach angle should have an effect on the movement time and thus the slope for each approach angle should be different, and thus the change in approach angle would change the slope of the regression line. A revised Fitts' law equation incorporating this consideration remains to be formulated.

The results showed that Fitts' law reasonably applied to both the RMLC and LMRC conditions, however the main observation from the tests was that participants completed the task faster in the RMLC condition than in the LMRC condition. One study compared dominant and non-dominant hand task performance and found that the non-dominant hand was well suited for tasks that do not require precise action and the dominant hand moved faster than the non-dominant hand (Kabbash, MacKenzie and Buxton, 1993). Based on this, the difference in performance between the two conditions can be explained. First of all, all participants in this experiment were right-handed. For them, they can move faster with their right hand. Secondly, compared with target acquisition task, pushing to click is much easier, which was simply a gesture requiring no target acquisition accuracy, although in this study this was not specifically tested and the component movement times could not be separated. Thus moving their right hand to control the movement of the cursor (which requires more accuracy) is much easier than moving their left hand to control. In the RMLC condition participants moved their right arm to control the movement of the cursor while using their left arm to push to click, which was much easier for them compared with using their non-dominant hand to complete tasks requiring accuracy (moving to point). Thus they completed the task faster in the RMLC condition than in the LMRC condition.

Unfortunately, the proportion of error trials was very high (49% overall). It is likely that conducting the pointing task via the Kinect system was really a difficult task, and this is supported by the participants' rating of task difficulty. Noticeable vibration in the screen cursor might also have contributed to the high error rates, although if this was the main reason it should have affected all the the participants in a similar way. However, inspection of the error rates showed that the overall value was driven by relatively high error rates for 5 of the participants. This might have arisen because of the software requirement that if a participant made an error that trial was repeated and it had to be correctly responded to for 5 consecutive trials. In other words, a participant might have to keep repeating a similar movement, which might have accelerated muscle fatigue, and some participants may have been stronger than others. Arm strength was not measured in the study. However considering among the 5 participants with especially higher error rates, 3 of them were female while 2 of them were male. The difference in arm strength might not be able to explain their higher rates well. The significant correlation between MT and errors for the LMRC condition (i.e. target acquisition movements by the non-dominant limb) suggests that arm dominance may have played a significant role in the high error rates. Some people have greater hand dominance than others (Carla, Crosby Marwan and Wehbe,1994) , so it is possible that those with the greatest dominance were those with the highest error rates, The degree of hand/arm dominance was not tested in the study. However, the fact that the average error rates were comparable for the RMLC and LMRC conditions (80.3 vs 79.1) suggests that dominance alone cannot explain the high error rates by the 5 participants. It might be that the instructions were misunderstood by some subjects, and this might be indicated by the fact that only 5 of the participants had much higher error rates than others. Considering participant 1 have especially longer time for practicing, if taking out of his data, there is a significant correlation between participant height and the error rates (r=0.53) which reflects that, the taller the participant is, the higher error rates he would have. This might be due to the limitation of the system. Since while doing the calibration, a virtual rectangular space would be provided. Participants need to move inside this limited space (that's why they need to maintain the standard posture, in order to keep themselves moving inside the limitation). And when the participant moved to the "edge" of the rectangular, the vibration of the cursor would become very serious and errors might occur. Considering all of the participants stood on the same fixed point to conduct the experiment. The distance might not be appropriate for those taller participants. They are much easier to move beyond the limitation.

The positive correlation between MT and errors for the LMRC condition shows that when participants made errors, they slowed down, which suggest that they were following instructions. No trade-off between speed and accuracy was found. The participants conducted the experiment based on the instruction in which they were instructed to balance the speed and accuracy. Unfortunately, the experiment did not have a way of checking that instructions had been correctly understood. It is also possible that some participants had insufficient practice, for example, participant 1 had the longest practice time and had the lowest errors. Unfortunately, the practice times were not formally recorded to test for this possibility. The need to maintain the standard posture for a long time in order to be recognized by the system may have made participants feel extremely tired and when the participants failed to maintain that posture an error might have been registered. However test for the correlation between the fatigue ratings and the errors for the RMLC and LMRC condition showed no significance.

Further error analysis on each angle under two conditions (Fig. 4.5 and Fig. 4.9) showed that for LMRC, moving left arm to across the midline of the body (shoulder adduction) from the left to the right resulted more errors than moving this to the left away from the body (shoulder abduction). While for RMLC condition, moving the right arm to across the midline of the body (shoulder adduction) from the right to the left also resulted more errors than moving to the right away from the body (shoulder abduction). Analysis of *b* value (Fig 4.6 and Fig 4.9) also showed the same trend. The 'b' values were greater for shoulder adduction arm movements across the midline of the body which reflects a higher rate rate of information transmission and greater difficulty. The pectoralis major, latissimus dorsi and teres major are all involved during adduction of the arm and these muscles are responsible for gross rather than fine movements. Different muscle groups (supraspinatus) are involved when abducting the shoulder/arm away from the middle line of the body. The different characteristics of different muscle groups may explain the difference in performance for these two kinds of movements. Unfortunately, in this study the participants were not asked about the difficulty of making the movements at different angles from the body, but this can be incorporated into future work.

Another interesting finding was the interaction of gender and target size. Generally speaking, women completed the task faster than men and the difference was even greater for smaller targets. According to Kimura's (2000) hunter-gatherer hypothesis, one possible explanation might be women are better than men at tasks that require more accuracy. Due to the noticeable vibration in the current research, pointing at the targets (both of big and small targets) require more accuracy instead of speed. Thus women were generally faster than men and this effect is especially significant for smaller targets.

5.1.2 Postures and the Qualitative Survey

Posture

From the results of the analyses of average starting angles under both LMRC and RMLC conditions it was found that the largest change in extremity posture was wrist deviation. The average wrist extension angle for both hands was around 35 degrees. Extension of the wrist for extended periods might result in fatigue, and possibly MSDs in the wrist. For both conditions the shoulder flexion angle of the moving arm was greater than that of the clicking arm (RMLC: 43° vs. 24°, LMRC: 40° vs. 28°), which means the moving arm lifted higher than the clicking arm during the experiment. The risk of getting localized muscle fatigue (LMF) was significantly increased by positioning the hands above shoulder level, and this posture will cause significant discomfort even when using light weight (Wiker, Chaffin and Langolf, 1989). During the whole experiment participants had their hands about shoulder level (see Figure 3.2), and usually the moving arm was higher than the clicking arm. Considering the experiment lasted about half an hour, long periods maintaining this posture might result in significant fatigue. This was consistent with the survey results, in which most of the participants reported that their moving arm was more tired than their clicking arm under both conditions.

Regarding the change in various angles under both conditions, the change in the angle of the clicking arm was greater than that of the moving arm because of the different gestures conducted by each arm. For the moving arm, it mainly moved on a plane with a small angle change usually occurring in the elbow and shoulder. The clicking arm, because of the "pushing" gesture, had greater angle change in the elbow and shoulder, possibly with a large angle change in the wrist if participants also waved their hand during the process.

A significant difference between female and male participants was found in the left wrist extension angle under the LMRC condition. The beginning wrist angle for males was larger than that for females, meaning female participants had a more neutral wrist posture than males but the change in that angle for females was smaller than that for males. The standard gesture for clicking is pushing; due to the software, waving the hand was sometimes recognized as clicking. Although all of the participants were given the same instructions, some of them discovered this and continued to use this gesture whenever they wanted to click. This was noted in some of the participants' feedback. Although this gesture might not work very well, participants chose to use it since they thought it was much easier to wave than to push. This might be the reason for the bigger change of the wrist flexion angle for male participants (probably more male participants found this trick). Generally speaking, there weren't many differences between female and male participants' gestures. This was mainly because all of the participants were given the same instructions and were instructed to keep a similar posture throughout the experiment in order to be recognized by the system (see figure 3.2).

Survey

The correlation test between posture data and comfort ratings showed that the bigger the change in the elbow angle of the clicking hand during the experiment, the higher participants would rate their comfort levels. Comparing the elbow angle under the RMLC condition, when participants started to push and when they just stopped pushing, the ending angle was more natural than the beginning angle. Thus the bigger the change, the more relaxed the participants might have felt.

Generally speaking, participants had negative feedback about this interaction experience, except that participants felt neutral about the enjoyment aspect. Fatigue was the biggest problem. The whole experiment lasted about half an hour for each participant. Complaints mainly focused on the long time spent maintaining the standard posture, which caused extreme fatigue in the upper arm and shoulder.

Compared with traditional interaction methods, this system is more natural with less equipment needed. Users can be free from a keyboard and mouse. However, from this research, the operation of the device, which needs repetitive movement and awkward postures, might not be appropriate. More natural and relaxed gestures might need to be developed in the future, and tasks that are appropriate for this interaction method might be interesting to consider.

Another characteristic of the Kinect system is the voice command, which was not examined. The arm fatigue is the biggest problem while using the system. Users need to conduct a series movement to complete one pointing (moving and clicking). In the future, a combination of voice command with natural gesture control might solve this problem and make the best use of this system. For example, for the pointing task, the cursor would automatically choose the target near the cursor, no accurate control of the moving arm is required. Voice command then can be taken to 'click' instead of pushing another arm. Decreasing the system lag is another important aspect to reduce the arm fatigue. Samsung has just introduced its 2012 HDTV, which includes a built-in camera and a microphone to enable a feature called Smart Interaction. It combines the voice and gesture control, trying to create a more natural communication. User controls the cursor through their hand. Gestures which can be recognized include lifting hand up (scroll up), moving hand down (scroll down), waving (go back), and turning their hand into a fist (run). No coordinated hand movement gets involved. Based on the current research, "selecting" smaller targets with the Kinect system could be painful considering the lag, the noticeable vibration and the long duration of awkward postures. Samsung makes some interesting improvements. The system would recognize the information which is clickable and highlight it with a bubble when the cursor passes around it. No accurate control on the cursor is needed in order to click the target. The Smart TV and the Kinect both integrate voice commands to operate. However the voice commands are not natural enough for a user to interact with the system. Future voice control may focus on "understanding" the "natural language" instead of just recognizing the limited "commands" which have been set up in the system.

5.2 Limitations and Further Research

5.2.1 Limitation and Further Research of the Fitts' Law Study

During the course of the experiments several limitations arose, and they are discussed here.

Considering the R^2 of the observed data for all of the approach angles, and the revised Fitts' law model $ID = \log_2 (A/W+1.0) + c \sin \theta$ (Murata and Iwase, 2001), was relatively low, some other models might be interesting to evaluate and a new revised model might be proposed to describe coordinated hand movement using the Kinect system more accurately. On the other hand, the movement is real 3D; to describe the movement of the motor system under the experimental conditions more factors that might affect movement time could be taken into consideration. For example, one study incorporated one more angle into the calculation of the index of difficulty (Cha and Myung, 2010). ID was calculated by $ID_{Extended} = c\ \theta 1 + d \cos\theta 2 + \log_2 (D/W+1)$, in which θ1 refers to the angle between the positive z-axis and the target location and θ2 refers to the angle between the positive y-axis and the projected target location on the x-y plane (Figure 5.1). This model improved the R^2 from 0.488 to 0.765. However this model hasn't been tested in the current research. Since θ1 and θ2 need to be measured through equipment developed by the authors. It was something like a channel of sensors. Participants moved inside of the channel so that the angles could be measured during the movement. This angle information was not available for the current research.

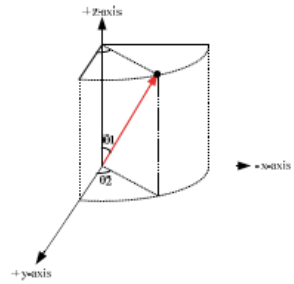


Figure 5.1 Movement in 3D Space

In this experiment all of the participants were right-handed and they performed better under the RMLC condition than under the LMRC condition. Further research could include left-handed participants to compare their performance in both the LMRC and RMLC conditions. Based on the hypothesis that the difference in performance between the two conditions might be due to handedness, the expected result would be that a left-handed participant would conduct the task faster under the LMRC condition than under the RMLC condition. Results from this might be useful during design to define the coordinated hand movement in order to improve user performance.

Concerning the test for fit of the Fitts' law model, the test would have only 3 levels of ID if computed by the conventional formula, making a comparison between models impossible because the conventional model ignores the effect of the target angle. However, in this study, 15 ID levels were derived from the modified Fitts' equation and were verified to be applicable to the observed data. In any further research more target sizes and amplitude levels could be manipulated to get enough ID levels for the comparison of fit between the conventional formula and the current revised formula.

The lag effect was not taken into consideration in the current research. Relatively small lags might cause considerable degradation in performance when the targets are small (Ware and Balakrishnan, 1994). The effect of lag on performance and the application to the revised Fitts' model could be tested in a future study.

The software used in this experiment to allow Kinect to recognize the response gestures to control the PC can be improved to provide better control in the future. With the current software, the cursor often appeared to vibrate while the participant was responding to the trials, which was also noted from the participants' feedback. The effect of cursor vibration on movement time was even more significant for smaller targets. This may have adversely affected the results. The vibration might have enlarged the effect of target size on movement time. The large difference in movement time between large and small targets might come from cursor vibration. Thus an improvement in the software might help rule out this possible problem in a future study.

Only 2D targets were used in the present research. Previous studies on 2D and 3D targets showed that 3D views were better for shape understanding while 2D views were better for precisely judging relative positions, e.g., directions, distance (John and Cowen, 1999). A comparison of 2D and 3D targets can be conducted to see whether there would be differences in Fitts' task performance. Results of this may have an impact on the interface icon design.

