THE SEX DIFFERENCE IN ROD BALANCING: CONFIRMATION OF THE DIFFERENCE AND A TEST OF THREE HYPOTHETICAL EXPLANATIONS[1]

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    Summary.—Previous studies have shown that men can balance a dowel rod on the index finger for a longer time than women can. The factors that account for the difference are unknown, but the difference may be attributable either to a difference in whole-body agility or a difference in the use of visual cues. Three experiments involving a total of 62 adult women with a mean age of 21.2 yr. ($SD = 3.8$) and 62 adult men with a mean age of 21.9 yr. ($SD = 6.6$) tested these potential explanations. Experiment 1 replicated the sex difference and assessed the relevance of whole-body agility by comparing standing and seated conditions. Experiments 2 and 3 explored the role of rod length and visual fixation point, respectively. Each experiment yielded a significant sex difference, but the difference was not affected by the participant's posture, the length of the rod, or the fixation point. Possible alternative explanations for the difference include differences in (1) the speed of processing degree of visual tilt; (2) arm mass, which affects the inertia of the balancing system; and (3) experience in open-skill sports.

    During the 1970s, several dual-task studies used dowel rod balancing as a manual task to be performed while the participant was engaged in a concurrent activity such as reciting a sentence. The balancing task entailed keeping a dowel rod, approximately half a meter in length, upright on the tip of the index finger for as long as possible. The studies were designed to test hypotheses about hemispheric specialization by eliciting interference between various non-manual tasks and simultaneous balancing of rods on either the left or right index fingertip (Kinsbourne & Cook, 1971; Hicks, 1975; Lomas & Kimura, 1976; Johnson & Kozma, 1977). Although the predicted asymmetries of interference usually were observed, i.e., greater interference between speaking and right-hand balancing than between speaking and left-hand balancing, there was also an unexpected

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sex difference in balancing performance. As noted in a literature review by Hiscock, Perachio, and Inch (2001), men were able to balance the dowel much longer regardless of whether a concurrent non-manual task was being performed (e.g., Lomas & Kimura, 1976; Johnson & Kozma, 1977). In the Lomas and Kimura study, for instance, 9 of the original 12 female participants had to be replaced because their mean duration across all conditions was too short (≤5 sec.). Moreover, the replacement participants performed so poorly in the single-task conditions that no further decrement in balancing time was obtained in the dual-task conditions.

The reason for the large sex difference in balancing times is unknown. Many other manual tasks yield little or no difference. While the average finger-tapping rate of men exceeds that of women, the difference is much smaller than the difference in rod-balancing performance (Bornstein, 1986; Peters & Servos, 1989; Heaton, Grant, & Matthews, 1991; Ruff & Parker, 1993; Lezak, Howieson, & Loring, 2004). Sex differences are even smaller and less consistent on the Purdue Pegboard and Grooved Pegboard tests, two other manual tasks that are commonly included in neuropsychological assessments. On these peg-moving tasks, women tend to outperform men (cf. Bornstein, 1986; Peters & Servos, 1989; Ruff & Parker, 1993; Spreen & Strauss, 1998; Sykes Tottenham, Saucier, Elias, & Gutwin, 2005).

Analyses of various other motor tests have failed to yield sex differences commensurate with the large difference in rod balancing. The Lincoln-Oseretsky Motor Development Scale, which includes multiple measures of whole-body balancing (e.g., walking backward, crouching on tiptoe, standing on one foot), shows no large or consistent sex differences in children between the ages of 6 and 14 years (Sloan, 1955). Nolan, Grigorenko, and Thorstensson (2005) found that the standing balance of boys was worse than that of girls at 9–10 years, but no significant difference was seen at the ages of 12–13 and 15–16 years. A study of standing balance in adults aged 50–67 years failed to find a significant difference between men and women when data were adjusted for the individual's height (Bryant, Trew, Bruce, Kuisma, & Smith, 2005). A meta-analysis of 64 studies of motor skills in children and adolescents indicated that large post-pubertal differences (favoring boys) are found only for measures of throwing velocity and distance and for five other activities that depend on "speed, power, muscular strength, and endurance" (Thomas & French, 1985, p. 274). The five discriminating tasks are the dash, sit-up, long jump, shuttle run, and grip strength. Although adolescent boys outperformed girls on measures of balance, pursuit tracking, and tapping, the effect sizes were no greater than one standard deviation. Of the activities that appear to be most closely related to rod balancing—agility, anticipation timing, reaction time, fine eye-motor coordination, and flexibility—some differences favored boys, some favored girls, and all were small in magnitude.

