Gender stereotyping, training and practice factors related to learning a complex visual motor task

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Abstract: This study examines the effect of interpolated tasks and gender on adaptation to two altered task components—compatibility and order of control. Participants (20 men, 16 women of college age) directed a cursor onto a circular target on a monitor as quickly as possible. A joystick directed cursor movements, having either position or velocity control order and compatible or incompatible mapping, depending on the testing conditions. Overall, male participants' movements were faster and more accurate than movements of the female participants. However, female participants' performance did not significantly differ from that of the male participants when the participants practiced two task factors simultaneously and females benefited significantly more than males from the practice. The testing conditions (context) significantly contributed to the performance differences in female participants. In conclusion socioeconomic and cultural values and subsequent gender roles influence performance differences between men and women in a novel stimulus response compatibility task. Women should be given more freedom, encouragement and positive reinforcement to explore and participate in certain visual spatial tasks during early childhood.

Subjects: Physical Sciences; Engineering & Technology; Sports and Leisure; Social Sciences; Behavioral Sciences; Education

Keywords: gender differences; stimulus response compatibility; learning and skill acquisition; training; adaptation; controls and input devices

ABOUT THE AUTHOR

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PUBLIC INTEREST STATEMENT

This paper demonstrates that current social, cultural, and task contexts, not the motor control and learning deficiencies affect women's performance in complex visual motor tasks. The results showed that, although males' performance appeared to be better overall (largely due to small differences accumulates) across conditions, women performed as well as men and even better for accuracy when practicing the altered task factors simultaneously in a complex visual motor task. Therefore, gender differences in performing visual motor tasks should not be exaggerated because they may carry a greater risk of promoting gender-based discrimination in the workplace. However, we should not ignore differences just because the current social, cultural, and task contexts in real-life motor skills are advantageous to males and may discourage women from becoming involved in performing certain visual motor tasks.
1. Introduction

Certain occupations are still considered to be more appropriate for men rather than women because of the gender stereotyping of jobs and the belief in innate gender differences (Shinnar, Giacomin, & Janssen, 2012). This is because gender stereotyping related to learning certain skills may discourage women from holding certain occupations. Therefore, this study explores the effect of interpolated tasks and gender on adaptation to two altered task components—compatibility and order of control.

The task in this study can be related to technology and science-related occupations and to the operation of workplace machinery (Wallace, 1971; Worringham & Berringer, 1998). Generally the operation of complex and heavy industrial machines such as cranes, earth movers, aircraft and drones, is still a male-dominated job in the industrial sector. Although the female workforce has generally increased in the industry, females still constitute only a small minority of those working as heavy machinery and aircraft operators and in technology and science-related occupations (Blume-Kohut, 2014; Kahle, Parker, Rennie, & Riley, 1993; Terlecki, 2004). It would be useful to determine to what degree, if any, gender-based performance differences might explain the gender gap in technology and human–machine interaction, such as operating drones, aircraft and heavy industrial machines.

A number of studies have shown that men were faster, more accurate and more efficient than women when performing visual motor tasks related to real-life experience (Grantcharov, Bardram, Funch-Jensen, & Rosenberg, 2003; Kass, Ahlers, & Dugger, 1998; Schueneman, Pickleman, & Freeark, 1985; Thorson, Kelly, Forse, & Turaga, 2011). A previous study has shown that men had a significantly lower error rate than women when estimating the orientation angle of a ship viewed on a submarine periscope simulator (Kass et al., 1998). Likewise, among medical students and resident surgeons, males performed better than females in “Minimally Invasive Surgical Training”; males were faster, more accurate and more efficient than their female counterparts (Grantcharov et al., 2003; Rosser et al., 2007; Schueneman et al., 1985; Thorson et al., 2011).

This is thought to be because: (1) men are believed to be more involved in the human–machine interaction process (Barnett, Van Beurden, Morgan, Brooks, & Beard, 2010; Feng, Spence, & Pratt, 2007; Garcia, 1994; Griffith, Voloschin, Gibb, & Bailey, 1983; Levine, Vasilyeva, Lourenco, Newcombe, & Huttenlocher, 2005); and (2) receive greater freedom, encouragement and positive reinforcement than women to hold certain occupations, and to explore and participate in certain activities related to movement speed, object controlling, visual aiming, and target-acquisition tasks during early childhood (Grantcharov et al., 2003; Hyde, 2005; Kass et al., 1998; Sanders, 2013; Schueneman et al., 1985; Shinnar et al., 2012; Subrahmanyam & Greenfield, 1994; Tzuriel & Egozi, 2010).

