2004

Using rotation cues to aid cursor manipulation with control-display misalignment

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DOI: <https://doi.org/10.31979/etd.vzc3-bcmx>
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USING ROTATION CUES TO AID CURSOR MANIPULATION
WITH CONTROL-DISPLAY MISALIGNMENT

A Thesis

Presented to

The Faculty of the Graduate Program

in Human Factors and Ergonomics

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Thomas G. Lee

August 2004

UMI Number: 1424510

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IN HUMAN FACTORS AND ERGONOMICS

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ABSTRACT

USING ROTATION CUES TO AID CURSOR MANIPULATION WITH CONTROL-DISPLAY MISALIGNMENT

By Thomas G. Lee

This study examined the effectiveness of rotation cues in assisting operators manipulating a cursor while compensating for rotational misalignment between input controls and device output display. Forty right-handed participants carried out simple targeting tasks with a computer trackball while their controls were rotated to create a mismatch with the display they were viewing. Participants' Card Rotations Test scores were used to match participants across the four groups according to their spatial ability. Types of cues in the study included (1) visual, (2) kinesthetic, (3) visual and kinesthetic together, and (4) a control group that did not use any cue. Results indicate that the kinesthetic cue condition produced the shortest path length required to execute targeting movements.

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Introduction

Use of telemanipulation systems continues to grow as technological advances generate potential applications. Currently, a variety of usability issues hinder operators of these systems from achieving a sense of telepresence, i.e., feeling as if they are physically located at the site of the controlled instrument. One particular concern is that occasionally operators are forced to view image displays with coordinate frames that are not matched with the coordinate frame of their input controls. This disparity between control and display is caused by a misorientation of the camera(s) positioned at the site of the remote device being controlled. Typically, some type of partial automation is used to correct for control misalignments, but the need still exists for manual back up in case of a malfunction in the system. For example, the remote manipulator system (RMS) arm on the Space Shuttle Orbiter faltered during a mission, thereby forcing the crew to operate the arm manually, while viewing an image display that was misaligned with their hand controls (Hawley, 1995).

The purpose of this investigation is to examine the effectiveness of rotation cues to assist operators of a telemanipulation system with a rotational misalignment between the input controls and the device output display. Developing techniques that can help operators adapt to these types of misalignments is essential because such conditions can occur in various

teleoperation systems. One possible solution is to develop a technique that includes both hands in the control operation, which could assist the operator who is trying to compensate for a rotated frame of reference.

Guiard (1987) proposed a model for human bimanual control that uses the analogy of the hands as collaborating *abstract motors*, which results in the formation of a kinematic chain. In contrast to the popular viewpoint that the dominant hand is more skilled than the non-dominant hand, he suggests that a division of labor exists between the hands and they complement each other by filling specific roles. The dominant hand executes fine motor movements, while the non-dominant hand provides a postural role. For example, when driving a nail, the non-dominant hand positions the nail, while the dominant hand operates the hammer.

Guiard's model is supported by research that demonstrates a synergistic effect on performance for bimanual control, as compared to unimanual operations. Research also suggests that bimanual control permits participants to map motion of the dominant hand relative to the position of the non-dominant hand (Hinckley, Pausch, & Profitt, 1997). Consequently, bimanual operations provide the operator with a frame of reference, giving the operator additional spatial information otherwise less apparent in unimanual operations.

Ellis, Adelstein, and Welch (2002) tested individuals performing a

simple targeting task while using a stylus and graphics tablet. Results showed that positioning the hand not directly manipulating the stylus, so as to indicate the amount of existing rotational misalignment (termed “kinesthetic cueing”), helped to reduce control disturbances by 64%. Another study employing a kinesthetic cue produced similar results, showing a reduction in path length while performing targeting tasks (Adelstein, Ellis, Smith, & Welch, in press). In this study, a survey of participants’ technical background, (i.e., exposure to mathematics, physics, or engineering), revealed that those with greater exposure to technical training benefited more from the kinesthetic cue. Additionally, individuals with higher technical ratings had shorter path lengths and also waited longer to make their targeting movements than those with lower technical ratings.

