

Gender-Specific Movement Strategies Using a Computer-Pointing Task

Linda E. Rohr

Memorial University of Newfoundland
Canada

ABSTRACT. Females typically demonstrate a movement time advantage for tasks requiring high levels of manual dexterity, whereas males are notably better at targeting activities. According to D. Kimura (2000), the hunter-gatherer hypothesis primarily accounts for those performance advantages; that dichotomy fails, however, when one makes movement outcome predictions for tasks that are not clearly fine-motor or interceptive in nature. Investigators have recently proposed that time constraints (M. Peters, 2005) and gender-specific response style differences (M. Peters & P. Campagnaro, 1996; L. E. Rohr, 2006) affect motor performance. Here, the author used a computer-pointing task measuring both movement error and movement time in 16 participants to further investigate response style differences. Kinematic and linear regression analyses between resultant error and both movement time and task difficulty reinforced the notion that gender-specific movement biases emphasize speed and accuracy, respectively, for men and women.

Key words: gender differences, movement strategies, pointing task, speed-accuracy tradeoff

Although it is unlikely that a single explanation adequately accounts for motor performance differences between men and women, Kimura (2000) suggested that evolution is the greatest contributor to human motor performance differences. According to Kimura, motor and cognitive skills were selected as traits through natural selection or survival-of-the-fittest. Given the distinct roles males and females adopted throughout history, each gender became more proficient at motor and cognitive activities unique to his or her position in society. The hunter versus gatherer roles throughout evolution explain that skill dichotomy. Refined hunting skills increased the likelihood of males surviving to reproductive age, ultimately enhancing the probability that the ability to become proficient at those skills or

traits was passed along to future generations. Therefore, primarily on the basis of their evolutionary roles as hunters in society, males tended to be more proficient at completing targeting tasks and other activities that enabled them to become strong hunters in society. Such interceptive movements have been labeled *targeting tasks* (Kimura); one can test them in the laboratory by using ball tossing (Hall & Kimura, 1995), intercepting a ping-pong ball, and dart throwing (Watson & Kimura, 1991).

Moreover, males outperform females on cognitive tasks emphasizing spatial or mental rotations (Collins & Kimura, 1997; Halpern, 2000; Kimura, 2000; Peters, 2005), the water level task, the rod and frame test, and those activities requiring mathematical computations (Royer, Tronsky, Chan, Jackson, & Marchant, 1999). For instance, Peters showed that males complete a mental rotation task faster than females do, and proposed that males and females have "response styles differences" (Peters, 2005, p. 183). Complementary work by Galea and Kimura (1993) showed that males were able to learn a navigational task faster than females could. Kimura suggested that motor and cognitive skills evolved in strong hunters as they mentally mapped hunting fields and developed a complex mental representation of the terrain surrounding their homeland. In essence, skills that are critical for successful hunting activity are performed better by males than by females.

In contrast, females tend to be more proficient at verbal memory tasks or at activities with a verbal or language component (Halpern, 2000; Kimura, 2000). Factors such as dif-

Linda E. Rohr, School of Human Kinetics and Recreation, Memorial University of Newfoundland, St. John's, Newfoundland and Labrador, A1C 5S7 Canada. E-mail address: lerohr@mun.ca

ferences in general intellectual abilities, attention, perceptual speed, incidental memory, or speed of verbal access (Duff & Hampson, 2001) fail to account for that advantage. In addition to cognitive abilities, females routinely demonstrate a performance advantage for tasks that are fine-motor in nature. Females, the "gatherers" in society, used their fingers extensively for berry gathering, basket weaving, and other activities requiring precise control of the distal musculature (Kimura), significantly contributing to the modern-day gender-dependent differences in motor performance.