The majority of these studies (Adam et al., 1999; Blough & Slavin, 1987; Cohen, Pomplun, Gold, & Sekuler, 2010; Dorfberger, Adi-Japha, & Karni, 2009; Landauer, 1981; Landauer, Armstrong, & Digwood, 1980; Moreno-Briñeman, Diaz, Campos-Romo, & Fernandez-Ruiz, 2010; Sanders & Walsh, 2007, 2013; Schiff & Oldak, 1990) argued that gender differences in performing a visual motor task may be related to differences in visual information processing, motor-learning mechanisms and decision-making strategies between men and women. Some of these studies posit that women have advantages in motor selection and movement preparation stages, not movement execution (Cohen et al., 2010). In contrast, men take more risks, whereas women are more cautious when it comes to judging an object’s motion in space (Blough & Slavin, 1987; Schiff & Oldak, 1990). However, some of these studies demonstrated that practice eliminates early performance deterioration in women who benefit from training more than men (Blough & Slavin, 1987; Hubona & Shirah, 2004; Hyde, 2005; Schiff & Oldak, 1990; Schueneman et al., 1985).

On the other hand, some studies have related gender differences to human evolution, such as the ancestral hunter-gatherer mode of life. These studies suggest that men are better at certain skills such as judging the timing and speed of a moving object and the skill of mental rotation that are claimed to be essential in hunting in an unknown territory. Women excel in skills related to
attention, word and face memory, reasoning speed, social cognition, and object location memory, which would benefit gathering (Gur et al., 2012; Kaufman, 2007; Landauer, 1981; Sanders, 2013; Silverman, Choi, & Peters, 2007; Silverman & Eals, 1992).

Alternatively, some studies proposed that gender differences in performing a visual motor task may be related to different brain activation patterns and organization of hand-arm movements in men and women. For example, male subjects had higher subcortical activation and “interhemispheric asymmetry” and exhibited greater brain activation and functional connectivity compared to females during a finger-tapping task and playing video games (Amunts, Jäncke, Mohlberg, Steinmetz, & Zilles, 2000; Hoeft, Watson, Kesler, Bettinger, & Reiss, 2008; Lissek et al., 2007).

Recently, Ilamkar (2014) argued that slower and more accurate female performance may be associated with the sex hormones that affect sensory and motor association and the information-processing speed in the central nervous system. Previously it has been hypothesized that performance differences between men and women may be related to the effects of sex hormones, specifically androgens and estrogens, on neural processing (Baker & Weiler, 1977; Barral & Debû, 2004; Broverman, Klaiber, Kobayashi, & Vogel, 1968; Kalb, Jansen, Reulbach, & Kalb, 2004; Rammsayer & Lustnauer, 1989).

It is expected that males may have advantages for the performance of a directional SRC task used to test the differences in this study. It has been reported that men have more experience in certain tasks such as playing video and computer games, and they are more involved in the human–machine interaction process. Therefore, this prediction is based on the previous studies assuming that gender-related life-skills activities may contribute to male performance advantages in visual motor skills (Barnett et al., 2010; Castel, Pratt, & Drummond, 2005; Feng et al., 2007; Garcia, 1994; Grantcharov et al., 2003; Griffith et al., 1983; Lawton, 2001; Levine et al., 2005; Rosser et al., 2007; Schueneman et al., 1985; Subrahmanyam & Greenfield, 1994; Thorson et al., 2011).

It is probable that the environmental context may affect performances for females significantly more than for males when performing a complex visual motor task. Therefore this study designed to explore that whether practice factors (i.e. sequential and concurrent practice) and altered task components (compatibility and order of control) may have different effects on the performances of female and male participants during the adaptation to two-task components in a directional SRC task. This assumption is based on the evidence that task contexts, such as current designs of control display in technology and machines, favor men over women (Hubona & Shirah, 2004; Hyde, 2005).

Additionally this study assumes that females may experience significantly higher aftereffect caused by previously practiced (interpolated) task factors, while performing a retention task. This assumption is based on a theory that adaptation to a visually changed environment requires two motor control processes, strategic calibration and spatial alignment (Moreno-Briseño et al., 2010). Strategic calibration, which does not lead to aftereffects, regulates the motor command. On the other hand spatial alignment, which reorganizes the motor and visual information, leads to large aftereffects. It has been claimed that males employ larger strategic calibration, resulting in a faster adaptation rate and a smaller aftereffect, whereas women employ larger spatial alignment, resulting in a larger aftereffect (Moreno-Briseño et al., 2010). However, a number of studies have stated that early performance deterioration in women can be eliminated by practice because women benefit from training more than men do (Blough & Slavin, 1987; Hubona & Shirah, 2004; Schiff & Oldak, 1990; Schueneman et al., 1985).