As a follow up, the current study will examine the effectiveness of visual rotation cues versus the aforementioned kinesthetic cue in assisting operators performing a simple targeting task. The possibility of an additive effect from using concurrent visual and kinesthetic cues will also be examined.

The correlation reported in the Adelstein, Ellis, Smith, and Welch study between technical background and task performance was derived from an informal survey. Thus, the current study sought to use a more formal, established test, hoping to find a comparable correlation. In order to

determine spatial orientation skills of individuals, the Card Rotations Test from the ETS Kit of Factor-Referenced Cognitive Tests was administered (see Appendix B). The test is made up of two sets of ten problems, with each problem consisting of a row of nine objects. The test requires participants to determine which of the last eight objects in the row are the same or different as the first object. Participants must mentally rotate the last eight objects to determine if they have been simply rotated (same as the first object) or rotated and flipped (different than the first object). This test was chosen because it is believed that the mental rotation of objects is similar to what participants will be required to do in the current experiment. Normative data provided by ETS for the Card Rotations Test, indicates a reliability rating of .87 (Ekstrom, French, Harmon, & Derman, 1976).

Current Experiment

While sitting at a desktop computer, participants will manipulate a cursor (using a trackball) in order to carry out simple targeting tasks. The task will involve moving the cursor from a starting point located in the center of the display, to targets appearing one after another at different locations that are equal in distance from the starting point.

The experiment will test the following two hypotheses:

H1. Participant groups that are provided rotation cues (visual, kinesthetic, and visual and kinesthetic together) will perform better on targeting tasks

than the control group, which will not receive any direct rotation cue. Task performance will be measured by normalized path length, average velocity, and movement time.

H2. Spatial orientation skill determined by participants' scores on the Card Rotations Test will be correlated to performance on targeting tasks based on normalized path length and longer wait times, similar to the findings of a previous study (Adelstein et al, in press) where individuals with greater technical skill waited longer before beginning targeting movements.

Dependent Variables

Dependent measures for the current study will include: (1) Wait Time – the amount of time elapsed from the appearance of a target until the cursor is moved beyond a 3-pixel radius from the starting region over the 100 pixel target distance; (2) Movement Time – amount of time elapsed after leaving the starting region until contact is made with the target; (3) Average Velocity – measured in pixels/second; and (4) Normalized Path Length – the amount of distance traveled from the starting region until contact is made with the target. Each individual in the study will have their own normalization factor that is derived from the average of their path lengths recorded during baseline movements performed prior to the experiment. The normalization factor will be divided into their path lengths to determine the normalized path length.

Method

Participants

The current study included 40 (26 male and 14 female) participants selected from local college students and lab assistants from NASA Ames. All participants were naïve to the purpose of the study. Participants were required to have normal or corrected to normal vision, along with no known neuromotor impairments. The Edinburgh Handedness Inventory was used to determine that all participants were distinctly right-handed (see Appendix C). Participants were paid \$20 for their participation in the study.

Materials

The Card Rotations Test was administered prior to data collection in order to obtain a measure of spatial orientation skills. The study was conducted using a standard desktop computer with the Windows NT operating system. As in previous kinesthetic cueing experiments, a custom computer program written in the C++ language was used for the manual targeting task (Adelstein et al., in press; Ellis et al., 2002). Participants used a Primelogic Off-Table Trackmouse as the input device. This computer trackball device was modified and embedded in the test stand so that it could be operated solely with the index finger of the right hand.

During the kinesthetic cue condition participants used a plastic rectangular (11cm x 7cm x 1cm) box as the cuing object for the left hand. As

shown in Figure 1, both the trackball and the kinesthetic cue were concealed under a cardboard cover to prevent participants from viewing their hands. Participants were seated so that the monitor was at eye level with an eye-to-monitor distance of ~80 cm. At this distance, the cursor subtended a visual angle of $.36^{\circ}$ and the target a visual angle of $.22^{\circ}$. The monitor used was a Samsung 15-inch flat-panel Liquid Crystal Display (LCD) (model: SyncMaster570S) configured to a screen resolution of 1024 x 768.