Even though laboratory studies have used sophisticated methods to obtain more detailed information about various sensory and motor aspects of movement control, many of those studies did not assess sex differences (e.g., Redon, Hay, Rigal, & Roll, 1994; Hay & Redon, 1997; Lavrysen, Helsen, Tremblay, Elliott, Adam, Feys, *et al*., 2003; Hay, Bard, Ferrel, Olivier, & Fleury, 2005). There are exceptions, however. Rohr (2006a) found that adult men performed faster than women on a computerized pointing task that requires rapid movements, but women were more accurate than men. The accuracy of women remained constant across difficulty levels, but men made larger errors as the difficulty increased. In a second study (Rohr, 2006b), men performed faster on a Fitts (1954) movement task irrespective of whether the hand or foot was being moved. Sykes, *et al*. (2005) reported that adult men are more accurate than women in throwing and aiming at targets in both near and extrapersonal space. A study by Joseph and Willingham (2000) found no significant sex difference in performance on a computerized pursuit-tracking task after scores were adjusted for previous experience with joysticks. Nonetheless, men performed significantly better than women on an inverted tracking task (with the joystick rotated 180°), and this sex difference was not nullified by adjusting for previous joystick experience.

A sex difference in rod balancing might reflect strategy differences between men and women. An fMRI study by Gorbet and Sergio (2007) revealed sex differences in the activity of several cortical regions as adult participants made specified visually guided movements with their hands or with a joystick. The differential activation patterns were observed in the absence of performance differences. Strategy differences can be invoked to account for Rohr's (2006a) finding of opposite sex differences for speed and accuracy, and the involvement of strategy differences has been considered in motor studies that involve a significant perceptual component. For instance, Hansen, Elliott, and Tremblay (2007) reported that women's performance on a goal-directed aiming task was disrupted more than that of men by perturbing visual input, but only if the perturbation occurred during the movement itself and not during the movement-planning phase. The authors concluded that men are more dependent on visual input for movement planning and women are more dependent on visual input for movement execution. Tremblay, Elliott, and Starkes (2004) found that attention instructions reduced the amount of perceptual bias in women as the body is rotated from an upright position to a 45° supine position. However, men showed less bias than women irrespective of attention instructions.

Thus, the literature provides numerous examples of motor tasks on which differences are found, and many of the differences favor men. Nonetheless, mean differences on some tasks favor women and, apart

from activities in which the greater speed and strength of the mature man is an important factor, the magnitude of the difference typically falls below 1 standard deviation. Against this backdrop, the unusually large differences in dowel rod balancing are unprecedented and unexplained. The present study assesses some hypothetical reasons for this difference.

From the performer's perspective, the dynamics of balancing are straightforward. The rod may remain vertical for several seconds, after which a slight perturbation causes the top of the rod to move laterally. Once the rod begins to deviate from a vertical orientation, its angular velocity increases rapidly, control is lost, and the rod is likely to fall to the floor. Control can be retained only if the supporting finger is moved rapidly in the direction which the top of the rod is falling. If the corrective hand movements are too slow or they overshoot or undershoot, the rod will continue falling or its fall will be interrupted only temporarily before it begins to fall again. The initial loss of control often leads to a phase in which control is diminished and the performer continues to "chase" the rod until it falls to the floor. Much of the chasing appears to involve corrections of excessive magnitude, e.g., "over-controlling" movements.

Three experiments were conducted to investigate factors that might account for the previously observed sex difference in rod balancing performance. The objective of the first experiment was to replicate the findings of prior studies with respect to the large sex difference and then to test the contribution of body movement to this difference. Specifically, standing performance was compared with seated performance to test the hypothesis that men's superior performance is the result of faster or more adaptive whole-body movements.

Experiments 2 and 3 tested the hypothesis that differences in performance between men and women are related to differences in the use of visual feedback. Visual perception is important for body balance (Weissman & Dzendolet, 1972; Cody & Nelson, 1978), and it may be even more important for rod balancing because success requires rapid and precise responses to angular changes in the position of the rod. If men are quicker to perceive small deviations from verticality, then they would be able to react more quickly and to make adjustments when the rod is minimally deviated from the vertical and relatively easy to bring back under control. In Exp. 2, the quality of the available visual information was manipulated by varying the length of the rod. In Exp. 3, visual strategies were altered selectively by specifying a fixation point on a dowel rod of fixed length.

<div align="center">Experiment 1</div>

This experiment had two conditions: (1) balancing the dowel rod in a standing posture and (2) balancing the dowel rod while sitting.

Hypothesis 1. The mean balancing duration will be greater for men than for women.

Hypothesis 2. Balancing times for woman and men will be greater in the standing condition than in the seated condition.

This is based on the assumption that standing allows greater freedom of movement than sitting. In the standing position, the whole body can move in addition to the arm to maintain control of the rod. However, in the seated position only the arm and upper body are used to control the rod.

Hypothesis 3. There will be a Sex × Posture interaction indicating that the performance advantage for men is greater in the standing condition than in the sitting condition.

This third hypothesis assumes that the whole-body movements of men will be faster or otherwise more adaptive than those of female participants.

Method

Participants.—Fifty-two right-handed undergraduate students (26 women, 26 men) from psychology classes at the University of Houston were recruited to participate in the first experiment. The participants received extra course credit for their participation. The mean age for female participants was 24.0 yr. (SD=5.2), and the mean age for male participants was 24.2 yr. (SD=6.5). The small age difference was not significant (t<1). All participants indicated right-hand preference (laterality quotient>0) on a modified version of the Edinburgh Handedness Inventory (Oldfield, 1971), and all reported having normal or corrected-to-normal vision. Each participant signed an informed consent form at the beginning of the experimental session, and each participant was debriefed at the end. This experiment and the subsequent experiments were approved by the university's institutional review board.