Several practical applications may result from the present study including: (1) showing the differences in male and female performance of the task contexts during the learning of a complex visual directional SRC task; (2) decreased training time for new complex visual motor tasks in men and
women; and (3) discovery of new learning strategies by exploring adaptation effects that may differ between men and women.

2. Method

2.1. Participants
A total of 36 young adults, 20 male and 16 female, with an average age of 23 years (SD = 2.73 years) volunteered as test participants. Participants who were students at a state university received neither course credit nor a subject fee for their participation. No participant had any physical disorder affecting hand-arm movement. No participant was tested when he/she appeared to be tired, fatigued, or not mentally alert. Participants visited the laboratory once where they were tested for approximately two hours. Participants had no information about the experiment and its procedures until the day they were tested. All participants were tested according to human subjects’ procedures that were approved by the Institutional Review Boards (IRB) and participants’ informed consent was obtained.

2.2. Materials
The experimental task was to guide a cursor (a white circle about 1 cm in diameter) onto a circular target (a colored circle about 2.5 cm in diameter) on a computer screen as quickly as possible (see Figure 1). These movements were made with a hand-held joystick having either compatible (joystick and cursor movements are in the same direction) or incompatible (joystick and cursor movements are reversed) task with position or velocity control order, depending on the test.

2.2.1. Position control order
A task such as guiding a cursor onto a target on a screen by using a joystick is relatively easy to execute if the control system is based on position (zero) control order. This is because there is no lag between the joystick and cursor movements; the position of the cursor corresponds to the position of the joystick. Thus, a single unidirectional movement will cause a single unidirectional output motion in position control order. Therefore, position control order tasks are considered natural and well-learned.

![Figure 1. Compatible and incompatible task. The generic task was to guide the cursor onto the target as quickly as possible using hand movements on a joystick.](image-url)
2.2.2. Velocity control order
As the control order increases, it becomes more difficult to execute such tasks because the visually guided hand movements are disrupted by altered input and output between the control and display. For example, in first order (velocity) control, the position of the control corresponds to the velocity of the controlled object. Therefore, bi-directional movement is needed to cause a unidirectional output motion on the screen.

2.3. Dependent variables
Four dependent variables were used to measure the performance of each participant.

2.3.1. Reaction time
This measures the capabilities of the participant to anticipate and initiate the required action. Therefore, Reaction time (RT) represents the interval between a target appearing on the monitor and hand, joystick, movement initiation.

2.3.2. Movement time
This indicates how quickly the participant moved the cursor to the target. Thus, Movement time (MT) is an interval from movement initiation until the cursor first enters a target. It means that MT began when RT ended. Therefore, MT represents the motor performance of the first movement execution phase.

2.3.3. Homing time
This indicates a combination of target acquisition and re-acquisition time. It simply measures the participants’ capabilities of controlling the fine movements during the last phase of movement execution to complete each trial. Therefore, Homing Time (HT) is the interval between first and final entry into the target area. In other words, HT begins when MT ends. During first entry, if the cursor was held inside the target area for 1 s, the value of HT was zero.

2.3.4. Directional error
This occurs when the initial direction of the cursor movement is in the wrong direction that is more than 90° away from a straight line to the target. For example, if the target is at 12:00 (positioned radially at the angle of 0°), and the movement is straight to the target or is within a “pie shape” which is 45° to the left or right of the straight line (this would be 90° total) then there is NO error. However, if the movement is outside of this “pie shape” then the maximum degree of error will be the Directional error (DE) measurement. The values were converted to an absolute number expressed in degrees. In other words, DE indicates how much the direction of the initial cursor movement deviates from a straight path to the target. Therefore, DE measures the accuracy of the initial movement responses that are important to the performance of a directional SRC task.

2.4. Procedure
During the tests, participants were seated in an adjustable-height chair in front of a monitor approximately one meter away, and held a joystick that was mounted on the side of the chair. Participants were prevented from seeing movement of the joystick by an occluding screen while tasks were being performed. Participants were informed about the purpose and description of the task by written and oral explanations. They were not informed about the conditions under which they performed the task.

Participants moved the cursor immediately and kept it in the target for one-half of a second after the appearance of the target and an accompanying beep. The target turned blue when the participant successfully placed the cursor in the target. If the cursor was not held in the target long enough or passed through too quickly, then the target returned to its original color (red, green, yellow, or white depending on the condition). Targets were presented randomly on the monitor and were positioned radially at angles of 0°, 45°, 90°, 135°, 180°, 225°, 270°, and 315°. Customized software recorded the data from the joystick and monitor.
Upon completion of each trial, the target disappeared before the next trial began. Furthermore, if a participant started moving the cursor before the target was presented or did not have the joystick in a neutral position, an ‘anticipatory error’ message appeared on the screen and the trial was repeated. The target randomly appeared at one of eight positions on the computer screen and remained there until successful completion of the trial. When a participant completed the required task, the next trial followed after an inter-trial interval of 5–6 s. The computer changed the tasks from compatible to incompatible without manually rotating the joystick 180°. Cursor movements and target positions were displayed on a computer controlled color monitor.