Procedure

Participants began by reading and signing an informed consent form (see Appendix C). The Edinburgh Handedness Inventory was then administered to ensure that the participants were predominantly right-handed. The participants then took the Card Rotations Test, which consisted of two sets of ten problems. Each set was three minutes in duration, with the participants taking a short break between sets. The Card Rotations Test scores were employed to balance participants according to spatial ability when assigning them into four groups: 1) kinesthetic cueing, 2) visual cueing, 3) kinesthetic and visual cueing combined, and 4) a control group with no rotation cue.

Following the Card Rotations Test, participants were read instructions from a script explaining the targeting task. The participants were then provided with a brief practice period where they performed three blocks of

Figure 1. **Participant performing the targeting task.**

He is using the kinesthetic cue with the left hand, while manipulating the track ball with the right hand. The cardboard concealed both hands from the participant.

targeting movements with no rotation of controls and with no cue. This was followed by a baseline period of five blocks of targeting movements, also with no rotation and no cue. Participants were also instructed to develop a constant movement speed that they would then maintain for the remainder of the experiment. Throughout the study, each block consisted of eight separate target acquisitions.

At this point, participants were informed of the possibility of rotational misalignment between input device and device output display. The participants were also informed that this misalignment may vary between the blocks. The control group, which was not provided with a cue, was instructed to make a normal targeting movement to the first target of that block and determine the direction and degree of rotation from that movement. Detailed instructions were given to each group regarding how to use their particular type of rotation cue. A brief three-block practice session followed during which participants were allowed to try the targeting task with their assigned cue. During the practice session, participants were encouraged to ask the experimenter any questions they might have.

The targeting task required moving a computer trackball with the right index finger to manipulate a cursor, starting from the center of the screen, to 3mm (10 pixels) -diameter circular targets. The targets appeared on the screen 30mm (100 pixels) from the screen's center, one at a time, in

eight canonical directions (0° , 45° , 90° , 135° , 180° , 225° , 270° , and 315°). Each of the eight targets was displayed only once in random order during each experimental block. After the cursor reached an individual target, the target would disappear, the cursor would reappear at the screen's center point, and the next target was displayed.

Each block was presented at one of the five possible input-to-display rotations (0° , $\pm 24^\circ$, or $\pm 54^\circ$). This resulted in 40 unique combinations of target directions and input-to-display rotations. There were three replications of each block, for a total of 120 trials. Within each group of participants, the presentation order of the five input-to-display rotations was varied between participants. A tone sounded to signal the end of a block. Participants were permitted to take breaks between the blocks.

During the kinesthetic cueing condition, participants placed their left hand, with their thumb and index finger 90° apart; against the corner edge of a plastic rectangular (11cm x 7cm x 1cm) box (see Figure 2). The experimenter aligned the box before each block, so that the index finger of the participant's "cueing hand" represented the direction of trackball motion required for straight-up motion on the display screen.

For the visual cueing condition, an arrow appeared and remained in each of the four corners of the display, just outside of the range of the targets.

Figure 2. **Kinesthetic Cue**

The direction that the index finger of the cueing hand is pointing represents the direction the trackball must be manipulated for the cursor to go straightforward.

The arrows, 35mm in length, were oriented so that they could be utilized in the same fashion as an index finger with the kinesthetic cueing condition, thus indicating the straight-ahead input direction. A third subject group received both the kinesthetic cue and the visual cue simultaneously. The fourth group, which received no rotation cue, served as the control group.

Results

A 4 x 3 x 5 (Cue x Repetition x Rotation) mixed-design analysis of variance (ANOVA) was conducted on each of the dependent variables. Data from the first trial of each block was omitted for analysis since the control group was instructed to use the first targeting movement to determine the amount and direction of rotation present. Also, the experiment monitor had to physically place the kinesthetic cue at the beginning of each block. Because of this uncontrolled set-up time, the wait time measurement for the first target when using the kinesthetic cue was not usable.