If 3D targets would be used, the effects of monocular cues on movement time would be interesting to be studied. Fitts' law predicted movement time through factors, such as approach angle, target size and distance. However, for 3D targets, other factors may also impact the movement time (Liao and Johnson, 2002). Research showed that for targets located at the lower-back and upper-front, shadow information would facilitate the target acquisition task.

In the present research, participants conducted "air pointing" through their hand with visual feedback. Another research on "air pointing" studied the performance with and without visual feedback (Cockburn, Quinn, Gutwin, Ramos and Looser, 2011). Different air pointing techniques were proposed and compared. Results showed that large movements on the 2D plane are both rapid (selection times under 1 s) and accurate. Eyes-free interaction has many benefits for users. It can be rapid because it does not require continual conscious monitoring (for example, reaching to keys while touch typing), and convenient because users do not need to shift their visual attention (for example, they can maintain eye contact with another person) (Cockburn et al., 2011). Thus the eyes-free air pointing interaction is also worthwhile being studied.

Finally, in this study, although responses were 3D, 2D targets were used. In the future, 3D targets and 3D responses might be used in a virtual 3D world to test the extension of Fitts' law in 3D space.

5.2.2 Future Posture Research

In the future, more gestures (waving, rotating, turning into a fist etc.) might be recognized and merged with computer operation, creating more topics that might be interesting to look at. Based on the interaction analysis results, females performed better than males on smaller targets. It was possible that there was a difference in female and male posture. Male participants might have moved in a larger range with lower accuracy while female participants moved in a smaller range with higher accuracy. The difference was not significant due to the system limitations (all of the participants were instructed to keep the same posture during the experiment in order to be recognized by the Kinect). Further studies could permit participants to change position, allowing for larger movements. A variance test of the different postures between females and males could then be conducted.

Correlations between the gestures that participants used and the movement time (MT) could be run to test whether the difference in gestures would relate to differences in MT. Some gestures might be more appropriate for participants than others and help complete the task faster.

Questions asked at the end of the survey were somewhat confusing. Instead of asking participants which hand was more tired under a specific condition (LMRC or RMLC), it would be better to ask them which side of the body was more tired.

Appendix A : Survey

Please circle the number you think is applicable based on your experience, what do you think of using Kinect to complete this task under this situation?

Ease of use	Difficult--------------------Easy
	1 2 3 4 5
Comfort	Uncomfortable-----------Comfortable
	1 2 3 4 5
Enjoyment	Hated-------------------Enjoyed
	1 2 3 4 5
Fatigue	Tired--------------------Not tired at all
	1 2 3 4 5

For LMRC, which hand is more tired? _____

For RMLC, which hand is more tired? _____

Thanks for your participation!

Appendix B: Fitts' task raw data (LMRC condition)

Participant 1

A	W	R	ID	ERR	MT
128	32	3.1	2.3	0	1803
256	32	0	3.2	0	1635.3
128	32	1.6	2.3	0	1558.8
128	32	5.5	2.3	0	1568
128	64	0	1.6	0	1344
128	32	2.4	2.3	0	1485.8
256	64	2.4	2.3	0	1261.8
256	32	1.6	3.2	0	1734.8
256	64	4.7	2.3	0	1508.8
128	64	3.9	1.6	0	1196.3
128	64	4.7	1.6	0	1093
128	64	2.4	1.6	0	1157
256	64	5.5	2.3	1	1403.8
256	64	1.6	2.3	1	1258.3
128	32	0.8	2.3	1	1303.5
256	64	0	2.3	0	1400.8
256	32	3.1	3.2	0	1562.5
128	64	0.8	1.6	0	1005
256	64	0.8	2.3	0	1149.5
128	32	4.7	2.3	0	1242.3
128	64	5.5	1.6	0	1100.5
256	32	0.8	3.2	2	1937.5
256	64	3.9	2.3	0	1536
256	32	3.9	3.2	0	1592.5
128	64	1.6	1.6	0	1520
128	64	3.1	1.6	0	1303.8
256	32	5.5	3.2	3	1733
256	32	4.7	3.2	0	1727.5
256	64	3.1	2.3	0	1282.5
128	32	0	2.3	0	1403.5
128	32	3.9	2.3	0	1386
256	32	2.4	3.2	0	1401

Participant 2:

A	W	R	ID	ERR	MT
256	64	0.8	2.3	0	2855
128	64	0.8	1.6	1	1312
256	32	3.9	3.2	2	1901.8
256	32	0.8	3.2	2	1744.5
128	64	3.9	1.6	0	1370
128	32	3.1	2.3	1	1563.5
256	64	3.1	2.3	0	1441
128	64	2.4	1.6	0	1369.5
128	64	1.6	1.6	0	1016.5
128	32	3.9	2.3	3	1327.3
256	64	3.9	2.3	0	2261.5
128	32	1.6	2.3	0	2241.5
128	32	0	2.3	1	1892
128	64	5.5	1.6	0	1608.3
128	32	2.4	2.3	0	1781.3
256	64	0	2.3	1	2302.8
128	64	3.1	1.6	0	1388.8
256	32	5.5	3.2	3	1788
256	64	4.7	2.3	1	2211.5
256	32	4.7	3.2	0	2452.5
128	32	5.5	2.3	3	1309.3
256	64	5.5	2.3	0	1309.3
256	32	0	3.2	3	2016.3
128	64	0	1.6	0	1115.3
128	32	4.7	2.3	1	2615.5
256	64	2.4	2.3	0	1224

256	64	1.6	2.3	1	1145
256	32	2.4	3.2	5	3331.8
128	64	4.7	1.6	0	1250.5
256	32	1.6	3.2	3	1585.5
256	32	3.1	3.2	5	1798.3
128	32	0.8	2.3	1	1749

Participant 3:

A	W	R	ID	ERR	MT
128	32	2.4	2.3	4	1458.5
256	64	5.5	2.3	1	3408.8
256	64	2.4	2.3	1	1439.3
256	32	3.9	3.2	0	1680.8
128	64	4.7	1.6	0	2332
256	64	3.9	2.3	1	1216.8
256	64	3.1	2.3	3	1322.5
128	32	5.5	2.3	6	2815.8
128	32	3.1	2.3	6	1338
256	32	3.1	3.2	8	1805.5
128	64	3.9	1.6	1	1559.5
256	64	4.7	2.3	0	1981.3
256	32	4.7	3.2	3	2628.5
128	32	4.7	2.3	6	3545.3
128	64	1.6	1.6	0	3350
256	64	0.8	2.3	1	1766.8
128	32	3.9	2.3	0	1462.8
128	64	3.1	1.6	0	1018
128	64	0.8	1.6	3	2110.3
256	64	1.6	2.3	0	1942
128	32	1.6	2.3	6	2351.8
256	32	5.5	3.2	3	2055.3
256	64	0	2.3	3	2008.5
128	64	2.4	1.6	0	2457
128	64	5.5	1.6	0	1306.5
256	32	0.8	3.2	0	2390.8
256	32	1.6	3.2	1	2140.8
256	32	0	3.2	7	3003
128	64	0	1.6	1	1365
128	32	0.8	2.3	7	2117.8
128	32	0	2.3	1	2037.3
256	32	2.4	3.2	2	3276

Participant 4:

A	W	R	ID	ERR	MT
128	32	3.9	2.3	2	1501.3
128	64	5.5	1.6	0	1361.3
256	64	1.6	2.3	0	1552.3
256	64	3.1	2.3	3	1208.8
128	32	3.1	2.3	8	1310.5
256	32	3.9	3.2	12	2000.8
128	64	2.4	1.6	0	1856.3
256	32	0	3.2	2	1595
128	64	0	1.6	1	1119.3
256	32	1.6	3.2	3	1786
128	32	5.5	2.3	6	1084
128	64	3.9	1.6	1	2722.5
128	64	4.7	1.6	1	1166.5
256	32	5.5	3.2	20	2593.5
256	64	3.9	2.3	3	3408.5
256	32	4.7	3.2	6	1154.3
128	64	3.1	1.6	2	1536.8
256	64	5.5	2.3	1	1470.3
256	32	2.4	3.2	7	1403.8
256	64	4.7	2.3	0	1267.5
128	32	4.7	2.3	4	1057

128	32	1.6	2.3	7	8194.3
256	32	0.8	3.2	5	1645.8
256	64	2.4	2.3	1	1287
128	32	0	2.3	8	2554.3
128	64	1.6	1.6	0	1174
128	32	2.4	2.3	1	1244.5
128	32	0.8	2.3	16	1957.8
256	64	0.8	2.3	6	2656
256	64	0	2.3	0	2223.3
128	64	0.8	1.6	3	1333.8
256	32	3.1	3.2	10	7074.8

Participant 5:

A	W	R	ID	ERR	MT
256	64	5.5	2.3	1	1790.3
128	64	1.6	1.6	1	1813.5
128	64	3.9	1.6	0	1739.3
128	32	3.9	2.3	1	1833
256	32	3.1	3.2	4	1977.5
128	32	2.4	2.3	3	1462.8
128	32	5.5	2.3	1	1731.3
128	64	3.1	1.6	0	1630.3
256	32	1.6	3.2	2	2285.3
256	64	1.6	2.3	0	1673
128	32	3.1	2.3	2	1724
256	64	4.7	2.3	0	1763
256	32	0.8	3.2	9	2902
128	64	0.8	1.6	2	1407.8
256	64	0	2.3	1	1606.5
256	64	0.8	2.3	0	2012.3
128	64	5.5	1.6	0	1540.8
256	32	4.7	3.2	1	2195.8
128	64	2.4	1.6	0	1587.3
128	32	1.6	2.3	2	1653.8
128	64	0	1.6	0	1560
256	32	2.4	3.2	2	2519.5
128	32	0	2.3	0	1934.5
256	32	3.9	3.2	0	1766.5
128	32	0.8	2.3	1	1844.8
256	64	2.4	2.3	0	1630.3
128	32	4.7	2.3	2	1548
256	32	5.5	3.2	0	2523.3
256	64	3.1	2.3	1	1836.8
256	64	3.9	2.3	1	1797.8
256	32	0	3.2	10	1969.5
128	64	4.7	1.6	0	1443

Participant 6:

A	W	R	ID	ERR	MT
256	32	2.4	3.2	8	3584.3
128	32	0.8	2.3	5	2004.5
128	32	0	2.3	4	1759
128	64	2.4	1.6	1	1841
128	64	4.7	1.6	0	1708.3
128	32	3.9	2.3	2	2129.5
128	64	3.9	1.6	0	2086.3
128	32	5.5	2.3	1	2539
128	64	0.8	1.6	0	1817.3
256	64	0.8	2.3	0	2406.3
256	32	3.1	3.2	2	2835.5
128	32	4.7	2.3	1	2063.3
256	64	4.7	2.3	0	1965.8
128	32	1.6	2.3	3	2203.8
128	32	3.1	2.3	1	2090.5
256	64	5.5	2.3	0	2297

256	32	1.6	3.2	1	3065.5
256	32	3.9	3.2	7	2944.5
128	64	5.5	1.6	0	1661.8
256	32	0	3.2	2	4738.5
256	32	5.5	3.2	6	3003.3
256	64	3.1	2.3	0	5062.3
128	64	3.1	1.6	0	2344
256	64	0	2.3	1	2390.8
128	32	2.4	2.3	1	2266
128	64	0	1.6	1	1556.3
128	64	1.6	1.6	0	2125.3
256	32	0.8	3.2	6	3291.8
256	64	3.9	2.3	0	2519.3
256	64	2.4	2.3	0	2387
256	32	4.7	3.2	3	2925.3
256	64	1.6	2.3	1	1751.3

Participant 7:

A	W	R	ID	ERR	MT
256	32	0.8	3.2	2	3533.3
256	32	4.7	3.2	3	3646.5
128	64	3.9	1.6	0	1852.5
256	32	3.1	3.2	2	2406
256	64	3.9	2.3	0	1941.8
256	64	2.4	2.3	0	2164.5
128	32	4.7	2.3	0	1895.3
128	32	1.6	2.3	6	2281.8
128	64	0	1.6	0	1400
128	64	2.4	1.6	0	1665.3
128	32	0	2.3	2	1587.3
128	32	0.8	2.3	5	1310.5
256	64	1.6	2.3	0	1396.5
128	32	3.9	2.3	3	1844.8
128	32	2.4	2.3	3	1435.3
128	64	1.6	1.6	0	1341.5
256	32	1.6	3.2	0	1677
256	64	4.7	2.3	0	1841
128	64	3.1	1.6	0	1220.8
256	64	0.8	2.3	1	1778.5
256	32	2.4	3.2	2	2332.3
128	32	3.1	2.3	0	1649.5
256	64	3.1	2.3	0	1891.3
128	64	4.7	1.6	2	1361.3
128	64	5.5	1.6	0	1571.5
256	32	3.9	3.2	3	2367.3
256	64	0	2.3	0	2234.8
256	32	0	3.2	1	2628.5
256	32	5.5	3.2	1	3311
256	64	5.5	2.3	5	2242.5
128	64	0.8	1.6	0	1251.8
128	32	5.5	2.3	3	2156.5

Participant 8:

A	W	R	ID	ERR	MT
256	32	3.1	3.2	26	3736
128	64	0	1.6	3	1867.8
128	64	1.6	1.6	1	1653.3
128	64	3.1	1.6	0	2441.5
256	64	3.9	2.3	2	2702.8
256	64	3.1	2.3	0	3502
256	32	3.9	3.2	1	9313.3
128	32	0.8	2.3	13	6259.3
128	64	3.9	1.6	0	2476.5
256	32	2.4	3.2	13	5331
128	32	3.9	2.3	3	2503.8