Procedure.—Each participant was asked to perform 20 experimental dowel-balancing trials. Each trial entailed balancing a wooden dowel rod (1.3 cm diameter × 46 cm; 30 g) vertically on the index finger of the right hand. On 10 of the trials, the participant balanced the dowel rod in a standing position. In this condition, he or she was allowed to move freely within a marked rectangular space of 2.18 × 2.67 m. The boundaries of this space were clearly marked with lines of tape stuck to the floor. The participant was instructed to begin each trial facing in a specific direction, and he or she was asked to avoid turning his or her back to the experimenter while balancing the rod.

On the other 10 trials, the participant was asked to balance the wooden rod in a sitting position. The participant sat in a wooden, straight-backed,

armless chair and was instructed to start each trial with both feet on the floor and his or her back pressing against the back of the chair. The chair was positioned in the middle of the marked rectangular space and the seated participant was facing in the same direction as in the standing condition.

The experimental session was divided into four blocks of five trials each, with standing and sitting trials alternated between blocks. The order of standing and sitting blocks was counterbalanced across participants within each sex so that an equal number of women and men were represented in each order (standing first vs sitting first).

Measures.—A trial began when the participant was told "start," and a stopwatch was simultaneously activated. In agreement with previous studies (e.g., Hicks, 1975), a trial was considered to end if: (1) the dowel fell from the fingertip, (2) the dowel touched the wall, or (3) the dowel touched any part of the participant's body except the tip of the right index finger. A trial was discontinued if balancing time reached 120 sec. A stopwatch was used to record balancing time for each trial, and times were rounded to the nearest second. Irrespective of balancing duration on any trial, the trial was followed immediately by a 30-sec. rest period.

Analyses.—Mean balancing times for each of the 10 sequential trials within a posture condition were analyzed in a 2 (sex)×2 (posture)×10 (trials) analysis of variance (ANOVA) with repeated measures on the last two factors. Medians and logarithm-transformed (base 10) means were analyzed in the same manner. Medians and log-transformed means were used to achieve greater homogeneity of variance because performance on balancing tasks is highly variable within trial blocks and balancing times tend to be highly skewed to the right (Hicks, 1975; Sappington, 1980). All three indices are shown in the tables, but only the ANOVA results for log-transformed means are described in the text. Effect sizes are expressed as partial eta square values.

Results

Table 1 shows the means, medians, and log-transformed means for each sex within the standing and sitting position, and Fig. 1 shows the log-transformed means for men and women on a trial-by-trial basis. As one can see from this figure, as well as from the data in Table 1, the log transformation reduces variability across trials. Irrespective of dependent measure, the variability of women's balancing times is substantially less than that of men.

The analysis yielded significant main effects for each of the three factors as well as a significant interaction and a marginally significant interaction. A main effect for sex ($F_{1,48}=10.60$, $p<.005$, $\eta^2=0.18$) indicated that men had longer balancing times than women, and the significant main effect for posture indicated that performance was higher while standing than sitting ($F_{1,48}=38.67$, $p<.0001$, $\eta^2=0.45$). A significant main effect for tri-

TABLE 1
MEAN, MEDIAN, AND LOG₁₀ BALANCING TIMES IN SECONDS
ACROSS 10 TRIALS (EXP. 1)

Position	Women ($n=26$)		Men ($n=26$)	
		SD		*SD*
Standing				
M	3.50	1.82	8.49	7.19
Median	3.15	1.49	7.69	6.84
Log_{10}	0.60	0.15	0.82	0.29
Sitting				
M	2.69	1.37	5.47	5.22
Median	2.59	1.55	5.19	5.29
Log_{10}	0.52	0.14	0.67	0.24

als reflects an improvement in performance across each set of 10 trials regardless of posture ($F_{9,432}=9.77$, $p<.0001$, $\eta^2=0.17$). Trend analysis showed that this trial effect was largely linear ($F_{1,48}=35.78$, $p<.0001$, $\eta^2=0.43$).

The Sex × Trials interaction was significant ($F_{9,432}=1.95$, $p<.05$, $\eta^2=0.04$). Although Fig. 1 shows that men tended to improve more than women across trials, sex did not interact significantly with either the linear or qua-
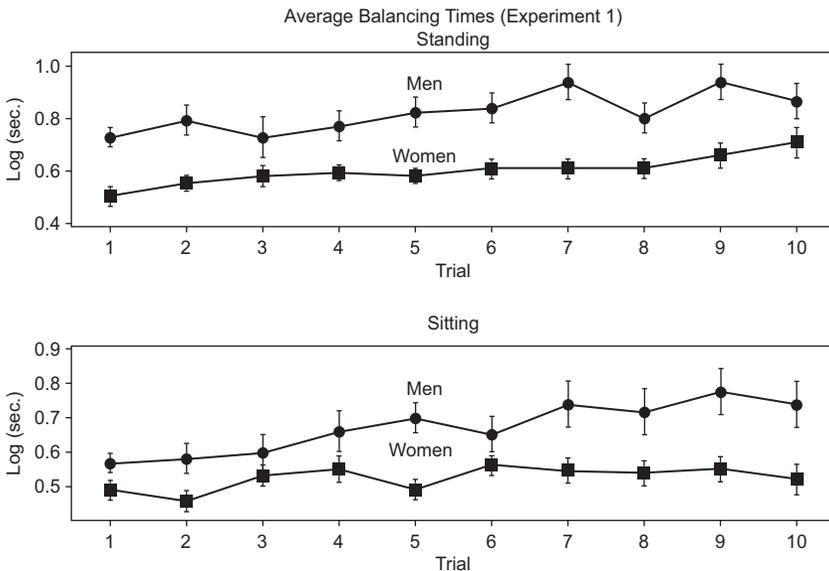