Each participant’s assignment was functionally random with the first male and female participants being assigned to the first testing condition, the second male and female participants assigned to the second testing condition, and so on (i.e. no participant was deliberately assigned to a particular test condition). Assignments to each condition were based on having an equal number of male and female participants tested by the next scheduled testing day.

There were four experimental groups (conditions) with eight participants (four male, four female) per group and were exposed to two distinct tasks (compatible and incompatible) with two different control orders, position and velocity (see Figure 1). A total of 480 (3 phases of 160) test trials were performed for each condition. All four experimental conditions were comprised of three phases, each of which was distinguished by the color of the target (red, yellow, or green). Each phase included 160 trials (20 blocks of 8 trials). Participants were allowed 10-min rest breaks between each test phase.

The first phase and the last phase, respectively, required performance of the same task, position control compatible (PC) and velocity control incompatible (VI) for all four groups. The interpolated task in the second phase, requiring another 160 trials, remained the same for group 1 (position compatible, PC), but was changed to position incompatible (PI) for group 2, to velocity compatible (VC) for group 3 and to velocity incompatible (VI) for group 4. This procedure yielded the following four experimental conditions:

PC-PC-VI: Participants continued to practice the first, position control compatible (PC) task during the second phase.

PC-PI-VI: Participants performed a position control incompatible (PI) task in the second phase between the PC and the velocity control incompatible (VI) tasks.

PC-VC-VI: A velocity control compatible (VC) task was interpolated between the PC and VI tasks.

PC-VI-VI: The interpolated task was the same as the velocity control incompatible (VI) task in the third phase.

2.5. Data reduction and analysis
The last 160 trials (retention tests) of each condition’s total of 480 trials were imported into a statistical package program (SPSS) to calculate a mean, standard deviation, and standard error of the mean trial for each participant. These descriptive data were used to graphically characterize performance and adaptation. A general Multivariate Analysis of Variance (MANOVA) with repeated measures was conducted on each of the test measures by simultaneously determining the effects of between-participant and within-participant factors on the dependent variables. An independent-samples t-test was made for each hypothesis with an alpha level of $p < 0.05$ selected to indicate significant differences.

The first analysis focused on the differences in the performance measurements excluding the testing conditions. The second analysis focused on whether testing conditions (sequential vs. simultaneous practice) have different effects on male and female participants’ performances for the retention (VI) task. Separate 2 (gender) × 2 (position vs. velocity control order) × 2 (compatibility vs.
Analyses of Variance (ANOVA) were performed on the ratio time (RT), movement time (MT), homing time (HT), and directional error (DE) data. For each of these dependent variables, emphasis was given to the gender differences in each of the four experimental conditions (PC, PI, VC, and VI). The gender (male, female) and four experimental conditions (position vs. velocity, compatible vs. incompatible) were the between-participant factors since the variable tasks required for all four conditions were completed by each gender and different groups of participants (Differences in the effects of within-participant factors were determined from trial block data, 8 levels, because all participants were exposed to the same number of trials, 8 trials for each block).

3. Results

3.1. Reaction time
For the RT data, males ($M = 439$ ms, $SD = 82$ ms) were significantly faster than females ($M = 565$ ms, $SD = 125$ ms), $t(31) = 3.33, p = 0.0024$ (see Table 1). A significant main effect of gender was observed, $F(1, 36) = 15.98, p < 0.001$, partial $\eta^2 = 0.363$, power = 0.971. In addition, reliable interaction involving gender, control order (position vs. velocity) and compatibility (compatible vs. incompatible), $F(1, 36) = 8.82, p = 0.006$, partial $\eta^2 = 0.240$, power = 0.818) was revealed.

Table 2 decomposes this interaction into all eight possible conditions, focusing on gender comparisons for the four experimental conditions (PC, PI, VC, and VI). These comparisons only revealed a reliable difference between males and females in the VC condition ($p = 0.005$). Although male participants were generally faster for RT, there was no statistically significant difference in RT for the VI task between the male and female participants of PC, PI and VI groups ($p > 0.05$) (See Table 2).