256	32	5.5	3.2	24	4025
128	64	2.4	1.6	3	2877.8
128	32	0	2.3	8	3139.3
128	32	1.6	2.3	5	5327.8
256	32	1.6	3.2	6	4637
128	32	2.4	2.3	12	4902
256	64	2.4	2.3	6	9531.3
128	32	3.1	2.3	4	2881.8
128	32	5.5	2.3	4	2250.3
128	32	4.7	2.3	4	3420
256	64	0.8	2.3	4	3088.5
128	64	4.7	1.6	2	2067
256	64	0	2.3	6	2457
256	32	0.8	3.2	5	10810.8
256	64	5.5	2.3	15	6727.5
128	64	5.5	1.6	5	1934.3
128	64	0.8	1.6	2	3892.3
256	64	4.7	2.3	2	2909.5
256	32	4.7	3.2	12	4083.5
256	64	1.6	2.3	2	4149.5
256	32	0	3.2	3	3229.3

Participant 9:

A	W	R	ID	ERR	MT
256	32	0	3.2	5	2956.3
128	64	0	1.6	0	1716
128	64	1.6	1.6	1	1146.8
128	64	4.7	1.6	1	1875.5
256	64	3.9	2.3	0	1672.8
256	32	4.7	3.2	0	2184
256	64	3.1	2.3	0	1459
256	32	1.6	3.2	0	2625
256	32	3.1	3.2	0	3272
128	32	2.4	2.3	0	2472.8
256	32	0.8	3.2	0	3435.8
128	64	2.4	1.6	3	2188
256	64	5.5	2.3	0	2281.8
256	64	0.8	2.3	3	2355.5
128	64	5.5	1.6	0	1224.8
256	64	2.4	2.3	0	2028.3
128	32	0.8	2.3	0	2254.5
128	64	3.1	1.6	0	1918.8
256	64	1.6	2.3	0	1579.5
128	32	5.5	2.3	3	1451
128	32	4.7	2.3	2	1505.5
128	32	0	2.3	1	3213.5
256	32	2.4	3.2	1	3400.5
256	32	3.9	3.2	1	3701.3
128	32	3.9	2.3	0	3564.3
256	32	5.5	3.2	1	3073
256	64	4.7	2.3	0	2605
128	64	0.8	1.6	0	4886.8
128	32	1.6	2.3	0	2211
128	32	3.1	2.3	2	3455.8
256	64	0	2.3	3	3096.5
128	64	3.9	1.6	0	1794

Participant 10:

A	W	R	ID	ERR	MT
256	32	0	3.2	24	6871.8
128	32	4.7	2.3	5	2426
256	32	4.7	3.2	7	7039.8
256	64	4.7	2.3	3	5136.3
256	32	2.4	3.2	6	7098
128	32	0	2.3	15	12831.3

256	32	5.5	3.2	9	9258.5
128	64	3.1	1.6	3	3225.5
128	32	3.9	2.3	6	14664
256	64	0	2.3	1	6902.8
256	32	0.8	3.2	22	11341.3
256	32	3.1	3.2	8	3814.5
128	64	1.6	1.6	2	2371.3
128	32	2.4	2.3	8	2538.8
128	64	5.5	1.6	5	3475.3
128	32	3.1	2.3	14	4157.5
128	64	3.9	1.6	2	2219.3
128	64	0.8	1.6	5	2558.3
256	32	3.9	3.2	14	3381.3
128	64	2.4	1.6	2	1567.8
128	32	0.8	2.3	8	3232.8
256	64	1.6	2.3	1	2457
128	64	0	1.6	1	1489.8
256	64	2.4	2.3	2	2434
256	64	3.1	2.3	1	1946.3
128	32	5.5	2.3	9	4438.3
256	64	5.5	2.3	9	5214.5
256	32	1.6	3.2	1	4906
128	64	4.7	1.6	0	2437.5
256	64	3.9	2.3	1	2172.5
256	64	0.8	2.3	2	1517
128	32	1.6	2.3	13	3198.3

Participant 11:

A	W	R	ID	ERR	MT
256	64	0.8	2.3	3	1844.8
256	32	0.8	3.2	9	2078.8
256	64	3.9	2.3	1	1525
256	64	5.5	2.3	0	1478
128	64	4.7	1.6	0	1899.5
128	32	2.4	2.3	2	1950
128	32	1.6	2.3	3	1844.8
256	32	3.9	3.2	6	1794
256	32	0	3.2	17	3252.5
128	64	3.1	1.6	2	1606.8
128	64	5.5	1.6	0	1907
128	32	3.1	2.3	2	1509.5
256	64	1.6	2.3	4	1589.8
128	64	3.9	1.6	0	1345.8
256	32	2.4	3.2	8	1977.5
128	32	4.7	2.3	1	1653.5
256	32	3.1	3.2	8	1891.5
256	32	5.5	3.2	5	2433.8
256	64	2.4	2.3	2	1517.5
128	32	0	2.3	15	1758.8
128	64	0	1.6	1	1669.3
128	64	0.8	1.6	0	1158
128	32	3.9	2.3	4	1341.5
256	64	4.7	2.3	0	1680.8
256	64	3.1	2.3	3	1778.5
256	32	1.6	3.2	5	1669.3
128	32	5.5	2.3	4	1973.8
128	32	0.8	2.3	12	2226.8
128	64	1.6	1.6	2	1477.8
256	32	4.7	3.2	7	2796.5
128	64	2.4	1.6	3	1298.5
256	64	0	2.3	1	5202.5

Participant 12:

A	W	R	ID	ERR	MT
128	32	3.1	2.3	0	2390.5

256	32	0	3.2	2	1735.5
256	64	1.6	2.3	0	1166
128	64	1.6	1.6	0	1938.3
256	64	0.8	2.3	0	1575.5
128	64	3.9	1.6	0	1860.3
256	32	3.1	3.2	0	2215.3
128	32	4.7	2.3	4	1727.8
256	32	3.9	3.2	1	1677
128	64	4.7	1.6	0	1958
128	32	0	2.3	3	1872
128	32	1.6	2.3	7	1829
256	64	5.5	2.3	0	1945.8
256	64	4.7	2.3	2	2066.8
128	64	0.8	1.6	1	1185.3
128	64	3.1	1.6	0	1365.3
128	64	0	1.6	0	1560
256	32	1.6	3.2	1	1731.8
128	32	2.4	2.3	4	1797.8
256	32	2.4	3.2	3	1462.8
128	32	0.8	2.3	2	1669.3
128	64	2.4	1.6	0	1657.5
256	64	3.9	2.3	1	1727.8
128	32	5.5	2.3	2	2562.3
256	64	3.1	2.3	0	1392.3
256	32	0.8	3.2	3	1221
256	32	5.5	3.2	1	1887.5
256	32	4.7	3.2	0	1883.8
128	64	5.5	1.6	0	1279.3
256	64	2.4	2.3	2	2379.3
256	64	0	2.3	1	2464.8
128	32	3.9	2.3	4	1267.5

Participant 13:

A	W	R	ID	ERR	MT
256	64	3.9	2.3	0	1392.3
256	32	3.1	3.2	1	1899.3
128	64	3.1	1.6	1	1283
256	64	5.5	2.3	0	1556.5
128	32	2.4	2.3	0	1521
128	32	0	2.3	4	1548.5
128	64	4.7	1.6	0	1072.5
128	64	5.5	1.6	0	998.3
256	32	4.7	3.2	0	1813.5
256	32	5.5	3.2	0	1505.8
256	32	1.6	3.2	2	2476.5
256	32	0.8	3.2	0	1899.3
128	32	4.7	2.3	1	1774.8
256	64	1.6	2.3	0	1243.8
256	64	4.7	2.3	1	1322.3
256	32	3.9	3.2	2	1747
128	64	0.8	1.6	0	1138.8
128	64	3.9	1.6	0	1045.3
128	32	5.5	2.3	1	1821.5
128	32	1.6	2.3	3	1209.3
128	64	1.6	1.6	0	1528.8
256	64	0	2.3	0	1470.5
128	32	3.9	2.3	2	1275.8
128	32	0.8	2.3	0	1353.3
256	64	3.1	2.3	0	1439.3
256	32	0	3.2	2	1735.3
128	64	2.4	1.6	0	1084.3
256	32	2.4	3.2	1	1653.5
256	64	0.8	2.3	0	1357.3
128	32	3.1	2.3	1	2102
256	64	2.4	2.3	1	1384.3
128	64	0	1.6	0	1154.8

Participant 14:

A	W	R	ID	ERR	MT
128	32	3.1	2.3	0	2133.3
128	32	3.9	2.3	2	2289.3
256	64	5.5	2.3	1	2032
256	32	5.5	3.2	5	3981.8
128	32	0.8	2.3	1	1774.3
256	32	3.9	3.2	1	2422.3
256	32	2.4	3.2	2	2792.3
256	64	3.1	2.3	2	2831.8
256	64	0.8	2.3	0	2804.3
128	64	5.5	1.6	0	3315
128	64	1.6	1.6	0	1521.3
256	32	1.6	3.2	6	7765
128	64	3.1	1.6	0	2141
256	64	1.6	2.3	2	3779.3
256	64	2.4	2.3	1	1923
128	32	4.7	2.3	3	1345.5
128	32	1.6	2.3	4	1536.8
256	64	0	2.3	16	2960
256	32	0.8	3.2	6	2441.3
128	32	0	2.3	0	1673
128	64	3.9	1.6	0	1439.3
256	64	3.9	2.3	0	2145.3
128	64	2.4	1.6	2	1907.3
128	64	4.7	1.6	1	2040
128	64	0.8	1.6	3	1088
256	32	3.1	3.2	1	3284
128	32	5.5	2.3	0	1587.5
256	32	4.7	3.2	1	2948.8
256	64	4.7	2.3	0	1934.3
128	64	0	1.6	0	1353.3
256	32	0	3.2	17	3057.5
128	32	2.4	2.3	0	1556

Participant 15:

A	W	R	ID	ERR	MT
128	64	3.1	1.6	0	1626.3
256	32	3.1	3.2	0	2312.8
256	64	2.4	2.3	0	1665.3
128	32	0	2.3	3	1977.3
256	64	5.5	2.3	0	1829.3
256	32	2.4	3.2	2	2874.3
256	32	5.5	3.2	3	2398.5
256	64	1.6	2.3	0	1681
256	64	0.8	2.3	1	1634.5
128	64	0	1.6	0	1361.3
256	64	3.1	2.3	1	1942.5
128	32	5.5	2.3	2	2765
256	64	3.9	2.3	0	2331.5
128	64	5.5	1.6	0	1579.5
256	32	3.9	3.2	3	3214.3
128	64	0.8	1.6	1	1860.3
128	64	4.7	1.6	1	2028
128	32	1.6	2.3	2	1841
256	64	4.7	2.3	0	2944.8
128	32	3.9	2.3	2	4662
256	32	1.6	3.2	1	2433.8
128	64	1.6	1.6	0	1435.3
128	32	3.1	2.3	0	1637.8
128	32	2.4	2.3	2	2352.3
256	32	4.7	3.2	3	2702.8
256	64	0	2.3	0	6797.3
128	64	2.4	1.6	1	1993
128	32	4.7	2.3	0	2234.8

128	32	0.8	2.3	1	2191.5
256	32	0	3.2	18	6491.3
128	64	3.9	1.6	0	1864
256	32	0.8	3.2	1	2574.3

Participant 16:

A	W	R	ID	ERR	MT
256	64	2.4	2.3	2	1770.5
256	32	0	3.2	12	3275.8
256	32	3.1	3.2	2	2133.3
128	64	1.6	1.6	1	1735.5
128	64	3.1	1.6	4	2516
128	64	4.7	1.6	0	1895.8
128	64	0	1.6	0	1661.3
256	32	3.9	3.2	2	2129.5
128	32	5.5	2.3	5	2831.5
256	64	1.6	2.3	3	2597.3
128	64	3.9	1.6	3	1548.5
128	32	3.1	2.3	4	2305
256	64	0	2.3	2	1969.3
128	32	1.6	2.3	2	6922.3
256	32	0.8	3.2	4	2788.3
256	32	5.5	3.2	26	2487.8
128	64	2.4	1.6	2	2905.3
128	32	4.7	2.3	7	1216.8
128	64	5.5	1.6	1	1911
256	64	5.5	2.3	2	2141
256	64	4.7	2.3	0	2983.8
128	32	0.8	2.3	1	1634.3
256	64	3.1	2.3	0	2734
256	32	2.4	3.2	1	2995
256	64	0.8	2.3	0	1926.5
128	64	0.8	1.6	1	1603
128	32	3.9	2.3	6	2351.5
256	64	3.9	2.3	1	2102.3
256	32	4.7	3.2	3	1661
128	32	0	2.3	3	1985.3
256	32	1.6	3.2	3	2207.3
128	32	2.4	2.3	6	3584.3

Participant 17:

A	W	R	ID	ERR	MT
256	64	0.8	2.3	0	2648.3
128	64	3.9	1.6	4	2391
256	32	0.8	3.2	1	2995
128	64	0	1.6	0	1489.8
128	64	4.7	1.6	1	2223
128	32	0.8	2.3	1	1603
128	32	3.9	2.3	8	2059.3
256	64	4.7	2.3	0	3693
256	64	1.6	2.3	2	1638.3
128	32	0	2.3	2	3170.5
256	32	3.9	3.2	4	2660
256	64	0	2.3	1	1836.8
128	64	0.8	1.6	0	1743
256	64	3.1	2.3	1	1965.5
256	64	5.5	2.3	0	2511.5
128	32	4.7	2.3	3	3045.8
256	32	2.4	3.2	1	2890
128	64	2.4	1.6	0	1259.8
128	32	5.5	2.3	2	2059.3
256	32	3.1	3.2	5	2047.5
128	32	3.1	2.3	1	1977
256	32	1.6	3.2	5	1731.8
128	64	1.6	1.6	1	1454.5