FIG. 1. Mean Log₁₀-transformed balancing times in seconds across 10 trials for standing and seated postures (Exp. 1). Error bars depict ±1 standard error of the mean (SEM).

dratic trend component of the trials factor ($p > .05$). The Sex × Posture interaction ($F_{1, 48} = 3.96$, $p = .05$, $\eta^2 = 0.08$) indicated a tendency for the standing posture to benefit men more than women.

Discussion

The results from Exp. 1 supported previous findings that men and women have significantly disparate balancing times when performing a dowel-rod balancing task (Hiscock, *et al.*, 2001). The ratio of male to female means in Exp. 1 ranged from 2:1 to nearly 3:1, depending on whether the participants were seated or standing, and the ratio of male to female medians ranged from 2:1 to nearly 2.5:1. Standard deviations were substantially smaller for women but, if a pooled standard deviation was used to represent overall variability, the magnitude of the mean sex difference was about 1.7 standard deviations. Given that the logarithm transformation reduces large numbers more than small numbers, male-to-female duration ratios for log-transformed means are difficult to interpret.

The findings also supported the hypothesis that a standing posture improves balancing performance relative to the performance obtained in a sitting position. The participants clearly found it advantageous to move freely within a specified area instead of remaining seated with both feet on the floor. The large improvement from the sitting position to the standing position showed that the rod balancing performance can be optimized by involving the trunk and lower limbs. It appears that the greater mobility afforded in the standing condition facilitates the rapid and large corrections that may be necessary to "rescue" a rod that has tipped substantially from the vertical orientation.

Balancing performance improved significantly across the 10 trials within each postural condition, and the pattern across trials differed significantly between men and women. However, because the significant difference was neither linear nor quadratic, one cannot conclude that men improved with practice more than women improved. Figure 1 shows primarily that women's performance showed less variability from trial to trial than did the performance of men. The reduced variability in women is probably a reflection of their relatively low balancing times.

Even though the Sex × Posture interaction was statistically significant, it accounted for only 8% of the between-subjects variance in balancing time. Standing benefited men more than women, but most of the sex difference is attributable to factors other than mobility. Women have significantly shorter balancing times than men irrespective of whether they are free to move.

<center>EXPERIMENT 2</center>

In order to balance a rod, a person must be able to make corrective arm movements, the utility of which depends on the fast and accurate

perception of deviations of the rod from the vertical position. A vertical rod that is pivoted at the bottom has the physical properties of an inverted pendulum (Oppenheim & Willsky, 1982; Franklin, Powell, & Emami-Naeini, 2005). A longer rod has a larger moment of inertia and less angular acceleration than a shorter rod. The longer rod falls away from verticality more slowly and gives the balancer more time to react. Increasing the length of the rod will enable the person to respond to smaller angular deviations from verticality and therefore make it easier to keep the rod in an upright position. (Mass is not a determinant of either inertia or acceleration, though the distribution of mass along the rod has an effect.)

The purpose of the second experiment was to explore the role of the rod's length on the balancing performance of men and women. In this experiment, men and women balanced rods of three different lengths: 36, 46, and 56 cm. It was hypothesized, based on the aforementioned physical principles, that both men and women would have higher balancing times for the longer rods.

Hypothesis 4. The magnitude of the sex difference would decrease with increments in the length of the rod.

If women are slower to detect small deviations from verticality, the slower angular acceleration of longer rods should nullify or reduce that disadvantage.

Method

Participants.—Thirty-six right-handed undergraduate students (18 women, 18 men) were recruited from psychology classes at the University of Houston. The mean age for female participants was 19.8 yr. ($SD=3.2$), and the mean age for male participants was 20.7 yr. ($SD=9.1$). The age difference was not significant ($t<1$). All participants had shown right-hand preference on a modified version of the Edinburgh Handedness Inventory (laterality quotient >0), and all participants reported having normal or corrected-to-normal vision.

Procedure.—The basic procedure was the same as in Exp. 1, except that in this experiment the participants balanced the dowel rod only in a standing position. Three rods were used: short (1.3×36 cm, 18.6 g), medium (1.3×46 cm, 30.0 g; same size as used in Exp. 1), and long (1.3×56 cm, 41.4 g). Each participant performed 30 trials, 10 for each of the three rod lengths. The order in which conditions were performed was counterbalanced across participants within each sex.

The participant was instructed, as in Experiment 1, to start each trial facing a specified direction of the room, and the participant was asked to avoid turning his or her back to the experimenter while balancing the rod. The criteria for ending a trial were the same as in Experiment 1.