3.2. Movement time
Overall, male participants were significantly faster for MT ($M = 865$ ms, $SD = 161$ ms vs. 1280 ms, $SD = 330$ ms), $t(31) = 4.60, p = 0.0001$ (see Table 1). The MANOVA for the MT data uncovered significant main effects of gender, $F(1, 36) = 38.77, p < 0.001$, partial $\eta^2 = 0.581$, power = 0.999, as well as compatibility (compatible vs. incompatible), $F(1, 36) = 4.81, p = 0.037$, partial $\eta^2 = 0.146$, power = 0.562.

Several interactions were also observed. These included 2-way interactions between gender and compatibility (compatible vs. incompatible), $F(1, 36) = 5.37, p = 0.028$, partial $\eta^2 = 0.161$, power = 0.609, and between control order (position) vs. compatibility and compatibility vs. incompatibility $F(1, 36) = 4.94, p = 0.043$, partial $\eta^2 = 0.138$, power = 0.535, as well as a 3-way interaction between gender, position control order vs. incompatibility, and compatibility vs. incompatibility, $F(1, 36) = 13.42, p < 0.001$, partial $\eta^2 = 0.324$, power = 0.942. Table 2 contains the means for this 3-way interaction. Making gender comparisons across all four conditions, only a reliable difference between males and females in the VC condition ($p = 0.001$) was present. There was no significant difference ($p > 0.05$) in MT, for the VI task, between female and male participants of PC, PI and VI groups (see Table 2).

Table 1. Mean performance scores of male and female participants

| Variable | Male M | Male SD | Female M | Female SD | t | df | p |
|----------|--------|---------|----------|-----------|---|----|---|
| RT (ms)  | 439    | 84.08   | 565      | 125.12    | 3.33 | 31 | 0.0024* |
| MT (ms)  | 865    | 161.36  | 1,280    | 329.71    | 4.60 | 31 | 0.0001* |
| HT (ms)  | 107    | 65.55   | 216      | 148.47    | 2.32 | 31 | 0.0279* |
| DE (deg) | 14     | 5.90    | 29       | 16.32     | 3.62 | 31 | 0.0011* |

Notes: Table represents mean ($M$) and standard deviation (SD) in milliseconds ms and degrees of male and female participants for velocity incompatible task (VI), excluding the testing conditions in, all four dependent variables; reaction time (RT), movement time (MT), homing time (HT), and directional error (DE).
* Differences are significant at $p < 0.05$. 
3.3. Homing time
For the HT data, a significant main effect of gender was observed, $F(1, 36) = 9.84$, $p = 0.004$, partial $\eta^2 = 0.260$, with males ($M = 107.35$ ms, $SD = 65.55$ ms) being significantly faster than females ($M = 215.69$ ms, $SD = 148.47$ ms), $t(31) = 2.32$, $p = 0.0279$ (see Table 1). A 3-way interaction involving gender, position vs. velocity control order and compatibility vs. incompatibility $F(1, 36) = 5.30$, $p = 0.029$, partial $\eta^2 = 0.159$, power = 0.604) was also present in the data. This 3-way interaction is represented in Table 2, which focuses on gender comparisons for the four experimental conditions. Like the previous dependent measures, the only reliable difference was between males and females in the VC condition ($p = 0.054$).

![Table 2: Statistical values of dependent variables for each test condition](image)

| Condition | Females | Males | $p$ | Cohen’s $d$ | Effect-size $r$ | Power |
|-----------|---------|-------|-----|-------------|-----------------|-------|
|           | $M$ (ms) | $SD$ (ms) | $M$ (ms) | $SD$ (ms) |               |       |
| Reaction time (RT) |
| PC        | 519     | 102   | 470 | 73     | 0.429           | 0.542  | 0.262 | 0.125 |
| PI        | 555     | 107   | 384 | 49     | 0.170           | 2.063  | 0.718 | 0.844 |
| VC        | 690     | 97    | 425 | 86     | 0.005*          | 2.891  | 0.822 | 0.999 |
| VI        | 495     | 129   | 479 | 100    | 0.844           | 0.141  | 0.070 | 0.055 |
| Movement time (MT) |
| PC        | 1,218  | 227   | 910 | 205    | 0.079           | 1.423  | 0.580 | 0.559 |
| PI        | 1,303  | 376   | 816 | 151    | 0.093           | 1.701  | 0.648 | 0.684 |
| VC        | 1,643  | 143   | 810 | 133    | 0.001*          | 6.030  | 0.949 | 0.999 |
| VI        | 957    | 98    | 922 | 167    | 0.711           | 0.253  | 0.126 | 0.067 |
| Homing time (HT) |
| PC        | 221    | 138   | 117 | 93     | 0.254           | 0.883  | 0.404 | 0.224 |
| PI        | 306    | 202   | 110 | 36     | 0.152           | 1.349  | 0.559 | 0.482 |
| VC        | 250    | 113   | 70  | 33     | 0.054*          | 2.165  | 0.735 | 0.870 |
| VI        | 86     | 52    | 132 | 81     | 0.344           | -0.679 | -0.321 | 0.179 |
| Directional error (DE) in deg. |
| PC        | 26     | 11    | 18  | 5      | 0.298           | 0.872  | 0.400 | 0.241 |
| PI        | 23     | 9     | 9   | 3      | 0.055*          | 2.142  | 0.731 | 0.863 |
| VC        | 46     | 23    | 12  | 5      | 0.064*          | 2.024  | 0.711 | 0.820 |
| VI        | 23     | 9     | 17  | 6      | 0.304           | 0.782  | 0.364 | 0.208 |