128	32	1.6	2.3	5	2071.3
128	64	3.1	1.6	0	1415.8
256	64	2.4	2.3	0	1443.3
128	64	5.5	1.6	1	1329.5
256	32	5.5	3.2	0	3361.8
256	64	3.9	2.3	2	1517
256	32	0	3.2	3	2936.3
128	32	2.4	2.3	0	1754.8
256	32	4.7	3.2	1	2472.3

Participant 18:

A	W	R	ID	ERR	MT
128	32	4.7	2.3	1	2398.8
256	64	0	2.3	1	1969.3
256	32	0.8	3.2	6	1606.5
256	32	0	3.2	4	2917.3
128	64	3.1	1.6	1	2956
256	64	0.8	2.3	0	1692.3
128	32	3.9	2.3	3	3346.3
256	64	3.9	2.3	5	2226.8
256	64	4.7	2.3	3	2390.8
128	32	1.6	2.3	5	1902.8
128	64	4.7	1.6	0	1833
256	64	1.6	2.3	1	1595.3
128	32	5.5	2.3	5	2211.5
128	64	0	1.6	1	1505.8
128	32	2.4	2.3	1	2745.8
256	64	2.4	2.3	2	1642
256	32	2.4	3.2	10	2013
256	32	5.5	3.2	13	3018.8
128	64	5.5	1.6	3	1770.3
256	32	4.7	3.2	11	2387
128	32	0	2.3	5	4028.8
128	64	2.4	1.6	2	1571.8
128	32	0.8	2.3	0	5249.5
128	64	0.8	1.6	0	3841.8
128	64	1.6	1.6	0	1314
256	32	1.6	3.2	1	2437.8
128	32	3.1	2.3	6	2359.3
256	32	3.1	3.2	9	5381.8
256	32	3.9	3.2	8	3514
128	64	3.9	1.6	2	1489.8
256	64	3.1	2.3	4	2414.3
256	64	5.5	2.3	0	2160.5

Participant 19:

A	W	R	ID	ERR	MT
256	64	5.5	2.3	1	1497.5
256	32	2.4	3.2	5	2012.3
128	32	1.6	2.3	0	1333.8
128	32	3.1	2.3	1	1895.3
256	64	1.6	2.3	0	1622.3
256	32	0.8	3.2	7	2304.8
256	64	2.4	2.3	0	1661.8
128	32	3.9	2.3	2	2172.3
128	64	0	1.6	7	1837
128	64	5.5	1.6	2	1224.8
128	64	4.7	1.6	0	1462.3
128	32	2.4	2.3	0	2036
128	32	0	2.3	0	2086.8
256	32	1.6	3.2	2	1708.3
256	64	3.1	2.3	4	1946.5
128	64	2.4	1.6	0	1205
128	64	0.8	1.6	2	1197.3
128	64	3.1	1.6	0	1739.5

256	32	0	3.2	3	2316.8
128	64	1.6	1.6	0	1509.3
256	64	3.9	2.3	0	1564.3
128	64	3.9	1.6	0	1837
256	32	3.1	3.2	4	2577.8
256	32	3.9	3.2	1	1817.8
256	64	0	2.3	0	1634
128	32	0.8	2.3	2	2012.5
256	32	5.5	3.2	1	2141
128	32	4.7	2.3	2	1731.8
128	32	5.5	2.3	7	2628.5
256	64	0.8	2.3	0	2180.5
256	64	4.7	2.3	1	2125.3
256	32	4.7	3.2	3	2231

Participant 20:

A	W	R	ID	ERR	MT
128	32	5.5	2.3	5	3088.8
128	32	3.9	2.3	0	2024.3
128	32	2.4	2.3	4	3042
256	32	0	3.2	5	1973.3
256	32	3.9	3.2	6	1798
128	64	4.7	1.6	1	1676.8
128	64	2.4	1.6	1	2730.3
256	32	0.8	3.2	9	2769.3
256	32	2.4	3.2	7	1622.5
128	32	4.7	2.3	6	2328.5
128	32	3.1	2.3	4	2207.3
256	32	5.5	3.2	8	2043.8
256	32	3.1	3.2	4	2246.3
256	64	3.9	2.3	0	2164.3
128	64	5.5	1.6	0	1505.8
128	64	0	1.6	2	1447
128	32	1.6	2.3	3	1755.3
256	32	1.6	3.2	1	3482.8
128	32	0	2.3	7	2609.5
256	64	0	2.3	2	4329.3
256	64	4.7	2.3	2	2082.5
128	64	0.8	1.6	0	1852.5
256	64	0.8	2.3	2	2550.5
128	64	1.6	1.6	0	2562.5
128	64	3.1	1.6	2	2968.3
128	32	0.8	2.3	2	2551
256	32	4.7	3.2	2	3346.5
256	64	5.5	2.3	0	1922.8
256	64	2.4	2.3	0	2597.5
256	64	1.6	2.3	0	2542.8
128	64	3.9	1.6	0	2375.3
256	64	3.1	2.3	2	2168.5

Appendix C: Fitts' task raw data (RMLC condition)

Participant 1:

A	W	R	ID	ERR	MT
256	64	0	2.3	0	3402.8
128	64	0	1.6	0	1232.3
256	32	5.5	3.2	1	1570
256	32	0.8	3.2	0	1267.8
128	64	1.6	1.6	0	953.5
128	32	4.7	2.3	0	1490.3
128	64	2.4	1.6	0	1125.3
128	64	5.5	1.6	1	1097.5
128	32	5.5	2.3	0	1201.3
128	32	0	2.3	0	1250.3
128	32	3.1	2.3	1	1311
256	64	3.9	2.3	1	1140.8
256	64	4.7	2.3	0	1198.8
256	64	3.1	2.3	0	1257.8
256	32	2.4	3.2	2	1212.5
256	64	1.6	2.3	3	1461.8
128	32	3.9	2.3	0	1417
256	32	0	3.2	1	1653.3
128	32	0.8	2.3	0	1314.3
128	64	0.8	1.6	1	1116.3
256	32	1.6	3.2	0	1570.5
256	64	5.5	2.3	1	1203.3
256	32	4.7	3.2	0	1453.5
256	64	0.8	2.3	1	1159.5
128	64	3.9	1.6	0	1311.5
128	64	3.1	1.6	0	1594.3
128	64	4.7	1.6	0	1401.3
128	32	2.4	2.3	0	2464.3
128	32	1.6	2.3	0	1162.8
256	64	2.4	2.3	0	1190
256	32	3.1	3.2	0	1616.8
256	32	3.9	3.2	3	1866

Participant 2:

A	W	R	ID	ERR	MT
256	64	0.8	2.3	2	1760.3
128	64	2.4	1.6	0	1278.5
128	32	0.8	2.3	1	1342.5
256	32	2.4	3.2	1	1592.5
256	32	5.5	3.2	23	3255
256	64	3.9	2.3	3	1903
256	64	2.4	2.3	2	2248.5
128	64	0.8	1.6	0	1473.5
128	32	3.1	2.3	1	1482.3
256	64	3.1	2.3	1	8050.3
128	32	3.9	2.3	0	1288.5
256	64	4.7	2.3	0	2375.8
256	32	3.9	3.2	5	1732.3
128	64	1.6	1.6	0	1104
128	32	4.7	2.3	2	1090.8
128	64	5.5	1.6	0	1009.8
256	64	0	2.3	0	1383.5
128	32	2.4	2.3	2	1379
256	32	0	3.2	1	1574.8
128	32	5.5	2.3	2	1420
128	32	0	2.3	2	1455.8
128	32	1.6	2.3	0	1438.8
128	64	0	1.6	0	1634.5
256	64	5.5	2.3	0	1491.3
128	64	3.1	1.6	0	1314.3
256	32	4.7	3.2	1	2026.5

256	64	1.6	2.3	1	1558.8
256	32	0.8	3.2	1	2035
128	64	3.9	1.6	0	2255
128	64	4.7	1.6	0	1250.5
256	32	1.6	3.2	2	4026
256	32	3.1	3.2	1	3378.8

Participant 3:

A	W	R	ID	ERR	MT
128	32	3.1	2.3	3	6368.5
256	64	0	2.3	3	1946.3
256	32	0.8	3.2	10	2019.8
256	64	4.7	2.3	2	4984.5
256	32	4.7	3.2	2	3868.8
256	64	5.5	2.3	0	3872.5
128	32	0.8	2.3	5	1563.5
128	32	1.6	2.3	5	4516
256	32	5.5	3.2	3	2890
128	64	4.7	1.6	2	3034.5
256	64	2.4	2.3	5	1895.3
128	64	5.5	1.6	0	3576
256	32	1.6	3.2	4	3525.5
256	64	0.8	2.3	0	3213.8
128	64	3.1	1.6	4	1985
128	32	4.7	2.3	0	2129.3
256	32	3.9	3.2	9	3014.5
256	32	3.1	3.2	3	2417.5
128	64	0	1.6	0	2632.5
256	64	3.9	2.3	1	1813.5
128	64	3.9	1.6	0	1411.8
128	32	5.5	2.3	3	3077.3
256	32	2.4	3.2	5	2199.5
128	32	0	2.3	2	2851
128	64	1.6	1.6	1	2168.3
256	32	0	3.2	3	2102.3
128	32	3.9	2.3	4	2344.3
128	32	2.4	2.3	3	2071
256	64	1.6	2.3	0	2765
128	64	0.8	1.6	1	2761.3
256	64	3.1	2.3	0	1634.3
128	64	2.4	1.6	2	2979.3

Participant 4:

A	W	R	ID	ERR	MT
256	64	1.6	2.3	0	2008.5
256	32	3.9	3.2	5	3381.8
128	64	3.1	1.6	1	1298.8
128	64	0	1.6	2	2570.3
128	64	1.6	1.6	2	1750.8
256	32	1.6	3.2	1	2199.5
256	64	4.7	2.3	0	1860.3
256	32	5.5	3.2	3	2285.3
256	64	5.5	2.3	2	1556.3
256	64	0.8	2.3	0	1575.8
128	32	0.8	2.3	1	1880
128	32	3.1	2.3	6	1645.8
256	32	0	3.2	3	2624.5
256	32	4.7	3.2	1	2772.5
256	64	3.1	2.3	7	2211.5
128	32	4.7	2.3	10	2238.8
128	64	4.7	1.6	1	1619
256	32	2.4	3.2	4	1766.8
128	32	5.5	2.3	3	3416.3
128	32	1.6	2.3	1	1544.5
256	32	3.1	3.2	4	4828

256	32	0.8	3.2	10	2121.5
128	32	2.4	2.3	6	1813.8
128	64	0.8	1.6	2	1653.5
256	64	0	2.3	0	1637.8
128	64	5.5	1.6	2	1517
128	64	2.4	1.6	0	2523.5
128	32	0	2.3	4	2008.3
256	64	3.9	2.3	0	2652.3
256	64	2.4	2.3	0	1712
128	32	3.9	2.3	4	3747.5
128	64	3.9	1.6	8	1751

Participant 5:

A	W	R	ID	ERR	MT
256	32	0.8	3.2	1	2878.3
128	64	4.7	1.6	1	2043.5
256	32	2.4	3.2	1	4875
256	64	3.1	2.3	5	3471
128	32	5.5	2.3	1	1825.5
256	32	3.9	3.2	10	2265.8
128	32	0.8	2.3	3	2885.8
256	32	4.7	3.2	3	3054
256	64	0	2.3	4	2265.8
256	32	0	3.2	2	3069.5
256	64	5.5	2.3	2	1696.5
256	64	1.6	2.3	4	2031.8
128	32	0	2.3	0	1614.8
128	64	0.8	1.6	0	1603
256	64	4.7	2.3	2	1868
128	32	2.4	2.3	2	2406.3
128	32	1.6	2.3	0	2503.5
128	64	3.9	1.6	1	1852.5
128	64	5.5	1.6	1	2113.8
256	32	5.5	3.2	8	2156.8
256	32	1.6	3.2	10	2971.8
128	32	3.9	2.3	5	3260.5
128	64	2.4	1.6	0	1622.3
128	64	3.1	1.6	0	1337.8
128	64	1.6	1.6	0	1493.5
256	64	0.8	2.3	0	1637.8
256	32	3.1	3.2	13	2437.5
128	64	0	1.6	0	1583.8
128	32	3.1	2.3	0	3163
256	64	3.9	2.3	0	2004.5
256	64	2.4	2.3	0	2035.8
128	32	4.7	2.3	1	1642

Participant 6:

A	W	R	ID	ERR	MT
256	32	0.8	3.2	3	2277.5
256	64	3.1	2.3	0	2265.8
256	64	5.5	2.3	3	1969.5
128	32	4.7	2.3	2	2262.3
128	32	0.8	2.3	1	3338.5
128	64	1.6	1.6	0	1825.3
128	32	3.1	2.3	3	1985
256	32	3.9	3.2	4	2761.3
256	32	4.7	3.2	3	3346
128	64	3.1	1.6	2	2632.5
256	32	1.6	3.2	6	2800.5
128	32	1.6	2.3	2	2453
256	64	3.9	2.3	2	2749.5
128	64	2.4	1.6	0	2328.3
256	64	1.6	2.3	0	2898
256	32	5.5	3.2	7	4434.5

256	32	0	3.2	2	4664.8
256	64	0.8	2.3	0	2473
256	64	4.7	2.3	1	1700.5
128	32	2.4	2.3	0	2562.5
128	64	0.8	1.6	0	1926.8
128	64	5.5	1.6	1	4879
256	64	2.4	2.3	0	1653.8
128	32	5.5	2.3	0	2956
128	64	3.9	1.6	1	1361.3
256	64	0	2.3	2	2258.3
128	32	3.9	2.3	2	1704.5
128	64	4.7	1.6	0	2320.5
128	64	0	1.6	0	1404
256	32	3.1	3.2	2	3475.3
128	32	0	2.3	0	2819.8
256	32	2.4	3.2	0	2799.8