Results

As in Exp. 1, means, medians, and log-transformed means were calculated. The aggregated data for each length of rod are presented in Table 2. A 2 (sex)×3 (length)×10 (trial) ANOVA with repeated measures on the last two factors was computed. The dependent measure was the log-transformed mean balancing time. The ANOVA yielded significant main effects for each of the three factors. The main effect for sex ($F_{1,34}=7.46$, $p<.01$, $\eta^2=0.18$) indicates an overall difference favoring men. As shown in Table 2, the mean balancing time for men was between 2.5 and 3.5 times as large as the mean for women, depending on the length of the rod. The main effect for rod length ($F_{2,68}=16.90$, $p<.0001$, $\eta^2=0.33$) indicated a roughly linear relationship between rod length and balancing time. Balancing times increased as rod length was increased. Finally, the main effect for trials ($F_{9,306}=3.45$, $p<.0005$, $\eta^2=0.09$) indicated an improvement of balancing performance over the 10 trials within a block of trials. This trial effect is attributable entirely to the linear trend component ($F_{1,34}=24.55$, $p<.0001$, $\eta^2=0.42$). Figure 2 shows the trial-by-trial performance after the data are averaged across rod lengths. The ANOVA yielded no significant interactions. In particular, the Sex×Length interaction was non-significant ($F_{2,68}=1.50$, $p>.20$).

Discussion

The results of Exp. 2 confirmed the expectation that longer rods would yield increased balancing times, presumably because the longer rod begins

TABLE 2
MEANS, MEDIANS, AND LOG$_{10}$ BALANCING TIMES IN SECONDS
ACROSS 10 TRIALS (EXP. 2)

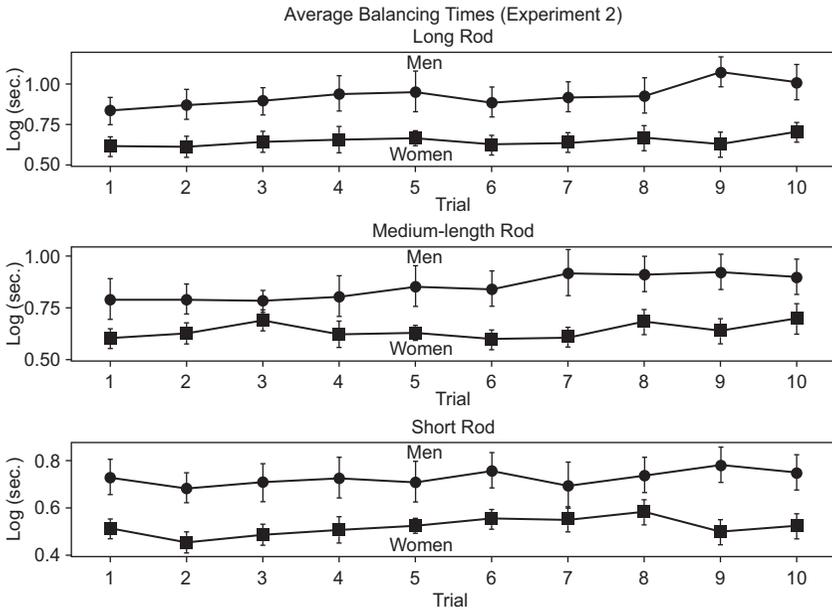| Rod Length	Women (*n*=18)		Men (*n*=18)	
		SD		*SD*
Short				
M	2.68	1.60	6.80	7.86
Median	2.61	1.63	5.78	6.05
Log$_{10}$	0.52	0.15	0.73	0.31
Medium				
M	4.21	3.04	11.57	18.83
Median	4.17	3.22	11.11	19.57
Log$_{10}$	0.64	0.21	0.85	0.38
Long				
M	4.08	2.90	14.10	19.22
Median	4.00	3.12	12.00	14.89
Log$_{10}$	0.64	0.20	0.94	0.36

Average Balancing Times (Experiment 2)

FIG. 2. Mean Log$_{10}$-transformed balancing times in seconds across 10 trials with rods 56, 46, or 36 cm in length (Exp. 2). Error bars depict ± 1 standard error of the mean (SEM).

its fall more slowly. The greater inertia and lesser angular acceleration of the longer rod allowed the balancer more time in which to make corrections necessary to counteract the rod's fall. In addition, small angular displacements were easier to perceive with longer rods because the corresponding horizontal displacements of the tip were greater than with shorter rods. In the absence of a significant Sex × Rod length interaction, it appears that women and men benefit similarly from the relative stability of the longer rods and from the more fine-grained visual information available from the longer rods. Female participants had substantially shorter balancing times than did men irrespective of rod length. Consequently, the results do not implicate slow detection of tilt or slow corrective action as a plausible explanation for the relatively poor balancing performance of women.

EXPERIMENT 3

The third experiment assessed the possibility of a strategy difference between men and women in the acquisition of visual information. Women might be less likely than men to use the full length of the rod for their spatial cues. In other words, perhaps women tend to fixate on the middle or lower part of a long rod instead of raising their gaze to the top of the rod, which would provide more fine-grained information about devi-

ations from verticality. To test this possibility, participants in Exp. 3 were asked to fixate on specified points along the rod.