Notes: Table represents male and female participants’ statistical values of 20 blocks, 160 trials, of VI task for each test conditions. $M = \text{mean (ms. deg.), SD = standard deviation.}$

*Differences are significant at $p < 0.05$.

3.4. Directional error
For the DE data, the MANOVA revealed a significant main effect of gender, $F(1, 36) = 20.64$, $p < 0.001$, partial $\eta^2 = 0.424$, power = 0.992, with males ($M = 14^\circ$, $SD = 5.90^\circ$) demonstrating lower mean error rates compared to females ($M = 29^\circ$, $SD = 16.32^\circ$), $t(31) = 2.32$, $p = 0.0279$ (see Table 1). A 3-way interaction involving gender, position vs. velocity control order and compatibility vs. incompatibility $F(1, 36) = 5.30$, $p = 0.029$, partial $\eta^2 = 0.159$, power = 0.604) was also present in the data. This 3-way interaction is represented in Table 2, which focuses on gender comparisons for the four experimental conditions. Like the previous dependent measures, the only reliable difference was between males and females in the VC condition ($p = 0.054$).

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4. Discussion
A general MANOVA with repeated measures and independent-samples t-test was conducted to test the hypothesis, under all the testing conditions in the four dependent variables. In this study male participants were faster and more accurate when performance is aggregated across conditions (see Table 1). There was a significant main effect of gender on the performance for all the dependent variables. However, when focusing on gender comparisons for the four experimental conditions (PC, PI, VC, and VI), the only reliable statistical difference was between males and females in the VC condition (see Tables 2).

The results of this study are consistent with previous findings (Blough & Slavin, 1987; Schiff & Oldak, 1990; Schueneman et al., 1985) that male participants were significantly faster overall for RT, MT, HT and had lower error rates (DE) than females who performed more slowly and with a higher error rate than males (see Table 1). However, the testing conditions (context) significantly contributed to the performance inconsistencies in female participants as illustrated by the significant difference in performance among the female participants assigned to one of the four testing conditions (groups) (see Table 2 and Figure 2).

The performances of the females assigned to the VI (PC-VI-VI) group were comparable with those of the males of the same group. Female participants of the VI group performed significantly better than the females of the PC, PI and VC groups. There were no significant differences in RT, MT and DE between male and female participants of the VI experimental condition; females actually had faster HT than males in the VI test condition (see Table 2 and Figure 2).

4.1. Gender differences
There was a strong support for the prediction that male had advantages for the performance of certain visual motor tasks. As shown in Table 1, male participants were significantly faster overall for RT, HT, and were more accurate for DE than females who performed more slowly and with a higher error rate than males.

This is interpreted to be the result of the experimental task used in this study, which was closely associated with previously popular video games, many of which employed joysticks for control. It is presumed that, in the USA, young adult males have had more experience and have spent more time in playing video games, and receive greater freedom, encouragement and positive reinforcement to explore and participate in certain activities related to visual aiming, and target-acquisition tasks during early childhood than have females (Barnett et al., 2010; Blough & Slavin, 1987, 1983; Dorfberger et al., 2009; Grantcharov et al., 2003; Gur et al., 2012; Hartmann & Klimmt, 2006; Kass et al., 1998;
It may be argued that attributing gender differences in performing certain visual-spatial tasks mainly to socioeconomic and cultural status reinforces the gender role that gives males advantages for mastering real-life tasks (Castel et al., 2005; Levine et al., 2005; Subrahmanyam & Greenfield, 1994). It has been claimed that females dislike video and computer games because of their stereotyping of the characters (which is thought to be associated with sexual gender roles) competitive elements, violent contents, and their lack of meaningful social interactions (Hartmann & Klimmt, 2006). Additionally, Shinnar et al. (2012) argued that because gender role, which shapes “gender typing of jobs”, women avoid certain tasks that are considered appropriate for the men. They (Shinnar et al., 2012) discovered that “perceived lack of competency” is one of the significant gender related barriers for women. This barrier has a significant negative effect on women performance for certain occupations in the USA. Therefore, women are more prone to the fear of failure and lack of competency that prevents them exploring and involving in learning certain skills or occupations usually dominated by men (Shinnar et al., 2012).