A strong argument against the hunter-gatherer hypothesis of Kimura (2000) and the paramount role of biological differences is related to individual experience with complex motor skills. For instance, catching and throwing, two activities in which males excel (Kimura), are greatly improved with practice (Nelson, Thomas, & Nelson, 1991). Such skills are important components of many game and sport activities that males tend to participate in much more frequently than females do (Vilhjalmsson & Kristjansdottir, 2003). Generally speaking, females have a significantly lower participation rate in both vigorous and moderate physical-activity programs (Trost et al., 1996) and coincidentally receive less encouragement to participate in both exercise play and rough-and-tumble play (Pellegrini & Smith, 1998). Therefore, skilled motor tasks like catching and throwing (i.e., targeting tasks, as defined by Kimura) may display a male performance advantage because of the greater experiences and learning opportunities for males. In an attempt to equate practice levels between males and females, however, Watson and Kimura (1991) statistically portioned out any influence of previous sport participation from the correlation between movement accuracy and gender for those complex motor skills. Their analysis suggested that there is a "basic difference between men and women's targeting ability which is not reducible to differential experience" (Kimura, 2000, p. 34). More recently Piek, Gasson, Barrett, and Case (2002) found basic gender differences in infants, suggesting some biological or hormonal influence on motor performance. Although experiences do collectively affect gender differences, evolution, specifically the hunter-gatherer hypothesis, is still an important consideration.

One limitation of the hunter-gatherer dichotomy is that numerous movement tasks can be considered both fine-motor activities and targeting tasks. For instance, pegboard activities require both an aiming component and good finger dexterity, whereas a simple tapping task has an aiming element, although good wrist and finger speed is also necessary for speedy task completion. Given the challenges of classifying tasks by using that dichotomy, psychomotor behavior, neuropsychology, human factors, and motor control researchers have defined alternative manners of classifying and quantifying tasks. Of particular interest, Fitts (1954) noted that different amplitude and target size combinations resulted in similar movement times, leading to the notion of index of difficulty. As either target width decreased or movement amplitude increased, task difficulty

(ID) increased. In conjunction, Fitts demonstrated that movement time increased linearly with ID increases such that movement time = $a + b \log_2(2 \times \text{amplitude/target width})$, where a and b are regression coefficients. The classic Fitts task involves reciprocal tapping between two targets, most often using the finger or a stylus to complete the taps; however, Fitts's law has been replicated for a variety of tasks, including hand, eye, and foot movements (Hoffmann & Sheikh, 1991), throwing tasks (Ettyre, 1998), and imaged activities (Cerritelli, Maruff, Wilson, & Currie, 2000; Decety & Jeannerod, 1995). To calculate ID for tasks in which there is a difference between the target size and the tapping object, one uses tolerance in the calculation—($ID = \log_2(2 \times \text{amplitude}/[\text{target size} - \text{object size}])$)—particularly when overall movement amplitudes are small and the object and target sizes are variable (Hoffmann & Sheikh).

An alternative approach for examining speed-accuracy relationships in goal-directed aiming is to manipulate movement time and measure movement endpoint variability or effective target width (Schmidt, Zelaznick, Hawkins, Frank, & Quinn, 1979; Woodworth, 1899; for a review, see also Elliott, Helsen, & Chua, 2001). Schmidt et al. varied movement time and demonstrated a negative linear relationship between movement time and effective target width. In the current study, participants were put in the awkward, if not impossible, situation of trying to complete a pointing movement within 400 ms. Given that it was highly unlikely participants could be both temporally and spatially accurate, the computer-pointing apparatus permitted me to compare individual speed-accuracy tradeoffs. The computer-pointing task lends itself ideally to examination of the resulting speed-accuracy relationship because one can easily and accurately manipulate movement amplitude, target size, and object size (as in Fitts, 1954) while measuring movement error (as in Schmidt et al.). Moreover, one can determine individual movement times regardless of the 400-ms movement time goal.