Participant 7:

A	W	R	ID	ERR	MT
256	32	5.5	3.2	0	3595.8
128	32	2.4	2.3	3	1299
128	32	4.7	2.3	2	1618.5
256	64	0	2.3	4	1743.3
128	64	0	1.6	0	1384
256	64	3.1	2.3	5	4914.8
256	32	3.1	3.2	7	2461
128	32	1.6	2.3	1	1595
256	64	1.6	2.3	1	1809.8
256	64	2.4	2.3	0	1552
256	32	4.7	3.2	2	2507.3
256	32	0.8	3.2	4	3155
128	64	2.4	1.6	0	1330
128	64	5.5	1.6	0	1431.5
128	64	4.7	1.6	0	1642
256	32	0	3.2	2	2792.3
128	32	5.5	2.3	0	2344
256	64	5.5	2.3	1	3678
128	64	3.9	1.6	1	1922.8
256	32	3.9	3.2	11	3759.5
256	64	0.8	2.3	0	2063
128	64	1.6	1.6	0	1403.8
256	32	2.4	3.2	5	2316.8
128	64	3.1	1.6	0	1915
128	32	0	2.3	0	2718.3
256	32	1.6	3.2	2	3404.8
128	32	3.1	2.3	1	2090.8
256	64	4.7	2.3	1	1665.3
128	32	3.9	2.3	8	4060
256	64	3.9	2.3	0	2406.5
128	64	0.8	1.6	0	1844.8
128	32	0.8	2.3	2	1376.8

Participant 8:

A	W	R	ID	ERR	MT
256	64	3.9	2.3	0	2523.3
128	32	2.4	2.3	4	2004.8
128	64	2.4	1.6	1	2429.5
256	32	1.6	3.2	3	2102.3
128	64	0	1.6	7	1459
128	32	0.8	2.3	6	2230.8
128	64	3.9	1.6	0	1329.8
256	64	5.5	2.3	0	1696.3
256	32	3.9	3.2	10	2991.5
256	64	0	2.3	5	3065
128	64	5.5	1.6	5	1478

256	64	4.7	2.3	2	3463
128	32	3.9	2.3	1	3381.5
256	64	3.1	2.3	2	2340
128	64	3.1	1.6	1	1821
256	64	1.6	2.3	0	2129.5
128	64	0.8	1.6	2	1556.5
256	32	4.7	3.2	2	2067
256	32	0.8	3.2	10	4052.5
128	32	3.1	2.3	10	2266
128	32	5.5	2.3	11	2047.8
128	32	1.6	2.3	7	1840.8
256	32	5.5	3.2	1	2343.8
256	32	0	3.2	4	2640.3
256	32	3.1	3.2	8	3127.8
128	32	0	2.3	7	1934.3
256	32	2.4	3.2	5	1809.5
256	64	0.8	2.3	2	2285.3
128	64	1.6	1.6	1	2110.3
128	64	4.7	1.6	0	2281.8
256	64	2.4	2.3	3	1868.3
128	32	4.7	2.3	1	2644.5

Participant 9:

A	W	R	ID	ERR	MT
128	32	4.7	2.3	0	2273.8
256	32	3.1	3.2	1	8201.8
256	32	1.6	3.2	1	8533.5
128	32	0.8	2.3	1	3739.8
128	64	3.9	1.6	0	1598.8
128	64	1.6	1.6	2	1669.5
128	32	3.1	2.3	4	3435.8
128	32	2.4	2.3	0	2449.3
128	64	4.7	1.6	0	1446.8
256	64	3.9	2.3	3	1462.3
128	64	3.1	1.6	2	3685
128	64	0	1.6	1	1478.5
128	32	1.6	2.3	5	4165.3
256	32	0	3.2	4	2203.3
256	32	0.8	3.2	5	4520.3
128	32	3.9	2.3	0	3069.5
256	64	5.5	2.3	2	2211.5
256	32	5.5	3.2	0	2379
128	64	2.4	1.6	1	1938.8
128	64	0.8	1.6	1	3186.3
128	32	5.5	2.3	3	2218.8
128	32	0	2.3	0	1692.5
256	32	2.4	3.2	14	3611.5
256	64	0	2.3	0	2632.3
256	64	1.6	2.3	1	2172.5
256	32	4.7	3.2	1	3287.8
256	32	3.9	3.2	3	5924.3
128	64	5.5	1.6	0	1517.3
256	64	3.1	2.3	0	2480.5
256	64	4.7	2.3	0	1985.3
256	64	2.4	2.3	2	1544.3
256	64	0.8	2.3	0	1680.5

Participant 10:

A	W	R	ID	ERR	MT
128	64	3.9	1.6	0	2530.8
256	64	2.4	2.3	5	2164.5
128	64	4.7	1.6	1	2456.5
128	32	3.1	2.3	3	1965.5
128	32	4.7	2.3	7	2452.8
256	64	4.7	2.3	2	3011

256	32	3.9	3.2	4	3861
256	64	5.5	2.3	3	2570
128	64	0	1.6	0	1314
128	32	3.9	2.3	6	2449.3
256	64	3.1	2.3	0	2445.3
128	64	3.1	1.6	1	1934.3
128	32	1.6	2.3	4	2581.8
256	64	0	2.3	0	1954
256	32	1.6	3.2	2	3299
128	64	0.8	1.6	3	1435
256	64	3.9	2.3	3	3685.8
128	32	5.5	2.3	7	2640.3
256	64	0.8	2.3	0	1642
128	32	0	2.3	9	2195.8
256	32	3.1	3.2	6	5663
256	32	5.5	3.2	6	3732
256	32	0.8	3.2	17	2429.8
128	64	1.6	1.6	1	1099.8
256	32	0	3.2	9	3303.3
128	64	5.5	1.6	1	1626.5
128	64	2.4	1.6	1	1447
256	32	2.4	3.2	9	2866.5
128	32	2.4	2.3	8	2281.8
256	64	1.6	2.3	2	1856.3
256	32	4.7	3.2	20	4964.8
128	32	0.8	2.3	1	2273.5

Participant 11:

A	W	R	ID	ERR	MT
128	64	3.9	1.6	0	1903.5
128	64	5.5	1.6	0	2160.5
256	64	3.9	2.3	1	2000.5
256	32	3.1	3.2	6	5725
128	32	5.5	2.3	2	1840.5
128	32	3.1	2.3	4	2343.8
128	64	3.1	1.6	0	1872
128	64	1.6	1.6	1	1649.8
256	64	5.5	2.3	1	2562.5
128	64	0.8	1.6	0	1954
128	32	1.6	2.3	1	2180
128	32	4.7	2.3	2	2839.5
256	32	5.5	3.2	6	2932.8
256	64	3.1	2.3	2	1984.8
128	32	2.4	2.3	5	1271.5
256	32	4.7	3.2	3	2343.5
256	64	2.4	2.3	1	2071
256	64	0	2.3	1	1883.8
256	64	1.6	2.3	0	2414
128	32	0.8	2.3	3	3042.3
256	32	0	3.2	5	3498.8
256	32	2.4	3.2	3	2304.8
256	64	0.8	2.3	2	2437.5
256	32	3.9	3.2	0	2738
256	64	4.7	2.3	4	2527
256	32	0.8	3.2	5	2000.8
128	64	4.7	1.6	0	1926.5
128	64	2.4	1.6	0	1930.5
128	32	0	2.3	2	3190.3
128	64	0	1.6	1	1501.3
128	32	3.9	2.3	4	1790
256	32	1.6	3.2	4	2164.5

Participant 12:

A	W	R	ID	ERR	MT
128	64	2.4	1.6	2	2051

256	64	3.9	2.3	3	2714
128	64	3.1	1.6	1	1033.5
128	64	3.9	1.6	0	987
128	64	4.7	1.6	1	1022
128	32	1.6	2.3	1	3155.3
256	64	3.1	2.3	2	1555.8
128	32	4.7	2.3	14	1263.5
256	32	3.1	3.2	15	1848.5
256	32	1.6	3.2	4	2246.5
128	32	3.1	2.3	0	2079
256	32	0.8	3.2	1	2008.8
256	64	0.8	2.3	1	1677
128	64	0.8	1.6	0	1563.8
128	64	5.5	1.6	0	1797.8
256	64	1.6	2.3	0	1782.8
256	32	5.5	3.2	1	2106.3
256	64	2.4	2.3	1	1618.5
128	32	0.8	2.3	3	1735.5
256	64	0	2.3	0	1903
256	32	2.4	3.2	5	1806
256	32	0	3.2	1	1938
128	32	5.5	2.3	0	1684.8
128	64	0	1.6	0	1408
128	64	1.6	1.6	1	1720
256	64	5.5	2.3	0	1619
128	32	3.9	2.3	2	1657.5
128	32	0	2.3	0	1521
128	32	2.4	2.3	3	1513.3
256	32	4.7	3.2	0	1634
256	64	4.7	2.3	0	1482
256	32	3.9	3.2	1	2535.3

Participant 13:

A	W	R	ID	ERR	MT
256	32	1.6	3.2	1	1493.8
128	64	4.7	1.6	1	1076.5
256	64	2.4	2.3	0	1076.5
256	64	0.8	2.3	1	1009.8
256	32	5.5	3.2	0	1334
128	32	5.5	2.3	3	1848.8
128	32	3.1	2.3	0	1146.5
256	64	4.7	2.3	0	1127.3
256	64	1.6	2.3	0	2039.8
256	64	3.9	2.3	2	1373.3
256	32	2.4	3.2	1	1135
128	32	0.8	2.3	2	1399.8
128	64	5.5	1.6	0	1871.8
128	64	2.4	1.6	1	1150.5
256	32	3.9	3.2	0	1341.8
256	32	0.8	3.2	2	1407.8
256	64	5.5	2.3	0	1146.5
128	32	2.4	2.3	2	983
128	64	3.1	1.6	0	807.3
256	32	3.1	3.2	0	1408
128	64	0.8	1.6	0	889
128	32	0	2.3	0	1334
128	64	3.9	1.6	2	1244
256	64	0	2.3	0	1205.3
256	32	0	3.2	0	1439
256	64	3.1	2.3	1	979
256	32	4.7	3.2	0	1404.3
128	64	1.6	1.6	0	1096
128	32	3.9	2.3	0	1166
128	32	4.7	2.3	1	1244
128	64	0	1.6	0	1224.8
128	32	1.6	2.3	1	1251.5

Participant 14:

A	W	R	ID	ERR	MT
256	32	3.1	3.2	8	2351.5
256	64	3.9	2.3	0	1364.8
128	64	5.5	1.6	1	1529
128	64	2.4	1.6	1	1119.5
128	32	3.1	2.3	0	1302.5
256	64	2.4	2.3	1	1404
256	64	1.6	2.3	3	1989
256	32	0	3.2	3	3170.5
256	64	0.8	2.3	0	1283
128	64	0.8	1.6	0	1431.5
128	64	4.7	1.6	0	1961.5
128	32	4.7	2.3	2	1844.8
256	32	3.9	3.2	1	2394.3
256	32	1.6	3.2	1	1821.3
128	32	0	2.3	0	2652
128	32	0.8	2.3	1	1408
128	32	3.9	2.3	1	2355.5
256	64	4.7	2.3	0	2835.3
128	64	1.6	1.6	0	1403.8
128	32	5.5	2.3	0	1630.3
256	64	0	2.3	0	1751
256	32	0.8	3.2	0	1927
256	64	3.1	2.3	2	1766.8
256	32	5.5	3.2	2	1977.3
128	64	0	1.6	0	1587.5
128	32	2.4	2.3	3	1454.8
256	64	5.5	2.3	0	2067
256	32	2.4	3.2	1	1657.3
128	64	3.1	1.6	0	2051.5
128	32	1.6	2.3	2	1911
128	64	3.9	1.6	0	1513.3
256	32	4.7	3.2	2	2106

Participant 15:

A	W	R	ID	ERR	MT
128	32	4.7	2.3	7	1801.8
256	32	4.7	3.2	2	2913.5
128	32	1.6	2.3	2	1673
256	64	0.8	2.3	0	1571.8
128	64	0.8	1.6	0	1162.8
128	64	3.9	1.6	0	1267.8
128	64	5.5	1.6	1	1263.8
128	32	5.5	2.3	21	1665
256	32	1.6	3.2	6	2184.3
256	64	4.7	2.3	6	2059.3
256	64	0	2.3	1	1256
128	32	3.1	2.3	3	1299
128	64	3.1	1.6	0	1119.5
256	64	5.5	2.3	2	1310.5
256	32	0	3.2	13	1922.3
256	32	3.1	3.2	60	3548.5
256	32	0.8	3.2	56	2074.5
256	64	1.6	2.3	1	2090.8
128	64	2.4	1.6	1	1283.3
256	32	2.4	3.2	2	1836.8
128	64	4.7	1.6	0	1373.3
128	32	0	2.3	0	1688.8
128	64	0	1.6	0	1294.5
256	64	3.9	2.3	0	1790.3
256	32	5.5	3.2	1	2437.8
256	64	3.1	2.3	4	1891.8
128	32	3.9	2.3	1	1602.8
256	32	3.9	3.2	4	1954

256	64	2.4	2.3	0	1571.5
128	32	2.4	2.3	2	1384.5
128	64	1.6	1.6	0	1267
128	32	0.8	2.3	0	1447

Participant 16:

A	W	R	ID	ERR	MT
256	64	4.7	2.3	0	1517.3
256	64	0.8	2.3	0	1317.8
128	64	1.6	1.6	2	967
128	64	0.8	1.6	1	1049
128	32	0	2.3	0	1587.3
128	32	0.8	2.3	1	1739.8
256	64	0	2.3	3	1762.5
256	64	3.9	2.3	8	2847.3
128	64	3.9	1.6	0	1685.3
128	32	4.7	2.3	5	4730.5
256	64	2.4	2.3	0	1899.5
128	32	2.4	2.3	2	1037.5
256	32	4.7	3.2	2	1560
256	64	5.5	2.3	2	1786.3
256	64	1.6	2.3	1	1844.8
128	32	5.5	2.3	1	1256
256	32	5.5	3.2	2	2878.3
128	64	3.1	1.6	0	1369
128	32	3.1	2.3	1	1555.8
128	64	0	1.6	1	1396.8
128	64	5.5	1.6	3	1435.3
256	32	1.6	3.2	3	1236.3
128	32	1.6	2.3	11	1650
256	32	2.4	3.2	3	3131.8
256	32	0.8	3.2	12	2074.8
128	64	2.4	1.6	0	1509.5
128	64	4.7	1.6	0	1286.8
256	32	3.1	3.2	4	3268
256	64	3.1	2.3	2	1903.5
128	32	3.9	2.3	2	3280
256	32	0	3.2	3	2722
256	32	3.9	3.2	12	5373.8

Participant 17:

A	W	R	ID	ERR	MT
256	64	1.6	2.3	4	4692
256	64	0.8	2.3	1	2137
128	32	1.6	2.3	4	3034.5
256	64	3.1	2.3	4	3385.3
256	64	5.5	2.3	1	1560.3
128	32	0	2.3	2	1879.8
128	64	0.8	1.6	3	1318
256	64	2.4	2.3	0	2488.5
128	32	4.7	2.3	2	2238.8
256	32	1.6	3.2	3	1860.3
128	64	3.9	1.6	1	1692.8
128	64	5.5	1.6	0	1501.3
128	64	0	1.6	0	1349.8
256	32	3.1	3.2	8	3213.5
256	64	3.9	2.3	2	2121.8
128	64	4.7	1.6	0	1685.3
256	64	0	2.3	1	1751.3
256	32	4.7	3.2	2	4298
256	32	2.4	3.2	4	2784.3
256	32	0	3.2	6	3568.5
128	32	5.5	2.3	0	2238.8
128	64	1.6	1.6	0	1915
256	32	0.8	3.2	3	3171

128	32	3.9	2.3	1	2102
128	64	3.1	1.6	2	1435
256	32	5.5	3.2	3	2671.5
128	32	2.4	2.3	2	2230.5
128	32	3.1	2.3	5	2211.5
128	32	0.8	2.3	1	2168.5
256	32	3.9	3.2	7	2500
128	64	2.4	1.6	0	1630
256	64	4.7	2.3	0	2028.5

Participant 18:

A	W	R	ID	ERR	MT
128	64	0.8	1.6	1	7370.8
256	64	1.6	2.3	3	2000.8
256	64	3.1	2.3	14	3042
256	32	1.6	3.2	7	2277.5
128	32	1.6	2.3	9	1813.8
256	64	3.9	2.3	24	1696.5
128	32	5.5	2.3	4	2359.3
128	64	4.7	1.6	1	2242.3
256	32	0	3.2	7	2831.3
256	64	5.5	2.3	5	1708.3
256	64	4.7	2.3	5	2031.8
256	32	3.1	3.2	18	3030.5
128	32	0.8	2.3	0	1887.8
256	32	5.5	3.2	10	2605
256	32	0.8	3.2	3	2780.5
128	64	3.9	1.6	3	1353.3
128	32	3.1	2.3	2	2242.3
128	64	2.4	1.6	2	1587.3
128	64	5.5	1.6	0	1669.8
256	64	0	2.3	1	1419.8
128	64	1.6	1.6	1	2172.3
128	32	0	2.3	5	2691.3
256	32	2.4	3.2	4	2051.5
128	64	0	1.6	0	1361
256	32	3.9	3.2	13	3003
128	32	2.4	2.3	8	2269.5
256	32	4.7	3.2	5	3471
128	32	4.7	2.3	4	1813.5
128	64	3.1	1.6	1	1661
128	32	3.9	2.3	0	2145
256	64	2.4	2.3	7	1794
256	64	0.8	2.3	4	1485.8

Participant 19:

A	W	R	ID	ERR	MT
256	32	3.1	3.2	1	2612.8
128	32	2.4	2.3	1	1298.3
256	32	0.8	3.2	5	1306.3
128	64	0	1.6	0	1119
128	32	4.7	2.3	3	1805.5
256	32	3.9	3.2	2	2710.8
128	32	3.9	2.3	1	1497.8
128	64	0.8	1.6	0	1813.3
128	64	3.1	1.6	1	1224.5
128	64	4.7	1.6	4	1572
256	64	0.8	2.3	9	1326
128	64	5.5	1.6	0	1259.3
128	32	0.8	2.3	4	1919
256	64	5.5	2.3	1	2008.5
128	32	1.6	2.3	2	1903.5
256	64	3.9	2.3	1	3350.3
256	64	4.7	2.3	2	1689
128	64	1.6	1.6	1	1306.3

256	32	5.5	3.2	5	1954
256	64	3.1	2.3	1	2573.8
128	32	0	2.3	0	2729.5
256	64	0	2.3	0	2148.8
128	32	3.1	2.3	1	2008.5
256	64	2.4	2.3	1	1825
128	32	5.5	2.3	4	1875.8
256	32	4.7	3.2	3	2644.3
128	64	2.4	1.6	0	1255.8
256	32	1.6	3.2	1	1665.5
256	32	0	3.2	0	2780.5
256	32	2.4	3.2	1	1840.5
128	64	3.9	1.6	0	1282.8
256	64	1.6	2.3	1	1910.8

Participant 20:

A	W	R	ID	ERR	MT
256	32	1.6	3.2	5	2683.3
256	32	5.5	3.2	5	2121.8
256	32	3.9	3.2	2	1860.3
256	64	1.6	2.3	3	1548.3
128	32	1.6	2.3	3	2418
128	32	4.7	2.3	2	2121.5
256	32	2.4	3.2	7	2078.5
256	32	3.1	3.2	9	5373.5
128	32	0	2.3	8	2835.3
256	64	3.9	2.3	2	2690.8
128	64	5.5	1.6	2	1895.3
128	64	0	1.6	0	2211
256	32	0	3.2	1	2211
256	64	2.4	2.3	0	1758.8
128	64	1.6	1.6	0	2008.5
128	32	0.8	2.3	2	2351.8
128	32	2.4	2.3	1	2488.3
128	64	0.8	1.6	1	2005
256	64	3.1	2.3	2	2617
128	64	3.9	1.6	0	1598.8
256	32	4.7	3.2	4	1844.5
256	64	0	2.3	0	1848.3
128	32	5.5	2.3	4	1899.5
256	32	0.8	3.2	2	3436
256	64	5.5	2.3	0	1525.3
256	64	4.7	2.3	1	1868
128	32	3.1	2.3	0	1832.8
128	64	2.4	1.6	1	1610.5
128	64	3.1	1.6	1	1731.8
256	64	0.8	2.3	2	1642.5
128	32	3.9	2.3	6	2589.5
128	64	4.7	1.6	1	1302.3

Appendix D: Posture raw data (From rear video camera, LMRC)

In degrees:

Participant	Gender	LB	LE	RB	RE
3	F	50	50	60	30
3	F	50	75	30	0
3	F	50	60	35	0
3	F	45	60	25	0
3	F	50	90	30	0
3	F	50	45	30	0
3	F	60	0	30	40
3	F	50	60	30	20
4	F	40	30	35	30
4	F	20	0	20	30
4	F	10	5	20	10
4	F	30	45	40	30
4	F	5	10	20	20
4	F	20	0	30	30
4	F	5	60	10	30
4	F	20	5	30	50
5	M	35	60	40	40
5	M	40	70	50	80
5	M	30	30	40	50
5	M	30	60	50	80
5	M	20	15	55	40
5	M	40	30	60	40
5	M	20	50	50	30
5	M	40	0	50	20
6	F	30	20	20	0
6	F	20	40	10	30
6	F	30	35	20	50
6	F	30	40	30	40
6	F	20	10	30	20
6	F	25	40	40	60
6	F	20	40	15	50
6	F	20	20	10	0
7	M	20	40	30	20
7	M	20	20	20	20
7	M	20	25	35	50
7	M	20	15	30	20
7	M	25	30	30	25
7	M	25	5	20	5
7	M	15	5	40	30
7	M	20	5	30	40
8	M	5	20	0	5
8	M	0	0	0	5
8	M	5	5	0	5
8	M	0	5	10	10
8	M	0	0	0	5
8	M	5	10	20	20
8	M	0	0	20	10
8	M	0	0	10	30
9	M	50	20	50	40
9	M	40	50	50	60
9	M	35	40	70	80
9	M	30	25	35	75
9	M	30	20	65	85
9	M	40	35	70	60
9	M	0	10	40	50
9	M	30	30	70	75
10	M	10	30	5	20
10	M	0	0	0	20
10	M	0	90	0	40
10	M	30	10	30	20
10	M	20	20	75	20

10	M	0	40	5	80
10	M	30	5	0	80
10	M	10	32	20	33
11	M	20	20	50	40
11	M	20	60	40	30
11	M	30	90	50	40
11	M	25	0	20	50
11	M	20	40	50	25
11	M	80	90	70	60
11	M	30	30	60	80
11	M	70	95	80	60
12	F	20	0	30	20
12	F	10	10	15	20
12	F	25	30	30	60
12	F	15	40	30	30
12	F	15	20	20	20
12	F	20	15	20	10
12	F	20	10	15	20
12	F	20	15	20	15
13	F	40	90	25	30
13	F	90	90	40	40
13	F	60	90	40	30
13	F	40	30	30	60
13	F	35	65	30	30
13	F	45	60	20	30
13	F	0	0	20	20
13	F	20	10	20	50
15	F	5	0	20	30
15	F	20	70	30	20
15	F	60	90	15	10
15	F	45	80	20	10
15	F	60	35	40	40
15	F	65	5	15	20
15	F	20	0	30	40
15	F	60	0	30	40
16	M	0	40	10	30
16	M	0	0	10	20
16	M	20	5	0	5
16	M	0	30	15	0
16	M	5	0	20	10
16	M	0	20	30	40
16	M	0	0	0	30
16	M	0	30	40	40
17	M	30	40	20	30
17	M	35	30	45	60
17	M	20	50	40	30
17	M	40	20	30	35
17	M	40	15	50	60
17	M	50	30	45	80
17	M	40	50	45	70
17	M	40	40	30	30
18	M	40	40	30	30
18	M	25	50	20	40
18	M	30	45	0	0
18	M	25	35	20	15
18	M	0	0	5	10
18	M	0	0	10	30
18	M	0	0	20	10
18	M	0	50	0	0
19	F	20	35	20	30
19	F	30	50	10	10
19	F	30	30	0	0
19	F	30	20	0	50
19	F	40	20	0	0
19	F	30	80	10	30
19	F	0	0	5	30

19	F	30	20	30	40
20	F	30	60	20	70
20	F	20	40	10	20
20	F	50	10	20	0
20	F	50	80	30	60
20	F	80	80	30	50
20	F	50	30	40	30
20	F	30	20	10	0
20	F	30	30	10	50

LB: Left shoulder abduction (Beginning angle)
LE: Left shoulder abduction (Ending angle)
RB: Right shoulder abduction (Beginning angle)
RE: Right shoulder abduction (Ending angle)

Appendix E: Posture raw data (From rear video camera, RMLC)

In degrees:

Participant	Gender	LB	LE	RB	RE
3	F	50	0	40	60
3	F	40	80	10	0
3	F	30	70	20	10
3	F	55	65	0	0
3	F	30	25	40	0
3	F	50	55	40	20
3	F	45	90	40	10
3	F	35	60	20	10
4	F	25	20	50	40
4	F	20	15	45	40
4	F	30	20	60	80
4	F	20	10	40	50
4	F	40	0	20	30
4	F	20	0	30	30
4	F	20	0	40	10
4	F	20	0	40	30
5	M	10	0	40	60
5	M	30	0	40	70
5	M	20	0	40	60
5	M	20	0	50	30
5	M	20	0	50	40
5	M	20	0	20	20
5	M	30	0	50	30
5	M	60	0	70	60
6	F	30	10	30	40
6	F	40	50	40	40
6	F	0	0	25	0
6	F	40	50	30	30
6	F	50	0	60	60
6	F	40	60	30	20
6	F	70	10	50	50
6	F	30	70	30	0
7	M	60	70	50	70
7	M	30	30	30	40
7	M	40	60	40	10
7	M	40	40	30	30
7	M	30	30	40	30
7	M	20	45	50	40
7	M	20	60	40	20
7	M	50	50	50	60
8	M	0	0	10	10
8	M	0	0	20	20
8	M	0	0	10	50
8	M	0	0	10	0
8	M	0	0	10	10
8	M	5	10	10	0
8	M	0	0	20	40
8	M	0	0	30	20
9	M	30	30	30	25
9	M	20	30	30	20
9	M	10	20	20	30
9	M	40	40	40	30
9	M	60	65	10	0
9	M	60	50	75	80
9	M	25	50	20	20
9	M	50	50	20	20
10	M	30	30	60	20
10	M	10	20	30	30
10	M	0	20	30	30
10	M	10	20	0	0