Cue Data

A between-groups analysis of the cue condition appeared to show partial support of the first research hypothesis that the three groups using a rotation cue would outperform the control group. This analysis showed a main effect across the cue condition for normalized path length, $[F(3,36) = 4.06, p < .05]$. When comparing the ANOVA results of the different cue conditions, the kinesthetic cue condition was the only group showing a

significantly lower normalized path length than the control group, [$F(1,19) = 14.93, p < .001$]. Descriptive statistics of normalized path length for the four cue conditions are shown in Table 1. ANOVA results also revealed that for the different cue conditions, the type of cue used during the targeting movement tasks failed to produce a significant difference for both movement time, $F(3,36) = 1.03, n.s.$ and average velocity, $F(3,36) = 1.45, n.s.$

Practice Effects

Since each participant performed three replications of the five eight-target blocks, it was possible to analyze performance across these three repetitions to check for improved performance as participants gained more experience with the targeting task. Looking at mean normalized path length for the first repetition ($M = 117.64, SD = 24.69$), second repetition ($M = 114.16, SD = 23.17$), and third repetition ($M = 112.57, SD = 21.30$), an improvement in performance was shown with more practice. A within-subjects ANOVA analysis testing for a main effect of repetition revealed a significant difference in normalized path length across the three repetitions, [$F(2,72) = 10.46, p < .01$]. Also, the mean movement time for the first repetition ($M = 1.98\text{sec}, SD = .64\text{sec}$), second repetition ($M = 1.89\text{sec}, SD = .58\text{sec}$), and third repetition ($M = 1.82\text{sec}, SD = .52\text{sec}$) shows a significant decrease in the time needed to complete the targeting task as individuals acquired more practice, [$F(2,72) = 15.56, p < .01$]. No significant practice

Table 1.

Mean and Standard Deviation Scores (in pixels) for normalized path length according to cue type.

<u>Cue Type</u>	<u>Mean</u>	<u>SD</u>	<u><i>n</i></u>
Kinesthetic	106.57	18.59	10
Visual	119.50	24.86	10
Kinesthetic & Visual	115.02	25.07	10
Control	118.08	21.48	10

effects were observed for average velocity during the movements, $F(2,72) = 1.07$, n.s., indicating that participants followed the instruction to develop and maintain a constant movement speed.

Rotation Data

As expected, for all cue conditions, greater control disturbances were found for the larger rotations ($\pm 54^\circ$). Normalized path length [$F(4,144) = 153.12$, $p < .001$], movement time [$F(4,144) = 122.64$, $p < .001$], and average velocity [$F(4,144) = 20.19$, $p < .001$] all showed a main effect for rotation. During trials with large input-to-display rotations ($\pm 54^\circ$), participants displayed a reduction in path length with each successive repetition. However, this effect was not as noticeable during trials with smaller input-to-display rotations ($\pm 24^\circ$ or 0°). A comparison of improvement between large and small display rotations is shown in Figure 3. The ANOVA analysis for these findings indeed showed an interaction effect for repetition and rotation, [$F(8,288) = 2.68$, $p < .01$].

Card Rotations Test

The second research hypothesis that proposed a positive correlation between performance on the Card Rotations Test and normalized path length was not supported by a correlation analysis of the data ($R^2 = .01$, n.s.). Also, a non-significant correlation was found between participants' Card Rotations Test scores and wait time ($R^2 = .009$, n.s.).

Figure 3. Interaction between rotation and repetition

Points represent the mean normalized path length for each of the five possible rotations separated by the first repetition and third repetition.

Vertical lines depict standard errors of the means. Greater control disturbances for the larger rotations ($\pm 54^\circ$) are illustrated by a large increase in normalized path length. Also, more improvement is shown among the larger rotations from repetition 1 to repetition 3.

Additionally, the grouping of participants across conditions according to their performance on the Card Rotations Test produced four separate groups with a non-significant difference in mean test score, which was supported statistically, $F(3,36) = .09$, n.s.