> *Hypothesis 5*. The sex difference favoring men will be reduced when all participants are instructed to fixate on the same point along the rod.
>
> *Hypothesis 6*. The above-mentioned reduction will be greater for higher fixation points.

Method

Participants.—Another sample of 36 right-handed undergraduate students (18 women, 18 men) was recruited from psychology classes at the University of Houston. The mean age for female participants was 18.5 yr. (SD=1.0), and the mean age for male participants was 19.9 yr. (SD=2.3). Although the age difference was statistically significant (t_{34}=2.36, $p<.05$, two-tailed), the correlation between age and balancing time was not significant (r=.21). All participants were ascertained by the Edinburgh Handedness Inventory to have right-hand preference (laterality quotient>0), and all reported having normal or corrected-to-normal vision.

Procedure.—The basic procedure was the same as in the previous two experiments. As in Exp. 1, only the medium-length rod (1.3 cm × 46 cm, 30 g) was used. Visual monitoring strategies were manipulated across three conditions. In Condition 1 (low fixation point), the participants were instructed to fixate on a small piece of red tape 10 cm below the top of the rod. In Condition 2 (medium fixation point), the participants were instructed to fixate on a small piece of red tape on the top of the rod. In Condition 3 (high fixation point), the participants were told fixate on a small piece of red tape on the top of a 10 cm plastic extension to the rod. As the extension weighed less than 1 g, it had minimal effect on the stability of the rod during the balancing task.

Each participant performed 30 trials, 10 for each of the three fixation points. The order in which conditions were performed was counterbalanced across participants within each sex. All balancing was done in the standing position. The participant was instructed, as in Exps. 1 and 2, to start each trial facing a specified direction of the room, and the participant was asked to avoid turning his or her back to the experimenter while balancing the rod. The criteria for ending a trial were the same as in the previous experiments.

Results

Mean, median, and log-transformed mean balancing times for each condition are displayed in Table 3. A 2 (sex) × 3 (fixation point) × 10 (trial) ANOVA with repeated measures on the last two factors was computed

for the log-transformed balancing times. The ANOVA yielded only significant main effects for sex and trial. The main effect for sex ($F_{1,34}=12.02$, $p<.005$, $\eta^2=0.26$) indicated an overall difference favoring men ($M=15.4$ vs 5.2 sec.). Table 3 indicates that the mean balancing time for men across the three fixation points was between 2.4 and 3.4 times as large as the mean for women. The main effect for trial ($F_{9,306}=3.04$, $p<.01$, $\eta^2=0.08$) largely reflected an increase in balancing times across trials. This practice effect was confirmed by a significant linear trend ($F_{1,34}=19.12$, $p<.0001$, $\eta^2=0.36$), although the quadratic trend component was also significant ($F_{1,34}=6.68$, $p<.01$, $\eta^2=0.16$). The pattern of performance across trials for each fixation point is shown in Fig. 3. There was neither a significant main effect for fixation point ($F<1$), nor a significant Sex × Fixation point interaction ($F_{2,68}=1.63$, $p>.20$).

TABLE 3
MEANS, MEDIANS, AND LOG$_{10}$ BALANCING TIMES IN SECONDS
ACROSS 10 TRIALS (EXP. 3)

Fixation Point	Women ($n=18$)		Men ($n=18$)	
		SD		SD
Low				
M	5.79	3.32	13.90	13.33
Median	5.17	3.12	12.67	11.70
Log$_{10}$	0.75	0.20	1.00	0.27
Middle				
M	5.10	2.60	15.66	19.63
Median	4.86	2.44	14.00	19.28
Log$_{10}$	0.71	0.19	0.99	0.34
High				
M	4.83	2.27	16.50	17.35
Median	4.47	1.93	14.68	15.84
Log$_{10}$	0.71	0.17	1.03	0.33

For the purpose of assessing the effect of fixation instructions *per se*, the mean balancing time for both sexes and all three conditions was compared with the mean balancing time for the medium-length rod condition of Exp. 2, in which the rod length was identical. Direct comparison of mean log-transformed balancing times yielded no significant difference ($t<1$).