4.2. Sequential vs. simultaneous practice

The results clearly support the assumption that the context in which performance is measured is a significant contributing factor in the deterioration of female performances during adaptation to a complex visual motor task. While males of PC, PI and VC groups had overall better performance than females of the same groups, female performances under PC-VI-VI test conditions were similar to those of males and there were no significant performance differences in VI test conditions between genders (see Table 2). Table 2 shows that the performances of the females assigned to the VI (PC-VI-VI) group were comparable with those of the males of the same group. Female participants of the VI group performed significantly better than the females of the PC, PI and VC groups. There were no significant differences in RT MT, and DE between male and female participants of the VI experimental condition; females actually had faster HT than males in the VI test condition.

These results confirm that the context in which performance is measured is a significant contributing factor in slower and less accurate female movements during adaptation to a complex visual motor task. Although males had overall faster time and lower error than females of the same groups, the only reliable statistical difference was between males and females in the VC condition when focusing on gender comparisons for the four experimental conditions (PC, PI, VC, and VI).

Evidently, practicing the incompatible task with velocity order of control (VI) in the second phase (interpolated task) produced a greater advantage for females than male participants in the third phase of the retention task. In other words, participants may already have modified their strategies, such as adjusting the small joystick and cursor movements according to altered task factors, incompatibility and order of control. This suggestion may be substantiated by the performance of female participants of the VI group that was significantly faster and more accurate than that of female participants assigned to the PC, PI and the VC interpolated tasks (test conditions). Note that female participants assigned to VI group produced the best performances, which were not significantly different from that of the male participants, for the dependent measures in the third phase. It may be argued that women noticed and guessed the new rules of the changed task factors sooner than men.

4.2.1. Differences in movement strategies

The results of this study indicate that males and females exhibit similar strategies and movement behavior when the task is complex and unfamiliar such as the retention task, VI, in this experiment. When the participants switched from PC to VI task, the following modified movement behaviors were observed from both male and female participant’ hand (joystick) and cursor movements: (1)
hand (joystick) movements became more repetitive; (2) there were many small intermittent cursor movements on the screen; and (3) they moved the cursor first horizontally and then vertically toward diagonal targets, rather than straight, as in position control tasks. However, it must be noted that males adopted these movement patterns only when the two task factors (compatibility and control order) abruptly changed from position control compatible (PC) to velocity control incompatible (VI) after the several unsuccessful trials of the VI task. On the other hand, female participants used the preceding motor learning strategies even in relatively easier tasks such as PC, PI and VC and, most of the time, kept the same movement strategies much longer than male participants did, until they became more familiar with the changing task factors. In other words, females were more cautious—slower and making more intermittent joystick movements—while males were moving the cursor fast and straight to the target, which carried risks for overshooting (HT) and making more boundary and greater directional errors.

There is a consistency between these observed movement behaviors and proposed differences in movement strategies employed by men and women in this experiment. For example, Schiff and Oldak (1990) argued that men employ more risky and faster movement strategies and usually exhibit more competitive movement behaviors, such as motivation to beat their own time for each trial once they perceive the task is familiar and relatively easy to perform. Conversely, females exhibit more cautious movement strategies and appear to emphasize accuracy more than males do when performing visual spatial motor tasks (Schiff & Oldak, 1990). It appears that these motor behavior differences may contribute to women’s overall slower movements in visuomotor tasks (Schueneman et al., 1985).

Therefore, practicing two task components simultaneously (whole practice) emerged to be more beneficial for women than practicing two task components sequentially (part practice) for velocity incompatible tasks (VI). This is because practicing each component unnecessarily extends the time of training. Therefore, practicing the two task components simultaneously may be a more correct progression for women to learn a complex directional SRC task.

4.3. Interference and practice effect
As predicted, females experience significantly higher aftereffect, caused by previously practiced (interpolated) task factors, while performing a retention task (see Figure 2). The testing conditions (sequential practice vs. simultaneous practice of the task factors) significantly contributed to the performance inconsistencies (aftereffect) in female participants as illustrated by the significant difference in performance among the female participants assigned to one of the four testing conditions (groups) (see Table 2 and Figure 2). Although male participants were significantly faster and accurate for all the dependent variables than female participants across 20 blocks, female participants had greater improvement for RT, MT, HT, and DE than male participants by 20 blocks of practice (Figure 2). Actually, Homing Time (HT) for the VI task was consistently lower for females than for the male participants of the PC-VI-VI group.