Cue Effects Within Blocks

A $4 \times 7 \times 3 \times 5$ (Cue x Target Number x Repetition x Rotation) mixed ANOVA was run for the last seven targets of each eight-target block, using target number as a separate factor to determine whether performance improved during the course of a block. Results of the analysis indicate a non-significant result for interaction between cue and target number, $F(18,216) = 1.14$, n.s.

Separate $4 \times 3 \times 5$ (Cue x Repetition x Rotation) mixed ANOVAs were then run using data from the first three scored targets of each block and then for the last three targets of each block (trials 2-4 versus trials 6-8). The ANOVAs were run in an effort to reveal at what point during blocks that participants were able to benefit from their condition's cue. Results show a main effect across cue conditions for normalized path length in the first three trials of each block [$F(3,36) = 5.51$, $p < .01$], but not in the last three trials of each block $F(3,36) = 2.00$, n.s., suggesting that the effect of cue was stronger during the beginning of each block.

Additionally, the effect of repetition was present only during the first three trials of each block, [$F(2,72) = 13.12, p < .001$], while the last three trials of each block showed non-significant effects $F(2,72) = 2.59, n.s.$

Normalization effects

Post experiment feedback indicated that several participants complained that the trackball was too difficult to control, due to the size of the trackball or because of their lack of experience using that type of control device. Additionally, the data showed extremely erratic cursor movements indicating that some participants may not have understood the task they were supposed to do. In order to confirm that these participants were not skewing the data, a $4 \times 3 \times 5$ (Cue x Repetition x Rotation) mixed ANOVA was run similar to the initial analysis after removing the two worst performing participants from each cue condition, based on raw path length. The ANOVA results show that the effect for cue on normalized path length disappears if the two worst participants are removed from each group, $F(3,28) = 0.71, n.s.$

It is possible that the original path length differences found between cue conditions were just an artifact of the normalization process. The normalization process could potentially skew data if there is a large difference between a participant's raw path lengths during the baseline as compared to during the experiment. A participant's significant improvement

between the baseline and experiment could possibly yield artificially shortened normalized path lengths. Unfortunately, if this occurs it is impossible to be certain exactly what contributed to a participant's improved performance. In the current study, it is unknown whether this normalization process may have erroneously helped to produce the significant differences in path length found between the kinesthetic cue condition and the other cue conditions. Prior to the normalization, raw path length for all cue conditions showed a non-significant difference, $F(3,36) = .40$, n.s.

Discussion

In the current study there were two important findings: 1) the independent variable of cue condition showed significantly shortened normalized path lengths for the kinesthetic condition as compared to the visual, visual and kinesthetic together, and control conditions, and 2) the dependent variables normalized path length and wait time did not correlate with participants' test scores on the Card Rotations Test.

The first research hypothesis stated that groups provided with rotation cues would perform better on targeting tasks than the control group. This hypothesis was only partly supported by the data analysis. As found in previous studies, the kinesthetic cue helped to reduce the path length and movement time required to complete a targeting task. These findings lend support to Guiard's model of human bimanual action where he suggests that

two hands are better than one because the non-dominant hand helps to provide a frame of reference for the dominant hand.

The participants in the condition receiving both the kinesthetic and visual cues were instructed to try to use both cues, but in interviews following the experiment, every participant in that condition reported they were unable to use the two cues simultaneously and preferred to use only the visual cue. This may explain the similarities in overall performance between the group provided both cues and the group provided with only the visual cue. The second research hypothesis proposed a link between Card Rotations Test score and performance in targeting tasks. This hypothesis was not supported by the results of a correlation analysis. The intention of administering the Card Rotations Test was, in comparison to previous studies, to obtain a more formal measurement of the skills believed to be associated with mental coordinate transformations necessary for performing the targeting movements in the presence of control-display rotations. The absence of a correlation between the Card Rotations Test scores and performance on the targeting tasks could be due to the physical manipulation of the trackball involved in the targeting task, something not necessarily being represented by the skills measured by the Card Rotations Test.