Discussion

The results from Exp. 3 further confirmed the sex difference in rod balancing and indicated that the difference was found irrespective of fixation point. The latter conclusion was qualified, however, by an unexpected fail-
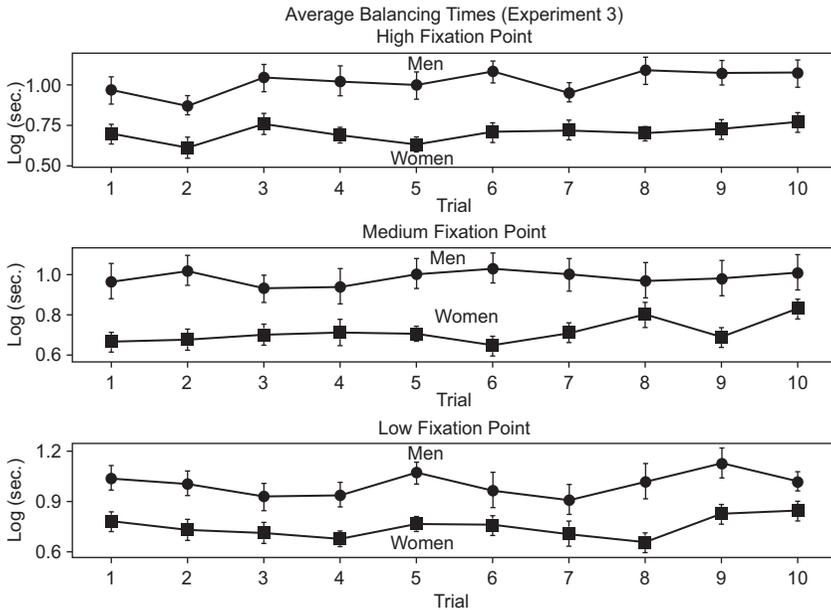
Fig. 3. Mean Log_{10}-transformed balancing times in seconds across ten trials with fixation points 56, 36, or 36 cm above the bottom of a 46-cm rod (Experiment 3). Error bars depict ±1 standard error of the mean (SEM).

ure to find an overall effect for fixation point in either women or men. The data cast doubt on the validity of the underlying assumption that focusing one's attention as high as possible on the rod is an advantageous strategy for successful rod balancing. In addition, there was no significant difference between average balancing times in Exp. 3 (with specified fixation points) and in the comparable condition of Exp. 2 (the same rod length but with unconstrained fixation). Thus, visual fixation point is not an important determinant of rod balancing performance for participants of either sex.

GENERAL DISCUSSION

The findings confirm previous observations in the research literature of a large sex difference in dowel rod balancing. The difference was statistically significant in all three experiments. The mean balancing durations typically were two to three times as long for men as for women, and the average effect size across the eight experimental conditions was 2.5 standard deviations, based on pooled standard deviations for men and women within each condition. ANOVA results indicated that the participant's sex accounted for 18 to 26% of the variance in balancing duration in each experiment.

   This is an unusually large sex difference for findings from either the human performance or the cognitive psychology literature (Thomas & French, 1985; Halpern, 1992). As noted previously, the magnitude of most differences in physical performance—except those that are biased by the greater size, speed, and muscular strength of the mature man—is less than one standard deviation, and women outperform men on several tasks. Similarly, in studies of cognitive abilities, sex seldom accounts for more than 5% of the variance in performance. Differences in linguistic skills such as vocabulary and verbal fluency are small and tend to favor women (Maccoby & Jacklin, 1974). Although many more men than women are found at the high end of the distribution of mathematics ability, average differences between men and women are relatively modest (e.g., Benbow, 1988). Moreover, women tend to outperform men in computation, as distinguished from mathematical reasoning (Engelhard, 1990; Halpern, 1992; Gallagher, De Lisi, Holst, McGillicuddy-De Lisi, Morely, & Cahalan, 2000), and the mathematics grades and achievement test scores of women equal or surpass those of men even at advanced levels of study (Kimura, 1999). On perceptual and visuospatial tasks, a realm in which differences favoring men are common, the magnitude of most differences are small, and there are instances in which women outperform men (Voyer, Voyer, & Bryden, 1995; Kimura, 1999). In their meta-analysis of results from 286 studies of spatial ability, Voyer, *et al*. (1995) calculated the overall weighted mean d to be 0.37, which is a small effect by Cohen's (1988) classification system. The male advantage is statistically significant but sufficient to explain only 3% of the variation in performance.

   One visuospatial task, the mental rotation task of Shepard and Metzler (1971), reliably yields sex differences that account for more than 10% of the explained variance in overall performance. Sanders, Soares, and D'Aquila (1982) reported that sex accounted for 16% of the variance on a paper version of the Shepard and Metzler mental rotation task (Vandenberg & Kuse, 1978). In three other studies cited by Sanders, *et al*., the percentage of mental rotation performance attributable to sex ranged from 13 to 17% (Yen, 1975; Bouchard & McGee, 1977; Wilson & Vandenberg, 1978). Collins and Kimura (1997) showed that a large difference can be obtained on a two-dimensional mental rotation task if it is sufficiently difficult. Sex accounted for 23% of the variance in performance on the difficult two-dimensional task in the Collins and Kimura study. Voyer, *et al*. (1995), in their meta-analysis of measures of spatial ability, found that the 35 sex differences derived from the Vandenberg and Kuse mental rotation task had a mean effect size of $d = 0.67$, which was larger than the effect from 11 other categories of spatial ability tests. A d value of 0.67 indicates an effect that accounts for 10% of the variance.

The similarly large sex difference for rod balancing and mental rotation does not establish a causal link, and the authors know of no data to suggest even a correlation between the respective skills. Although both tasks require reconciling angular disparities, the two tasks otherwise are quite different. The mental rotation task requires matching details of two complex stimuli when one of them has been rotated in space by a variable number of degrees. One of the figures presumably must be rotated mentally so that its orientation is identical to that of the other figure. Only then can the two figures—one present and the other imagined—be assessed to determine whether they are identical. A strong relationship between response time and amount of angular displacement (Shepard & Metzler, 1971) suggests an internal analogue rotation, which men perform more rapidly and more accurately than women (Tapley & Bryden, 1977). Rod balancing requires correcting an angular displacement from the vertical orientation (and thus matching the position of the rod to its initial vertical position), but the required matching process involves spatial positioning without any regard for details in the appearance of the rod itself. Thus, one can conclude that the respective tasks are similar only insofar as both may require rapid processing of angular displacement, or tilt.