Recent evidence suggests that males and females differ on cognitive and motor tasks primarily because of their gender-specific movement approach, or movement bias (Peters & Campagnaro, 1996; Rohr, 2006). Males tend to think and move faster, without focusing on movement errors, whereas females seem more concerned with thinking or moving correctly (Peters, 2005) than with completing tasks quickly. One limiting factor in that work is that movement time and accuracy levels were not concurrently measured. The tradeoff between movement time and accuracy has not specifically been examined for males and females. My purpose in the current study, therefore, was to investigate whether men and women maintain similar speed-accuracy relationships when completing a simple pointing task. Given the apparent speed bias for males and the accuracy-highlighted movement approach for females (Peters; Rohr), parallel measurements of the speed and the accuracy of a movement task should provide further insight into the movement strengths of each gender.

Participants were asked to complete a pointing task for three ID values. I manipulated ID by varying movement amplitude, target width, and cursor size. Regardless of task difficulty, the goal movement time remained constant. The movement time (MT) goal (400 ms) was intentionally short, placing the participants in a situation in which they could not be both fast and accurate. I imposed that manipulation to see the effects on gender-specific biases for speed and accuracy. Without the MT directive, participants would not be forced to choose between movement speed and movement accuracy. Only when the movement-production system is stressed do gender specific movement strategies become evident (Peters, 2005). If females' preferred movement strategy is to highlight accuracy, results should show an increased movement time as target amplitude increases. In turn, if males adopt a speed-emphasized approach, the data should show an increase in overall movement error as task difficulty increases. That interaction should arise from the increase in MT required to complete the pointing task as task difficulty increases.

Method

Participants

Sixteen right-handed participants, 7 men and 9 women, volunteered to complete this study. Each had corrected-to-normal vision and completed the Waterloo Handedness Questionnaire, an instrument that enables one to quantify degree of handedness (Bryden, 1977). All procedures followed here received ethical clearance from the Office of Research Ethics.

Apparatus

A SummaSketch graphics tablet (30.5 cm \times 30.5 cm) was interfaced with a Pentium II computer that sampled the two-dimensional tablet data at a rate of 122 Hz. Participants sat at a table, with the graphics tablet directly in front of them and the 17-in. computer monitor directly beyond the far edge of the tablet. They used a modified computer mouse to complete the pointing movements. The mouse had four distinct, brightly colored buttons; I identified the central button as the one participants should click to denote the end of their movement.

A small circle at the near edge of the tablet identified the start position of the mouse. That position coincided with a circle near the bottom edge of the computer monitor. Three targets were used, all placed along the midline at distances of 4.5, 9.0, and 13.5 cm from the start position. For the near target (amplitude = 4.5 cm), the target size was 1.6 cm and the cursor size 0.6 cm, giving an ID value of 3.2. For the midtarget (amplitude = 9.0 cm), the target was 0.8 cm and the cursor 0.4 cm, with an ID value of 5.5. For the most distant target (amplitude = 13.5 cm), the target was 0.6 cm and the cursor 0.4 cm, which gave an ID value of 7.1. Overall, then, there were three targets or ID values used: 3.2, 5.5, and 7.1. There was a direct 1:1 mapping relationship between the cursor's and the

mouse's movement. In all cases, full vision of the arm, hand, and mouse were available.

Procedure

I asked participants to make 48 pointing movements, 16 to each of the three ID values. Targets were presented in blocks of 16, with the order of blocks randomized across participants. Instructions for each trial were to complete the movement within 400 ms. Participants were informed that reaction time was not of interest. Each trial began with the cursor in a home position near the lower edge of the monitor and ended when the participant clicked with the computer mouse at the goal location. After each trial, participants received movement time feedback (in ms) on the computer screen. In addition, all participants were reminded that their movements were to be completed within 400 ms.¹ The frequency of verbal prompts depended on individual performance levels: Participants who successfully achieved the MT goal received fewer prompts than did those participants who were relatively poor at meeting the MT goal. Instructions for Fitts's tapping tasks traditionally include the cues to move as quickly as possible while successfully terminating the movement within the target boundaries. In other words, accuracy is typically constrained and MT is measured. Here, participants were directed to primarily focus on maintaining a 400-ms MT.