Note that by design, the Card Rotations Test is a speeded test where individuals are given a short amount of time to complete many items. It

appears that the speed/accuracy tradeoff in the Card Rotations Test may not be comparable to the speed/accuracy tradeoff in the targeting tasks. While speed may benefit participants by ensuring they will complete more items on the Card Rotations Test, it can be more detrimental during the targeting task due to a different speed/accuracy tradeoff. This may be due to the partial mismatch between the skills required for these two tasks. For the Card Rotations Test, a participant only needs to mentally rotate objects to determine if a match exists. Performing such a task at faster speeds seems to have little penalty, since this task does not require precision movements. For the experiment's targeting task, a participant needs to mentally rotate the input-to-display misalignment and then directly transfer that information to a motor output. This additional task may be where a performance bottleneck occurred, since performing such a task at faster speeds is physically more difficult and thus carries a higher penalty. Perhaps a better comparison to the Card Rotations Test would be a targeting task that only requires the participant to simply indicate the desired movement's direction.

Previous research comparing different input devices showed that a trackball allowed for better performance compared to a trackpad when large control disturbance were present (Adelstein et al, in press). In future research it would be beneficial to further test a variety of input devices that could be used to perform this particular targeting task. Another

consideration is to modify the current trackball device so that the operator is using the thumb rather than the index finger. Several participants in the study reported they were more comfortable and more experienced using a trackball with their thumb and found it awkward to use their index finger.

It is possible that a simple 2-dimensional (2D) display limits this research's external validity since it does not resemble a "real life" situation. The problem of rotational misalignment within 3-dimensional (3D) displays has been investigated (Ellis, Tyler, Kim, & Stark, 1992), but advantages do remain for research using a simpler 2D interface as a precursor to studies with more complicated displays. Erratic cursor movements from some individuals in the current study indicate a struggle to make use of the rotation cue while performing the targeting task with a straightforward 2-D display. It is likely that a 3-D interface will increase the difficulty of navigation and will require an extensive training period for operators. A study in progress by Ellis uses a head-mounted display to create a fully immersive 3-D virtual environment where individuals are required to perform targeting tasks with rotational misalignment between controls and display. Since the kinesthetic cue has been shown to be beneficial in studies using a 2-D display, it will be interesting to see if these effects carry over to an egocentric 3-D display.

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Appendix A
Signed Approval Form

San José State
UNIVERSITY

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**Academic Vice President
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To: Thomas G. Lee
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Mountain View, CA 94043

From: Pam Stacks,
Interim AVP, Graduate Studies & Research

Date: November 1, 2003

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

“Using Cues to Compensate for Rotational Misalignment of
Controls”

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Pam Stacks, Ph.D. immediately. Injury includes but is not limited to bodily harm, psychological trauma, and release of potentially damaging personal information. This approval for the human subjects portion of your project is in effect for one year and data collection beyond November 1, 2004 requires an extension request.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services that the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.

cc: Dr. Kevin Jordan

Appendix B
Card Rotations Test

Name _____

CARD ROTATIONS TEST — S-1 (Rev.)

This is a test of your ability to see differences in figures. Look at the 5 triangle-shaped cards drawn below.

All of these drawings are of the same card, which has been slid around into different positions on the page.

Now look at the 2 cards below:

These two cards are not alike. The first cannot be made to look like the second by sliding it around on the page. It would have to be flipped over or made differently.

Each problem in this test consists of one card on the left of a vertical line and eight cards on the right. You are to decide whether each of the eight cards on the right is the same as or different from the card on the left. Mark the box beside the S if it is the same as the one at the beginning of the row. Mark the box beside the D if it is different from the one at the beginning of the row.

Practice on the following rows. The first row has been correctly marked for you.