The sequential practice, not the simultaneous practice, of the task factors produced significantly higher aftereffect (interference) in the performances of female participants than of male participants. According to the results, females of the PC, PI, and VC groups had significantly slower time for RT, MT, and HT, and higher error for DE, than did males (see Table 2 and Figure 2). However, female participants significantly reduced the aftereffects and improved their performances with practice.

These results are consistent with the previous (Bock, 1992; Cunningham & Welch, 1994; Pew, 1966). Changing the task factors, compatibility and order of control, caused significant aftereffect and performance deterioration in female participants than that of male participants. However, it should be noted that the initial aftereffects gradually decreased, significantly more, in females and adjustment to the new condition (adaptation) occurred with practice. Thus, females benefited significantly more than males from the practice while learning a complex directional SRC task.
It should be noted that this study does not provide direct evidence for gender differences that have been thought to be associated with sex hormones, androgens and estrogens, which may affect neural processes (Baker & Weiler, 1977; Barral & Debû, 2004; Broverman et al., 1968; Ilamkar, 2014; Kalb et al., 2004; Rammsayer & Lustnauer, 1989), nor does this study elucidate the differences in cortical activation areas and cerebral asymmetry in men and women (Amunts et al., 2000; Lissek et al., 2007). This study also does not give direct evidence for the conclusion that performance differences in complex visual spatial motor skills are associated with evolutionary selection processes which favor men in certain motor skills (Sanders, 2013; Silverman et al., 2007; Silverman & Eals, 1992) and brain functions (Amunts et al., 2000; Lissek et al., 2007).

Although this study also does not give direct evidence for socioeconomic causes for gender differences, it is very compatible with attributing gender differences in performing certain visual-spatial tasks to mainly socioeconomic and cultural influences. Cultural values and beliefs often reinforce the gender role that gives males advantages for mastering real-life tasks (Castel et al., 2005; Levine et al., 2005; Shinnar et al., 2012; Subrahmanyam & Greenfield, 1994). The results of this present study rather suggest that women should be given more freedom, encouragement and positive reinforcement to explore and participate in certain visual spatial tasks during early childhood. This is because many visual spatial tasks, like those used in this study, involving target-acquisition, visual aiming, and controlling an object’s speed, position, and direction on a display are often under-practiced by women. Mastering these visual motor skills is important because these skills can be transferred to real-life occupations, such as operating heavy machines, airplanes, drones, and medical surgery equipment that are often considered more appropriate for men.

This study implies that gender differences in performing visual motor tasks should not be exaggerated because they may carry a greater risk of promoting gender-based discrimination in the workplace (Hyde, 2005). However, we should not ignore differences just because the current social, cultural, and task contexts in real-life motor skills are advantageous to males and may discourage women from becoming involved in performing certain visual motor tasks. Subsequently it was argued that current social and environmental contexts, including the design of human computer and media interaction, favor males and that technological design should be geared toward a more gender-neutral, user-interface design (Hubona & Shirah, 2004).

4.4. Limitations and future research directions

The present study has limitations imposed by a small sample size and, therefore, further studies with a large sample size are necessary to explore the effects of gender role and job stereotyping on real-life tasks. The participants of this study were only 36 college students who were volunteered to serve as test subjects. Therefore, it may be difficult to assert that the sample size used in this study represents the general population in the USA.

Future studies should also consider the role of socioeconomic and sociocultural factors that may contribute to the performance differences between and within the genders. For example, it has been claimed that there are no differences in the performance on visual spatial tasks between boys and girls from lower socioeconomic status groups, even though in higher and middle socioeconomic status levels boys outperformed girls (Levine et al., 2005). This may be because there are differences in real-life experiences, including in early childhood, between men and women based on socioeconomic status.

It can also be suggested that participants’ computer games experiences should be considered in future studies that employ directional visual motor tasks. In this study the overall male performance advantage may be attributed to the time spent on playing computer games. Generally boys spend significantly more time to playing computer games than girls. Many computer games use a control device that gives men advantage over women in real life directional stimulus response compatibility (SRC) tasks. Therefore, future studies should include those participants with limited computer games experience as a control.
5. Conclusion

In conclusion, the current study with a limited sample size presents evidence that the current social, cultural, and task contexts, not the motor control and learning deficiencies affect women’s performance in complex visual motor tasks. The results showed that, although males’ performance appeared to be better overall (largely due to small differences accumulates across conditions), women performed as well as men and even better for HT when practicing the altered task factors simultaneously in a complex visual motor task. Therefore, it may be concluded that gender differences in complex directional visual motor tasks are often task-specific with inter-individual variability.

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