Kinematic data collected on the two-dimensional movement included reaction time, MT, peak velocity, time to and time after peak velocity, and resultant error. Reaction time was defined as the time between the appearance of the target and the beginning of the cursor movement. MT began when the cursor movement speed exceeded 5 mm/s and ended upon the mouse click.² Following Roy, Rohr, and Weir (2004), the click was deemed appropriate to demarcate the end of the movement, both temporally and spatially. Peak velocity was calculated as the maximum speed achieved during the course of the movement. The data-collection software provided real-time velocity calculations on the basis of a 3-point central differentiation algorithm. Each trial was represented by a bell-shaped velocity profile,³ and the time to the peak velocity point and the time after peak velocity were summed to the overall MT. I determined the resultant error by calculating the root of the sum of the *x*-error and *y*-error values squared. Each of the *x*-error and the *y*-error scores was based on the difference between the center of the target and the center of the cursor; the *x*-errors were error values in the mediolateral direction, and *y*-errors were over- or undershoots in the anteroposterior direction. Because overall movement error was of interest, I calculated resultant error at the point of the mouse click.

I compared data from the Waterloo Handedness Questionnaire between gender groups by using a *t* test, $p < .05$. Kinematic data were analyzed in a 2 (gender: men vs. women) \times 3 (ID value: 3.2, 5.5, and 7.1) mixed measures analysis of variance (ANOVA), $p < .05$.⁴ I used Tukey's Honestly Significant Difference Test to post hoc any signif-

icant effects. In an effort to be thorough, the variability in performance between the men and the women was also examined. I found no significant differences in variability between the men and the women for MT, time after peak velocity, or movement error.

In a secondary analysis, two individual regression equations were calculated for each participant. In the first equation, I regressed movement error on ID, whereas in the second, I regressed time after peak velocity on ID. I compared the dependent measures of slope and y intercept between genders by using a one-way ANOVA, $p < .05$.

Results

Waterloo Handedness Questionnaire

Results indicated no differences between the gender groups (men = 1.49, $SD = 0.397$; women = 1.54, $SD = 0.258$) with regard to degree of handedness; unpaired t test, $t(14) = 0.325$, $p = .75$, $SE = 0.09$.

Kinematic Analysis

No significant differences were found in reaction time. Men initiated their movements in an average of 302 ms ($SD = 149$ ms), women in an average of 306 ms ($SD = 112$ ms).

A main effect of gender for MT, $F(1, 14) = 6.93$, $p < .05$, showed that the men ($M = 429$ ms, $SD = 137$ ms) had a shorter MT on average than did the women ($M = 524$ ms, $SD = 166$ ms), although the instructions were to complete the task with a 400-ms MT. Cohen's d for that analysis was determined to be 0.62, a medium effect (Cohen, 1988), with $\eta^2 = 0.166$. A main effect of ID for MT was found, $F(2, 28) = 21.23$, $p < .01$; movements to the ID = 3.2 target ($M = 402$ ms, $SD = 92$ ms) were completed faster than were movements to the ID = 5.5 target ($M = 493$ ms, $SD = 142$ ms) or to the ID = 7.1 target ($M = 553$ ms, $SD = 194$ ms). No interaction between task

difficulty and gender was found for MT (see Table 1 for summary data), although the results approached statistical significance, $F(2, 28) = 2.71$, $p = .0837$.

A main effect of gender was found for resultant error, $F(1, 14) = 8.54$, $p < .05$. The women ($M = 4.57$ mm, $SD = 3.33$ mm) were more accurate than the men ($M = 6.91$ mm, $SD = 4.39$ mm). Although no main effect of task difficulty was evident for resultant error, an interaction between gender and difficulty was found, $F(2, 28) = 3.71$, $p < .05$. Here, the women showed no change in accuracy values across the three ID values. The men, however, demonstrated an increase in movement error as task difficulty increased, $F(2, 12) = 5.17$, $p < .05$.

