Cursor Orientation and Computer Screen Positioning Movements

James G. Phillips and **Tom J. Triggs,** Monash University, Clayton, Australia, and
James W. Meehan, Aeronautical and Maritime Research Laboratory, Melbourne, Australia

Implicit directional cues in arrowhead cursors could influence positioning of a cursor on the screen of the computer. Performance during cursor placement may benefit from compatibilities between cursor orientation and direction of movement. Arrowheads could also elicit illusory processes that may affect judgments of (a) the distances on the screen or (b) the location of the point of the arrowhead. To address the impact of the cursor's orientation on its positioning, we had 12 participants move cursors (crosshairs, leftward, or rightward arrow) leftward or rightward to targets (near, far) on a computer screen. Movement amplitude was more important than cursor orientation for initiation of rightward movements, whereas cursor orientation affected the duration of leftward movements and movements to farther targets. Arrowhead orientation contributed to the greater overshooting of far targets. There was little evidence that compatibility of orientation and direction of movement assisted response initiation or execution, and there was little indication that arrowhead cursors led to illusory effects that influenced cursor placement. Arrowhead cursors can provide irrelevant stimulus dimensions that distract users. This work can be applied to the design of cursors in graphical user interfaces. The use of orientation-neutral cursors or cursors whose stimulus dimensions are more relevant is recommended.

INTRODUCTION

Graphical user interfaces are a preferred mode of human-computer interaction (Baber, 1997). Typically using a pointing device, the operator places a cursor within a menu or elsewhere on the computer screen. Arrowhead cursors are found in a variety of applications (Dix, Finlay, Abowd, & Beale, 1998). The vertex of the arrow primarily indicates the location of a "hotspot" that interacts with icons and menus (Dix et al., 1998), but it also affords a directional cue that may be different from the desired axis of movement. In particular, arrowhead cursors often point to the upper left corner of the computer screen, and because key icons tend to be situated in the top left or top right of computer screens, there are likely to be many instances when cursor orientation is different from the desired cursor motion. Incompatibility between direction of the cursor and orientation of the arrow may affect the speed and accuracy of cursor positioning movements.

Poor pointing device performance means prolonged periods spent in relatively fixed postures, a potential risk factor for cumulative trauma disorder (Fogleman & Brogmus, 1995). There have been reports that cursor positioning is inefficient compared with normal positioning movements (MacKenzie, 1992; Maraj, Elliott, Lyons, Roy, & Winchester, 1998), requiring a greater number of corrective submovements. Some of these inefficiencies may reflect cursor shape and orientation. An understanding of mechanisms leading to inefficient cursor placement can provide guidelines as to the most effective cursor shape as a function of its screen location, direction of motion, or both. This study therefore addressed the impact of

Address correspondence to James G. Phillips, Psychology Department, Monash University, Clayton VIC 3800, Australia.
HUMAN FACTORS, Vol. 43, No. 3, Fall 2001, pp. 435–441.

cursor orientation on cursor positioning using a mouse.

The tip of an arrowhead cursor codes the *location* of a hotspot that interacts with menus and icons; however, arrows can also code *direction* (Kantowitz, Triggs, & Barnes, 1990). This effect is important because incompatibility between orientation of the cursor and required axis of motion may cause difficulty in initiating movements (Proctor, Van Zandt, Lu, & Weeks, 1993; Weeks & Proctor, 1990). Moreover, Worringham and Beringer (1998) reported shorter movement durations for visually compatible movements controlled by a joystick, indicating that any potential Stimulus-Response (S-R) incompatibility can also influence positioning times. Nevertheless, there are also reports that S-R incompatibility does not affect movements (e.g., Spijkers, 1990), so there is a need to consider additional mechanisms by which cursor shape may affect positioning times.