B									
		S ☒ D ☐	S ☐ D ☒	S ☒ D ☐	S ☐ D ☒	S ☐ D ☒	S ☐ D ☒	S ☐ D ☒	S ☐ D ☒
C									
		S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐
D									
		S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐

Your score on this test will be the number of items answered correctly minus the number answered incorrectly. Therefore, it will not be to your advantage to guess, unless you have some idea whether the card is the same or different. Work as quickly as you can without sacrificing accuracy.

You will have 3 minutes for each of the two parts of this test. Each part has 1 page. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

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Part 1 (3 minutes)

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

STOP.

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Part 2 (3 minutes)

11.									
	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	
12.									
	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	
13.									
	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	
14.									
	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	
15.									
	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	
16.									
	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	
17.									
	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	
18.									
	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	
19.									
	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	
20.									
	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	S O D O	

DO NOT GO BACK TO PART 1 AND

DO NOT GO ON TO ANY OTHER TEST UNTIL ASKED TO DO SO.

STOP.

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Appendix C

Edinburgh Handedness Inventory

Edinburgh Handedness Inventory

Age _____

Gender _____

ID _____

Have you ever had any tendency towards left handedness?

YES	NO
-----	----

Please indicate your preferences in the use of hands in the following activities by putting “+” marks in the appropriate columns. Where preference is so strong that you would never try to use the other hand unless absolutely forced to, put “++”. In any case to which you are really indifferent put “+” in both columns.

Some of the activities require both hands. In these cases the part of the task or object for which hand preference is wanted is indicated in parenthesis.

Please try to answer all the questions, and only leave a blank if you have no experience at all with the object or task.

		LEFT	RIGHT
1	Writing		
2	Drawing		
3	Throwing		
4	Scissors		
5	Toothbrush		
6	Knife (without fork)		
7	Spoon		
8	Hammer (upper head)		
9	Striking match (match)		
10	Opening box (lid)		
11	Which foot do you prefer to kick with?		
12	Which eye do you use when using one eye?		

L.Q.

Please leave these spaces blank

DECILE

Appendix D
Consent Form

PARTICIPANT CONSENT FORM

Please read completely

Your participation in the following experiment is considered “minimal risk.”

In this experiment you will be asked to use a computer mouse (or other input device) to move a cursor to various targets viewed on a monitor. You will not be allowed to see your hand during these target-pointing responses. After you have practiced this task for a while I will introduce a modification between where you move the trackball and where the cursor goes. Your task is to overcome this conflict and once again be able to move the cursor quickly and accurately to the designated target. As part of the experiment, you may be instructed on how to place your hands in order to assist you in overcoming the mismatch with which you are being confronted.

The aim of this research is to test various means of overcoming mismatches between hand movements and their visual consequences as viewed in visual displays.

We will use your data **anonymously**, along with the data from several other subjects. You will be assigned a number and any data that we collect from you will be affixed to your assigned number rather than your name.

Questions about this research may be addressed to the experimenter **Tom Lee** (650) 604-0827. Complaints about the research may be presented to **Dr. Robert Pellegrini**, Chair of Psychology Department, at (408) 924-5600. Questions about research participants’ rights, or research-related injury may be presented to **Dr. Joseph Pesek**, Associate Academic Vice-President – Graduate Studies & Research (408) 924-2481.

No service of any kind, to which you are otherwise entitled, will be lost or jeopardized if you choose to “not participate” in the study.

The only potential discomfort you may experience is becoming **sleepy** or **tired** from doing a repetitive hand movement task. Please let the experiment monitor know if you want to take a break to stretch, get some fresh air, etc., **at any time**.

Remember that your participation is entirely **voluntary**; you can leave the experiment room and quit the experiment *at any time*, and will be paid for the time you’ve worked up to that point. Finally, we reserve the right to stop using you as a subject, for any reason.

At the time you sign this consent form, you will receive a copy of it for your records, signed and dated by the investigator.

By signing below, you (1) give your consent to be a subject in this experiment, (2) understand this consent form, and (3) certify that you’re at least 18 years of age.

Signature

Date

Investigator’s Signature

Date

Appendix E
Participant Instructions

Instructions for Cursor Experiment

Thank you for participating in this experiment. The experiment should take about a half hour to complete.