Other mental rotation tasks, such as the card-rotation task used by Sanders, *et al*. (1982), yield weaker sex differences (Voyer, *et al*., 1995). Likewise, even though differences favoring men on the rod-and-frame test (Witkin & Asch, 1948) and the water-level test (Piaget & Inhelder, 1956) are well established, the magnitude of those differences is substantially less than the magnitude of the difference on Vandenberg and Kuse's (1978) version of the mental rotation task (Voyer, *et al*., 1995). Nevertheless, since all of these tasks share a common requirement for processing tilt, some overlap with the skills required for rod balancing seems plausible. If the key to balancing success is making corrections quickly, when the tilt is still small, a relatively modest difference in the ability to detect deviations from verticality might be sufficient to yield a much larger difference in balancing performance.

At least two additional categories of explanations for the sex difference in balancing remain to be evaluated. One category is physiological. It is possible, for instance, that having more mass in the arm is advantageous because of the greater inertia, strength, and stability it provides. This explanation could be investigated simply by comparing the performance of women with varying arm size or by determining if the difference disappears when subsamples of women and men are equated for arm size (cf. Peters, Servos, & Day, 1990). Another research strategy would involve changing the weight of the rod. In Exp. 2, changing the length of the rod caused its weight to change accordingly. But the weights of the shortest

and longest rods differed by 23 g—less than an ounce. As very little finger strength is required to support a stick weighing either 19 or 41 g, the absence of any apparent effect of weight is not surprising. It might be informative to assess the sex difference when much heavier rods are being balanced. Another physiological hypothesis concerns the afferent components of the motor system. One could speculate that proprioceptive systems in the muscles, tendons, or joints function differently in men and in women, although there currently does not seem to be overly compelling evidence of this possibility (Cug, Wikstrom, Golshaei, & Kirazci, in press). Another recent study suggests that there may be some sex differences in proprioceptive acuity during weight-bearing pivoting activities (Lee, Ren, Kang, Geiger, & Zhang, 2015), but it is unclear how such findings might be related to the rod-balancing task, given the minimal weight of the rods used in the current study.

Yet another category of explanation is suggested by findings from a brief sports-participation questionnaire that was completed by all participants in Exp. 3. Its purpose was to obtain information about past and current involvement in "open-skill" sports such as tennis, soccer, and basketball (Brady, 1996). Men reported about three times the number of open-skill sports as women and about three times the number of hours per week spent playing those sports. The sports variables were not correlated with men's dowel rod balancing performance, but for women the number of hours currently devoted to open-skill sports was positively correlated with balancing performance ($r = .59$; $p < .01$, one-tailed test; $95\% CI = .17, .83$). One provisional conclusion from these data is that the sex difference in rod balancing reflects, to some extent, men's more frequent participation in sports. A second tentative conclusion is that, at least among young female adults, participating in certain sports tends to enhance balancing performance relative to the performance of other women. Given the small sample sizes, especially within each sex, an actual link between athletic activity and rod balancing remains uncertain.

The present study supported the reliability and large magnitude of the previously observed sex difference in rod balancing, but it did not support hypothetical explanations involving posture while balancing, length of the rod being balanced, and visual fixation point. Admittedly, there were shortcomings in the methodology that may allow alternative interpretations of some of the findings. Recording the participant's eye movements would have mitigated concern that men and women might be exhibiting subtle differences in their gaze patterns. A strong manipulation of rod weight, independent of length, would have clarified the relevance of weight while addressing the plausibility of differential strength as a factor that contributes to the sex difference. Most importantly, a computer-based

methodology with kinematic analysis might allow a better understanding of sources of variability from one trial to the next, the temporal relationship between rod displacement and corrective action, the kinds of corrective actions that prove to be maladaptive, etc. If the act of rod balancing can be dissected into small discrete movements that can be tracked in real time, it should be possible to isolate the elements that differentiate a good trial from a bad trial and consistently good performers from individuals who perform less successfully.

Balancing a rod on the fingertip is a complex sensorimotor task that demands a high level of coordination among visual, tactual, motor, proprioceptive, and cognitive systems. Moreover, the substantial trial-to-trial variability of performance within an individual implicates additional factors that could be attentional, strategic, motivational, or emotional. Investigators have measured performance with the simple (but definitive) dependent variable of number of seconds until the rod falls to the floor, but it is unrealistic to expect to capture the complexity of the balancing act with so crude an index. Its crudeness notwithstanding, this measure consistently has yielded a remarkably large sex difference. More refined methods probably will be necessary to isolate the cause of the sex difference. On the other hand, such methods may show that there is no single causal factor. The large sex difference could be attributable to the additive effect of multiple small differences between women and men.

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