10	M	10	20	50	50
10	M	0	60	20	60
10	M	10	20	30	10
10	M	15	30	40	10
11	M	60	60	70	60
11	M	40	30	50	0
11	M	10	10	50	50
11	M	10	20	50	0
11	M	30	20	80	60
11	M	60	60	20	10
11	M	20	50	30	30
11	M	10	30	20	20
12	F	40	40	30	30
12	F	20	10	50	50
12	F	15	20	50	50
12	F	10	5	50	50
12	F	20	25	40	40
12	F	10	20	60	50
12	F	20	20	70	70
12	F	20	10	50	50
13	F	30	40	30	20
13	F	20	10	60	20
13	F	30	0	50	30
13	F	20	0	30	20
13	F	20	20	70	50
13	F	20	20	50	70
13	F	20	10	25	50
13	F	20	20	50	50
15	F	20	20	30	40
15	F	10	30	30	25
15	F	0	0	0	20
15	F	10	20	30	40
15	F	10	0	20	0
15	F	10	0	30	30
15	F	0	0	20	30
15	F	0	10	30	20
16	M	0	0	0	0
16	M	0	0	10	20
16	M	0	0	0	40
16	M	0	0	0	0
16	M	0	5	0	0
16	M	0	0	0	0
16	M	0	0	20	10
16	M	0	10	0	0
17	M	25	25	20	10
17	M	30	30	20	30
17	M	40	35	30	30
17	M	30	30	30	10
17	M	30	40	0	0
17	M	25	30	20	20
17	M	30	0	30	20
17	M	40	30	80	80
18	M	40	40	0	0
18	M	0	0	0	0
18	M	0	10	0	30
18	M	0	10	0	0
18	M	0	10	0	0
18	M	10	20	10	0
18	M	0	5	0	0
18	M	10	40	0	0
19	F	30	20	20	50
19	F	10	30	10	0
19	F	10	20	0	0
19	F	30	40	60	60
19	F	20	30	0	0
19	F	30	40	0	0

19	F	50	40	10	80
19	F	25	30	15	25
20	F	60	50	50	70
20	F	50	5	50	10
20	F	70	0	30	40
20	F	40	60	60	30
20	F	50	0	30	30
20	F	60	0	30	70
20	F	70	40	70	40
20	F	70	60	50	50

LB: Left shoulder abduction (Beginning angle)
LE: Left shoulder abduction (Ending angle)
RB: Right shoulder abduction (Beginning angle)
RE: Right shoulder abduction (Ending angle)

Appendix F: Posture raw data (From left video camera, LMRC)

In degrees:

Participant	Gender	AB	AE	BB	BE	CB	CE
3	F	40	40	85	90	150	140
3	F	30	70	80	100	150	150
3	F	60	60	80	100	150	150
3	F	70	30	100	100	160	160
3	F	70	50	110	110	150	160
3	F	60	50	90	80	160	160
3	F	70	20	80	80	160	150
3	F	70	80	100	120	160	150
4	F	80	70	90	80	160	160
4	F	30	40	60	75	160	160
4	F	40	20	60	60	160	160
4	F	20	10	70	80	160	150
4	F	0	70	60	80	150	160
4	F	20	80	50	90	160	150
4	F	0	0	40	40	160	160
4	F	40	40	80	80	170	170
5	M	10	60	90	120	140	140
5	M	10	10	90	90	150	150
5	M	10	5	100	90	140	155
5	M	10	5	90	100	150	160
5	M	10	10	90	90	140	140
5	M	10	0	90	80	130	130
5	M	10	0	80	60	135	120
5	M	10	60	80	110	140	130
6	F	20	50	60	70	150	140
6	F	30	20	60	70	140	130
6	F	30	50	80	85	140	125
6	F	50	40	70	80	140	150
6	F	40	20	70	70	140	130
6	F	40	50	70	80	150	150
6	F	30	50	80	70	140	140
6	F	40	50	70	80	150	150
7	M	50	50	80	100	150	160
7	M	30	10	80	60	150	150
7	M	20	50	60	70	130	150
7	M	30	30	70	70	130	125
7	M	50	40	90	80	120	140
7	M	20	50	60	80	140	120
7	M	20	80	70	100	130	130
7	M	30	80	80	110	130	130
8	M	30	30	80	80	140	140
8	M	30	30	70	70	150	155
8	M	30	70	80	90	170	160
8	M	20	30	70	80	170	170
8	M	30	30	80	70	160	170
8	M	30	30	100	90	160	160
8	M	30	60	80	80	150	150
8	M	10	60	70	70	130	130
9	M	60	80	100	110	130	130
9	M	80	70	110	130	140	150
9	M	60	50	95	95	140	140
9	M	70	50	110	120	150	150
9	M	70	70	110	100	150	140
9	M	70	60	110	100	130	150
9	M	50	80	85	90	150	140
9	M	60	50	110	100	150	150
10	M	30	80	80	100	140	130
10	M	30	50	90	100	140	130
10	M	20	85	80	100	130	130
10	M	40	40	90	90	140	140
10	M	40	70	80	100	140	130

10	M	40	30	80	90	130	140
10	M	10	70	90	90	130	140
10	M	40	40	75	70	150	150
11	M	50	70	100	110	140	130
11	M	70	60	90	90	130	130
11	M	60	80	90	80	110	110
11	M	80	60	90	90	110	110
11	M	70	30	100	90	100	100
11	M	60	100	90	110	90	90
11	M	80	60	100	90	110	110
11	M	60	40	90	80	120	100
12	F	30	60	50	80	150	160
12	F	20	40	60	40	160	160
12	F	30	30	50	50	170	170
12	F	70	60	80	80	170	170
12	F	30	70	80	60	170	170
12	F	20	20	60	50	170	170
12	F	40	70	70	70	180	180
12	F	30	70	70	60	180	180
13	F	80	80	130	120	170	160
13	F	80	80	140	140	180	180
13	F	80	90	140	140	180	180
13	F	80	90	140	140	180	180
13	F	70	80	130	130	180	180
13	F	70	80	110	110	180	170
13	F	70	70	110	110	180	170
13	F	70	60	110	110	180	180
14	F	20	30	80	80	150	130
14	F	20	20	60	70	140	140
14	F	30	20	80	70	130	130
14	F	70	30	80	80	120	120
14	F	20	80	80	90	140	130
14	F	20	40	90	80	130	170
14	F	20	10	80	60	120	130
14	F	10	50	70	100	130	130
15	F	60	70	70	60	170	170
15	F	80	20	90	80	170	140
15	F	20	90	80	100	160	170
15	F	30	80	80	110	140	140
15	F	30	60	90	80	150	140
15	F	70	90	70	110	160	150
15	F	50	70	100	90	150	170
15	F	20	60	80	70	160	160
16	M	20	60	70	90	150	140
16	M	40	10	90	60	130	140
16	M	30	20	60	70	140	120
16	M	20	60	70	100	140	140
16	M	30	60	80	80	130	150
16	M	40	30	80	70	140	170
16	M	40	40	80	80	140	130
16	M	30	10	70	70	140	150
17	M	40	30	80	70	140	150
17	M	20	50	70	70	140	150
17	M	60	70	90	50	140	140
17	M	30	20	80	80	140	140
17	M	40	60	80	60	140	140
17	M	60	50	70	70	150	140
17	M	50	30	60	70	130	150
17	M	20	40	50	50	140	150
18	M	20	60	60	90	140	130
18	M	20	40	80	50	130	130
18	M	20	20	60	70	140	210
18	M	20	20	60	70	120	180
18	M	20	70	80	50	150	130
18	M	60	40	80	80	150	140
18	M	30	20	60	60	140	140

18	M	20	40	60	60	140	140
19	F	50	0	100	60	140	130
19	F	50	40	80	80	130	130
19	F	50	55	80	90	140	130
19	F	60	10	90	60	140	130
19	F	40	10	70	90	140	140
19	F	60	20	70	60	140	130
19	F	50	60	80	90	130	120
19	F	40	70	80	70	130	130
20	F	20	40	40	30	180	170
20	F	30	30	60	80	170	170
20	F	30	0	60	60	170	160
20	F	50	20	60	60	150	140
20	F	40	0	80	100	150	150
20	F	40	30	50	50	160	150
20	F	40	0	70	80	140	140
20	F	40	0	70	50	130	140

AB: Left shoulder flexion (Beginning angle)
AE: Left shoulder flexion (Ending angle)
BB: Left elbow flexion (Beginning angle)
BE: Left elbow flexion (Ending angle)
CB: Left wrist flexion (Beginning angle)
CE: Left wrist flexion (Ending angle)

Appendix G: Posture raw data (From left video camera, RMLC)

In degrees:

Participant	Gender	AB	AE	BB	BE	CB	CE
3	F	60	80	60	180	160	150
3	F	0	20	30	110	150	180
3	F	10	60	60	180	150	180
3	F	0	60	90	180	180	180
3	F	10	70	40	180	140	180
3	F	40	70	50	180	180	210
3	F	10	70	50	180	150	200
3	F	50	70	70	170	180	180
4	F	50	50	90	140	130	120
4	F	30	60	80	140	140	120
4	F	30	50	90	120	140	130
4	F	30	30	80	100	140	140
4	F	10	30	60	110	150	130
4	F	20	40	70	110	150	140
4	F	20	30	60	160	140	110
4	F	0	60	60	140	150	120
5	M	30	90	80	180	140	120
5	M	30	100	70	180	130	110
5	M	30	90	70	180	150	120
5	M	30	90	70	180	140	110
5	M	30	90	110	180	130	120
5	M	30	90	80	180	140	120
5	M	30	90	80	180	130	120
5	M	10	100	70	180	140	150
6	F	30	40	80	90	120	240
6	F	10	10	60	60	140	240
6	F	0	0	50	60	130	240
6	F	30	120	60	180	140	110
6	F	40	60	60	90	130	210
6	F	70	80	90	120	130	130
6	F	40	90	80	170	130	130
6	F	60	110	90	180	120	120
7	M	0	70	50	130	120	220
7	M	0	50	60	100	130	180
7	M	0	60	50	90	120	220
7	M	0	20	40	60	120	140
7	M	0	10	60	70	130	210
7	M	10	50	60	100	130	180
7	M	0	90	60	170	130	180
7	M	0	80	40	160	130	170
8	M	30	40	70	100	180	210
8	M	30	50	50	50	180	230
8	M	20	30	50	30	180	180
8	M	30	30	50	70	180	180
8	M	10	20	40	80	180	200
8	M	20	20	60	80	220	200
8	M	30	30	50	90	180	210
8	M	20	30	60	80	180	200
9	M	60	110	100	140	140	150
9	M	60	80	100	120	140	140
9	M	80	80	90	130	140	150
9	M	70	70	80	100	150	180
9	M	60	50	70	110	170	180
9	M	70	70	60	120	130	180
9	M	60	60	70	80	160	140
9	M	60	80	70	130	140	210
10	M	60	70	70	150	150	180
10	M	70	30	70	110	150	210
10	M	10	50	30	50	140	210
10	M	0	0	50	80	180	180
10	M	0	70	50	70	180	180

10	M	10	70	80	150	150	180
10	M	0	100	60	170	180	180
10	M	30	70	60	140	140	200
11	M	70	70	90	130	150	270
11	M	40	70	60	120	140	270
11	M	50	70	60	110	150	270
11	M	40	80	70	120	180	270
11	M	20	30	60	70	140	270
11	M	50	80	70	120	160	270
11	M	30	40	60	100	180	270
11	M	30	60	60	110	140	270
12	F	40	40	50	110	140	180
12	F	50	30	80	120	120	180
12	F	0	10	40	90	130	200
12	F	0	20	50	110	160	190
12	F	40	10	40	70	130	180
12	F	40	60	40	55	140	160
12	F	20	30	60	60	180	180
12	F	70	20	50	70	130	180
13	F	0	90	30	150	140	220
13	F	30	60	50	90	140	180
13	F	70	100	60	180	150	180
13	F	30	60	50	130	140	210
13	F	60	80	80	140	130	180
13	F	0	60	50	110	130	180
13	F	70	80	50	140	130	180
13	F	0	30	50	110	130	210
14	F	20	10	60	50	140	120
14	F	10	10	50	110	120	180
14	F	10	10	60	60	130	230
14	F	10	10	70	90	130	180
14	F	0	0	80	90	130	180
14	F	0	0	60	80	140	210
14	F	10	10	60	70	130	240
14	F	10	10	60	60	130	240
15	F	30	90	40	180	180	180
15	F	20	70	30	180	150	180
15	F	20	70	30	150	160	180
15	F	20	70	40	180	160	180
15	F	20	70	30	150	150	130
15	F	20	0	30	90	140	180
15	F	0	10	40	70	140	220
15	F	20	70	30	140	140	200
16	M	0	10	30	60	120	230
16	M	10	20	50	70	130	240
16	M	20	20	70	70	180	260
16	M	10	20	50	90	130	260
16	M	0	20	60	90	130	230
16	M	0	0	50	60	150	250
16	M	0	0	60	60	130	250
16	M	40	50	60	150	110	220
17	M	30	80	70	170	130	150
17	M	30	30	70	120	120	250
17	M	20	20	60	70	140	250
17	M	30	10	60	80	120	240
17	M	0	10	70	130	140	250
17	M	20	30	60	140	130	200
17	M	20	30	50	160	140	180
17	M	0	0	40	130	130	210
18	M	10	10	20	70	140	230
18	M	10	10	20	80	110	240
18	M	10	10	40	80	130	250
18	M	10	10	30	40	170	220
18	M	10	10	40	50	130	220
18	M	10	10	30	70	150	210
18	M	10	10	60	100	150	220