A main effect of task difficulty for peak velocity, $F(2, 28) = 154.66$, $p < .01$, suggested that movements to the ID = 3.2 target ($M = 227$ mm/s, $SD = 50$ mm/s), ID = 5.5 target ($M = 405$ mm/s, $SD = 107$ mm/s) and the ID = 7.1 target ($M = 555$ mm/s, $SD = 137$ mm/s) all had different peak velocities. No other effects of peak velocity were noted.

Time to peak velocity was different for the three task difficulties, $F(2, 28) = 24.48$, $p < .01$ (ID = 3.2, $M = 158$ ms, $SD = 47$ ms; ID = 5.5, $M = 183$ ms, $SD = 147$; ID = 7.1, $M = 195$ ms, $SD = 40$ ms). No gender effect or interaction between gender and task difficulty were found for time to peak velocity.

A main effect of gender for time after peak velocity was found, $F(1, 14) = 7.33$, $p < .05$; that effect suggested that the men ($M = 245$ ms, $SD = 140$ ms) spent less time decelerating toward the targets than did the women ($M = 350$ ms, $SD = 159$ ms). In addition, a main effect of task difficulty, $F(2, 28) = 11.05$, $p < .01$, confirmed greater deceleration times as task difficulty increased (ID = 3.2, $M = 245$ ms, $SD = 99$ ms; ID = 5.5, $M = 310$ ms, $SD = 147$ ms; ID = 7.1, $M = 358$ ms, $SD = 197$ ms).

TABLE 1. Mean and Standard Deviation Data From the Interaction Between Gender and Task Difficulty

Gender	Movement time (ms)		Time after PV (ms)		Resultant error (mm)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
<i>ID 3.2</i>						
Men	380	85	222	100	5.2	3.2
Women	420	94	262	95	4.9	2.5
<i>ID 5.5</i>						
Men	437	119	243	125	7.4	5.0
Women	535	143	361	142	4.4	3.3
<i>ID 7.1</i>						
Men	472	176	269	179	8.1	4.4
Women	616	184	427	183	4.4	3.7

Note. ID = index of difficulty; PV = peak velocity.

An interaction between gender and task difficulty for deceleration time, $F(2, 28) = 3.45$, $p < .05$, followed the identical pattern as did the error data. The men showed no change in deceleration time across the three ID values. As task difficulty increased, however, the women significantly increased their deceleration time, with all three deceleration times differing from each other (see Table 1).

Secondary Analysis

I determined individual regression equations for each participant, both for movement error on ID and time after peak velocity on ID. I compared the slope and y-intercept values for those two equations between genders. On the basis of the prediction equations from that analysis, I generated plots. In each instance, I used the three ID values from the pointing task to generate the plots, illustrating three key points. First, at the easiest ID levels, no gender performance differences were present. Second, as task difficulty increased, performance differences between men and women emerged. Third, the nature of performance differences was such that the men biased their movements toward speed, whereas the women maintained high accuracy levels and sacrificed movement speed.

A main effect of slope for movement error on ID was found, $F(1, 14) = 5.95$, $p < .05$ (see Figure 1). Here, the men had a much higher slope ($M = 0.719$, $SD = 0.362$) than did the women ($M = -0.126$, $SD = 0.855$), suggesting that as task difficulty increased the men increased their error rates more than the women did. The effect of slope for time after peak velocity on ID approached significance, $F(1, 14) = 4.56$, $p = .051$ (see Figure 2). In that situation, the slope for the women ($M = 0.046$, $SD = 0.036$) was slightly greater than the slope for the men ($M = 0.013$, $SD = 0.02$), suggesting that as task difficulty increased, the women increased time after peak velocity to a greater extent than the men did. The y-intercept values did not differ for the two regression equations (see Table 2).