Obtain Informed Consent

Edinburgh Inventory

Card Rotations Test

Part I) Practice Period

First, I'm going to explain the task a little bit and then afterwards I'll let you do some practice.

What you will be doing is using a trackball to move a cursor on the computer screen. You'll use the index finger of your right hand to control the trackball. When you are moving the cursor you will not be allowed to look at your hands.

Please place your right hand on the trackball and your left hand on you lap. Beginning at the center of the screen, you will move the cursor to touch the target, which is the smaller circle. Targets will appear, one at a time, in different locations around the starting point. Once you hit the target the cursor will reappear in the center and the next target will appear.

Feel free to ask questions during the practice.

Do Practice movements (batch file "Batch_practice")

Part II) Baseline Period

We want you to develop a comfortable, steady speed of movement that you will be able to maintain. We expect each movement to take 1-2 seconds.

Now we'll have you do five more blocks that will provide us with a baseline. Please try to minimize conversation during this part of the experiment.

Do Baseline movements (batch file “batch_baseline”)

Part III) Explanation of Rotation

During the experiment, you will have to deal with a rotation of the control coordinates. What that means is that when you use the trackball sometimes it will seem like the cursor is moving in a different direction than what you intended. This is because your controls may have been rotated clockwise or counterclockwise an unknown amount, so that they don't match with the display you are seeing. For instance, if you try to move the cursor straight up, it may actually go a little to the left or right of where you intended. **Do you understand?**

Part IV) Explanation of the Cue

No Cue

I'll give you a chance to practice a few blocks, with rotation, before the actual experiment begins. During the first trial of each block you should make a normal targeting movement to determine the amount of rotation.

The rotation will remain the same until the tone signals the end of the block. At that time, you may have a new rotation.

Do practice movements (“batch file “Batch_democue”)

Kinesthetic Cue

Since the rotation makes it much harder to hit the target, we are going to give you a cue that should make it easier.

I would like you to place your left hand in front of you on the table, resting it against the plastic block in a position that we will demonstrate to you. We'll call this your cueing hand. The block will be

rotated either clockwise or counterclockwise, to match the amount of rotation of your controls. The direction the index finger is pointing will represent the direction you need to move the cursor for it to go straight up.

The rotation will remain the same until the tone signals the end of the block. At that time, you may have a new rotation.

I'll give you a chance to practice a few blocks before the actual experiment begins. Feel free to ask questions.

Do practice movements ("batch file "Batch_democue")

Visual Cue

Since the rotation makes it much harder to hit the target, we are going to give you a cue that should make it easier.

You're going to see four arrows located in each corner of the computer screen that will be rotated to match the amount of rotation of the controls. The direction that the arrows are pointing in will represent the direction you will need to move the cursor for it to go straight up.

The rotation will remain the same until the tone signals the end of the block. At that time, you may have a new rotation.

I'll give you a chance to practice a few blocks before the actual experiment begins.

Do practice movements ("batch file "Batch_democue")

Kinesthetic and Visual Cue

Since the rotation makes it much harder to hit the target, we are going to give you a cue that should make it easier.

I would like you to place your left hand in front of you on the table, resting it against the plastic block in a position that we will

demonstrate to you. We'll call this your cueing hand. The block will be rotated either clockwise or counterclockwise, to match the amount of rotation of your controls. The direction the index finger is pointing will represent the direction you need to move the cursor for it to go straight up.

Also, you're going to see four arrows located in each corner of the computer screen that will be rotated to match the amount of rotation of the controls. The direction that the arrows are pointing in will represent the direction you will need to move the cursor for it to go straight up.

The rotation will remain the same until the tone signals the end of the block. At that time, you may have a new rotation.

I'll give you a chance to practice a few blocks before the actual experiment begins.

Do practice movements ("batch file "Batch_democue")

Part V – Run experiment

Now we will start the actual experiment. Please do not talk or look at your hands while you are moving the cursor. You are free to take a break after the beeps if it is necessary.