18	M	10	10	20	60	110	180
19	F	30	40	90	130	130	180
19	F	30	20	60	100	140	180
19	F	10	10	50	90	130	180
19	F	10	40	50	110	130	180
19	F	0	10	60	100	130	180
19	F	10	10	60	100	150	180
19	F	10	40	50	110	130	180
19	F	10	10	70	100	140	180
20	F	30	30	70	130	180	180
20	F	20	20	60	110	180	180
20	F	40	100	70	180	140	110
20	F	40	100	80	180	140	110
20	F	50	90	110	180	130	110
20	F	20	80	70	150	130	130
20	F	30	80	80	150	160	120
20	F	20	80	70	150	180	180

AB: Left shoulder flexion (Beginning angle)
AE: Left shoulder flexion (Ending angle)
BB: Left elbow flexion (Beginning angle)
BE: Left elbow flexion (Ending angle)
CB: Left wrist flexion (Beginning angle)
CE: Left wrist flexion (Ending angle)

Appendix H: Posture raw data (From right video camera, LMRC)

In degrees:

Participant	Gender	AB	AE	BB	BE	CB	CE
3	F	20	80	70	150	130	180
3	F	5	90	50	180	130	180
3	F	5	80	30	170	120	170
3	F	5	80	60	160	130	170
3	F	20	60	60	180	140	180
3	F	30	60	70	170	130	180
3	F	5	80	50	160	140	170
3	F	10	80	80	160	180	180
4	F	40	40	50	110	140	150
4	F	40	50	80	110	130	150
4	F	50	40	80	110	130	160
4	F	30	50	50	110	140	140
4	F	40	50	70	130	130	130
4	F	60	70	100	160	130	130
4	F	40	40	70	70	140	160
4	F	40	40	70	120	130	150
5	M	20	100	70	170	110	130
5	M	30	90	90	180	130	180
5	M	30	100	100	160	130	130
5	M	30	90	80	180	140	150
5	M	30	90	80	180	140	150
5	M	20	110	80	180	150	140
5	M	10	90	70	180	140	170
5	M	20	90	70	180	140	170
6	F	30	90	70	180	120	120
6	F	30	100	60	180	130	110
6	F	20	80	60	140	110	120
6	F	10	90	70	180	110	120
6	F	60	90	60	150	140	180
6	F	30	90	70	170	130	130
6	F	20	70	60	110	150	210
6	F	40	100	70	180	140	120
7	M	40	90	70	130	140	220
7	M	30	60	70	100	130	180
7	M	40	90	70	130	140	220
7	M	50	60	60	80	120	210
7	M	80	90	80	130	90	220
7	M	-5	80	10	130	130	220
7	M	40	40	70	80	130	220
7	M	40	50	70	80	120	240
8	M	20	60	80	100	120	200
8	M	40	60	60	110	130	200
8	M	0	0	50	60	130	190
8	M	20	30	70	90	150	190
8	M	0	30	70	90	180	180
8	M	50	80	60	130	150	210
8	M	10	30	60	90	180	200
8	M	30	60	70	130	120	200
9	M	50	60	70	110	140	180
9	M	70	60	100	100	180	180
9	M	80	50	90	100	140	180
9	M	90	80	90	120	150	180
9	M	100	80	110	110	130	180
9	M	0	0	50	70	130	180
9	M	80	80	90	120	140	180
9	M	80	80	110	130	150	200
10	M	10	100	60	180	140	130
10	M	40	90	80	180	140	130
10	M	60	90	80	180	110	110
10	M	0	110	90	180	140	110
10	M	0	100	90	180	140	110

10	M	0	90	40	180	180	180
10	M	10	110	40	180	130	180
10	M	0	90	100	180	130	160
11	M	30	80	80	110	140	180
11	M	70	40	60	100	170	220
11	M	70	50	60	100	120	210
11	M	10	30	60	90	180	220
11	M	80	50	50	100	110	180
11	M	50	80	60	130	180	270
11	M	50	70	50	120	180	270
11	M	60	70	70	110	140	270
12	F	10	50	40	130	120	180
12	F	60	30	50	130	130	150
12	F	30	50	50	140	110	170
12	F	50	10	40	110	130	180
12	F	50	10	40	90	110	180
12	F	40	20	40	80	150	210
12	F	10	10	30	80	100	200
12	F	0	10	70	70	180	180
13	F	5	10	30	90	120	180
13	F	40	70	70	120	140	140
13	F	0	50	80	110	140	180
13	F	0	70	60	110	140	140
13	F	0	50	120	110	130	180
13	F	0	50	60	110	100	180
13	F	0	0	50	90	140	180
13	F	0	0	50	90	110	180
14	F	50	20	80	110	120	130
14	F	10	10	60	80	130	130
14	F	10	150	60	100	130	130
14	F	0	10	60	80	130	130
14	F	0	10	70	100	130	150
14	F	10	30	60	70	140	140
14	F	10	15	70	100	130	130
14	F	5	60	60	120	130	130
15	F	50	50	80	110	180	180
15	F	40	40	80	80	150	180
15	F	50	30	80	110	140	210
15	F	40	40	60	80	180	230
15	F	30	20	60	60	180	210
15	F	10	0	40	100	180	260
15	F	0	0	20	100	180	270
15	F	0	0	30	30	180	250
16	M	0	70	60	150	120	160
16	M	0	70	60	180	120	150
16	M	0	10	50	80	120	270
16	M	0	10	70	80	140	200
16	M	0	50	70	110	130	250
16	M	0	60	60	160	180	170
16	M	10	60	60	180	140	180
16	M	30	40	70	130	140	250
17	M	10	20	60	110	130	180
17	M	30	50	70	120	140	180
17	M	50	50	60	120	100	180
17	M	0	10	80	100	180	180
17	M	0	10	60	90	120	180
17	M	0	0	60	100	180	180
17	M	0	10	60	120	180	220
17	M	0	0	50	100	140	180
18	M	60	60	70	120	130	220
18	M	60	50	70	130	130	210
18	M	50	30	70	180	130	180
18	M	30	30	70	70	120	120
18	M	90	50	80	180	180	180
18	M	30	20	60	80	140	240
18	M	0	30	30	180	140	220

18	M	20	40	60	80	180	200
19	F	40	40	90	100	130	150
19	F	20	20	70	90	140	140
19	F	30	50	70	90	120	140
19	F	50	70	70	110	130	130
19	F	60	60	70	110	110	140
19	F	30	60	70	80	130	140
19	F	30	30	70	90	120	130
19	F	20	30	70	90	140	130
20	F	30	50	50	180	170	180
20	F	50	70	70	150	140	180
20	F	20	80	50	160	120	120
20	F	20	70	50	140	120	140
20	F	40	90	80	140	150	180
20	F	40	70	70	140	160	160
20	F	20	80	70	150	140	110
20	F	20	80	80	170	140	120

AB: Right shoulder flexion (Beginning angle)
AE: Right shoulder flexion (Ending angle)
BB: Right elbow flexion (Beginning angle)
BE: Right elbow flexion (Ending angle)
CB: Right wrist flexion (Beginning angle)
CE: Right wrist flexion (Ending angle)

Appendix I: Posture raw data (From right video camera, RMLC)

In degrees:

Participant	Gender	AB	AE	BB	BE	CB	CE
3	F	60	40	110	80	140	140
3	F	30	60	90	100	140	150
3	F	40	40	90	100	140	130
3	F	60	40	90	80	140	140
3	F	50	60	90	100	130	140
3	F	50	40	100	90	140	130
3	F	50	70	100	120	140	130
3	F	40	50	90	90	130	140
4	F	30	20	70	80	140	140
4	F	20	0	70	60	140	130
4	F	10	90	70	130	130	140
4	F	10	20	60	60	140	140
4	F	0	0	70	80	150	170
4	F	20	10	80	60	150	150
4	F	10	-10	70	60	180	140
4	F	40	20	100	70	130	140
5	M	0	40	80	120	160	180
5	M	30	60	90	90	180	180
5	M	10	70	100	100	180	180
5	M	60	10	100	100	170	170
5	M	30	10	110	100	170	170
5	M	20	30	80	80	170	170
5	M	10	70	60	60	170	170
5	M	10	70	60	60	170	170
6	F	30	10	80	60	130	130
6	F	40	70	90	100	120	120
6	F	40	20	90	60	140	120
6	F	20	70	60	80	120	120
6	F	40	10	70	60	120	120
6	F	40	10	50	40	110	110
6	F	30	30	60	60	130	130
6	F	50	50	90	100	120	130
7	M	40	50	110	110	140	140
7	M	70	60	110	110	140	140
7	M	60	40	120	110	120	120
7	M	70	50	120	110	120	120
7	M	60	70	110	120	130	120
7	M	80	90	100	140	120	120
7	M	70	60	110	110	130	140
7	M	60	80	120	130	140	130
8	M	30	25	80	80	140	140
8	M	60	40	80	70	130	130
8	M	70	50	90	80	140	130
8	M	30	40	70	80	130	130
8	M	70	30	80	70	140	140
8	M	50	60	80	70	130	140
8	M	35	20	80	60	160	140
8	M	50	20	80	70	140	170
9	M	30	70	80	70	140	140
9	M	70	30	90	90	130	130
9	M	20	70	90	90	140	140
9	M	60	70	100	90	150	150
9	M	60	60	80	90	150	140
9	M	40	50	80	80	150	150
9	M	50	70	110	100	140	140
9	M	50	40	90	80	140	140
10	M	70	40	100	80	140	130
10	M	30	80	70	80	140	150
10	M	40	80	80	100	160	150
10	M	70	10	85	50	150	140
10	M	30	60	70	70	150	150

10	M	60	70	80	80	150	150
10	M	80	20	90	80	140	160
10	M	40	60	80	80	140	140
11	M	70	90	100	100	190	180
11	M	80	80	100	100	180	180
11	M	80	90	100	110	180	180
11	M	90	90	120	110	180	180
11	M	90	100	120	120	180	180
11	M	80	80	110	110	180	180
11	M	85	70	120	110	180	180
11	M	80	90	130	130	180	180
12	F	50	40	70	60	180	180
12	F	70	70	130	90	170	180
12	F	80	80	150	80	150	170
12	F	50	50	110	80	160	160
12	F	20	10	40	50	170	180
12	F	30	10	60	80	150	160
12	F	50	20	100	60	160	170
12	F	30	10	80	60	180	180
13	F	70	20	90	70	130	130
13	F	60	90	100	130	120	130
13	F	60	70	120	130	120	120
13	F	70	80	110	130	120	130
13	F	70	80	130	120	120	140
13	F	60	90	110	140	130	120
13	F	80	90	130	140	120	120
13	F	70	70	120	110	120	110
14	F	30	30	80	80	140	140
14	F	30	40	70	80	130	130
14	F	20	10	70	80	120	110
14	F	10	10	70	60	130	130
14	F	5	70	60	100	120	130
14	F	10	60	70	90	120	120
14	F	10	10	60	80	120	120
14	F	10	10	60	60	120	120
15	F	10	50	30	50	160	160
15	F	10	20	30	30	160	160
15	F	10	30	30	30	160	180
15	F	30	80	60	80	180	180
15	F	20	40	50	50	160	160
15	F	30	30	60	60	170	180
15	F	30	10	40	40	180	180
15	F	60	50	50	40	150	150
16	M	40	30	90	80	140	140
16	M	30	30	60	60	140	140
16	M	10	70	60	90	140	140
16	M	20	80	80	120	140	140
16	M	40	80	90	130	160	150
16	M	60	10	90	70	150	180
16	M	60	50	100	100	150	150
16	M	70	60	100	90	160	160
17	M	50	20	90	80	140	110
17	M	60	60	110	110	130	110
17	M	40	30	80	90	130	130
17	M	30	60	80	90	130	140
17	M	30	50	80	70	130	130
17	M	30	20	70	60	140	140
17	M	40	50	70	70	150	130
17	M	30	30	70	80	140	130
18	M	10	30	20	70	130	130
18	M	30	20	40	90	130	180
18	M	40	40	70	80	140	130
18	M	40	20	70	50	140	150
18	M	60	80	70	90	150	150
18	M	40	20	80	50	140	140
18	M	30	20	50	60	130	130

18	M	40	30	60	60	140	130
19	F	60	60	110	90	120	130
19	F	70	40	110	100	120	150
19	F	60	80	110	110	120	120
19	F	30	70	70	90	120	130
19	F	50	40	90	90	130	120
19	F	50	80	90	90	130	130
19	F	60	50	90	100	130	130
19	F	50	70	90	90	130	140
20	F	40	20	60	80	130	150
20	F	50	20	80	70	140	130
20	F	50	30	90	70	130	130
20	F	30	50	60	60	140	140
20	F	30	70	60	70	140	100
20	F	50	20	80	50	130	130
20	F	30	70	70	80	140	140
20	F	20	90	70	120	140	140

AB: Right shoulder flexion (Beginning angle)
AE: Right shoulder flexion (Ending angle)
BB: Right elbow flexion (Beginning angle)
BE: Right elbow flexion (Ending angle)
CB: Right wrist flexion (Beginning angle)
CE: Right wrist flexion (Ending angle)

Appendix J: Survey raw data

Participant	Ease of use	Comfort	Enjoyment	Fatigue	LMRC	RMLC
1	3	2	3	1	L	R
2	5	2	4	1	R	L
3	2	1	2	1	L	R
4	3	2	3	2	L	R
5	2	2	4	2	L	L
6	3	3	4	2	L	L
7	4	3	3	3	L	L
8	1	2	2	2	L	R
9	2	2	4	2	L	L
10	4	2	3	2	L	R
11	2	2	3	3	L	R
12	4	4	4	3	L	R
13	4	4	3	3	R	R
14	4	3	4	2	L	R
15	1	1	1	1	L	R
16	1	1	3	1	L	L
17	2	2	4	1	L	Similar
18	2	3	2	2	L	R
19	3	2	4	3	R	R
20	3	3	3	2	L	L

LMRC: For LMRC, which hand is more tired?
RMLC: For RMLC, which hand is more tired?

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