Discussion

The movement paradigm in the present experiment included the explicit instructions to complete the pointing task with a goal MT of 400 ms; I presented verbal and numeric visual feedback after each trial. Kinematic data clearly demonstrated performance differences between the genders. Although RT was similar between groups, MT values—in particular, deceleration times—were different. The men completed the tasks with a shorter MT than the women did: In fact, the men's average MT was within 10% of the goal MT. At the lowest ID level, the women were also within 10% of the MT goal, suggesting they were able to complete the movement task in the target MT from a biomechanical and physiological perspective.

The most interesting data here arose from the interactions between gender and task difficulty for movement error and time after peak velocity. Movements to the easiest target (ID = 3.2) were not significantly different between the men

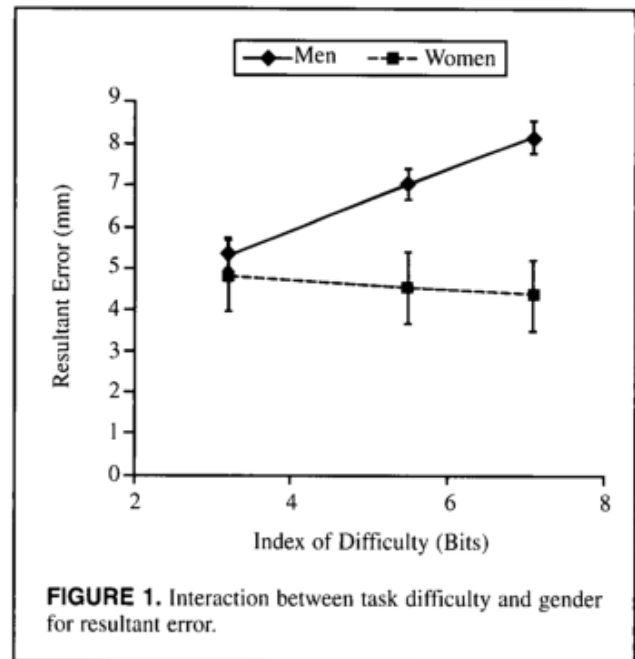


FIGURE 1. Interaction between task difficulty and gender for resultant error.

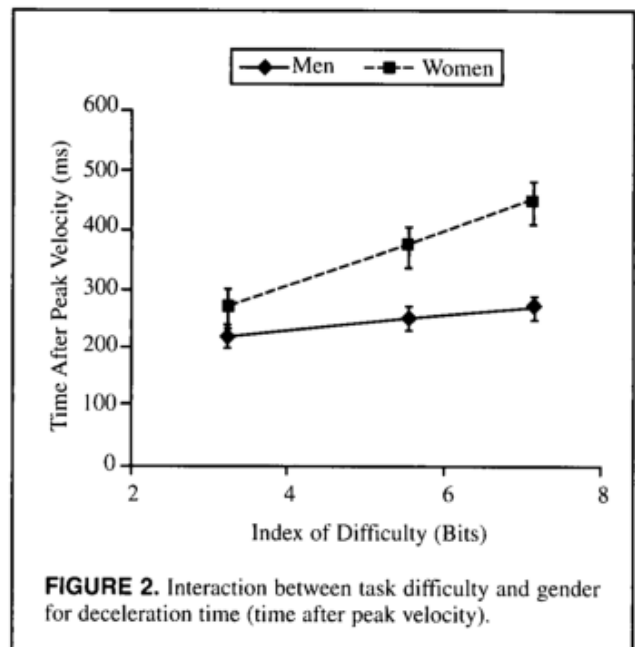


FIGURE 2. Interaction between task difficulty and gender for deceleration time (time after peak velocity).

and the women for those two measures. Participants were not forced to pick speed or accuracy to complete the movement, demonstrating that men and women's performances do not differ unless there is pressure from incompatible requirements to be simultaneously fast and accurate. For the two more difficult targets (IDs = 5.5 and 7.1), the men spent less time in deceleration and had greater movement error. In contrast, the women focused on maintaining a consistent accuracy level while increasing movement deceleration time. Following Peters (2005) and Rohr (2006), gender-specific movement biases were pushing or directing performance.