A number of geometric illusions in which distances are underestimated or overestimated involve arrowheads. With figures such as those producing the Müller-Lyer or Judd illusion (Day & Knuth, 1981), users overestimate distance when the arrow points in the direction to be judged and underestimate distance when the arrow points away from the direction to be judged. Such illusions can be produced by a single arrowhead (Greene & Nelson, 1997). Alternatively, the degree of visual acuity or screen resolution may affect perceived location of the vertex of the arrow, with poorer acuity/resolution leading to difficulty perceiving the vertex and hence a shortening of the arrow (see Morgan & Glennerster, 1991). A foreshortening of arrowhead cursors would lead to a tendency to overshoot the target when the arrow points to the target and a tendency to undershoot when the arrow points away from the target.

This being so, arrowhead cursors may generate problems in planning the extent of cursor movements as a function of the orientation of the cursor relative to the direction of motion. A kinematic analysis may assist in understanding such effects (see Daprati & Gentilucci, 1997), given that it has the potential to determine any disturbances to cursor trajectory as the operator seeks to compensate for the effects of cursor orientation.

In order to understand mechanisms contributing to efficiency in cursor positioning, the present study addressed the impact of cursor orientation relative to direction of motion. By pointing arrowhead cursors in directions compatible or incompatible with the axis of motion, it is possible to determine the impact of cursor orientation. A kinematic analysis allows for a determination of the nature of any effect of cursor orientation. S-R compatibility would be liable to cause differences in reaction and movement time. If cursor shape elicits illusory effects, then (a) arrows pointing in the direction of motion will lead to an overestimate of the distance to be moved – which would be characterized by overshooting of the target – and (b) arrows pointing away from the direction of motion will lead to an underestimate of the distance to be moved – which would be characterized by undershooting of the target.

METHOD

Participants

A group of 12 university students with a mean age of 22.2 years (*SD* = 4.4 years) were paid $6 (Australian) for their time. There were equal numbers of men and women, and all participants were right-handed (as established by a modified version of the handedness questionnaire from Bradshaw, Bradshaw, & Nettleton, 1990).

Apparatus and Task

The task was performed on an Aridyne (Melbourne, Australia) 486 IBM-compatible desktop computer with a 17-in. VGA monitor and a Microsoft (Redmond, WA) two-button mouse. The cursor could be a crosshair or an arrow pointing to the upper left or the upper right of the screen. The cursors were produced by an icon generator. The leftward and rightward arrows were 13 × 18 pixels in their horizontal and vertical aspects; the arrows were 22 pixels long with heads 14 pixels wide. The crosshair was 1 pixel thick and was 15 × 15 pixels in horizontal and vertical aspect. The arrows were of comparable sizes to those used in typical graphical user interfaces (e.g., Microsoft Windows). Participants moved a solid white cursor on a black screen toward a red-outline circle target.

Cursor location was sampled as x and y coordinates at 200 Hz (i.e., every 5 ms). Participants used the mouse to place a cursor in a starting location situated on the left or right side of the screen and were then required to move the cursor rightward or leftward to a near (95 mm) or far (190 mm) circular target of 10 mm diameter.

Procedure

Participants were seated so that they were aligned with the midline of the computer screen. They were instructed to use the mouse to position the cursor in the starting location, as indicated to them by the computer. The computer sampled the cursor location and indicated to the experimenter when the cursor was in the starting location. The experimenter then enabled the next trial. To start the trial, the participant clicked the mouse. The computer then presented a target on the other side of the screen, to which the participant was instructed to move quickly and accurately. Trials terminated 2 s after the cursor entered the target. Participants were presented with a block of 24 practice trials, which was followed by 10 blocks of 12 experimental trials.

Design and Analysis

For each trial, the analysis of kinematic features of cursor motion was performed along the x axis. To remove any quantization error (jitter), coordinates were low-pass filtered at 10 Hz. The coordinates of the resulting displacement function were differentiated twice using a nine-point central-finite differences algorithm to produce velocity and acceleration functions.

Total time was defined as the duration of time from target presentation to movement cessation. *Reaction time* was defined as the duration of time from target presentation to onset of cursor movement. *Movement time* was defined as the interval of time from onset of cursor movement to the point in time at which maximum displacement occurred. *Inefficiency of trajectory* was assessed using the number of cycles of acceleration and deceleration (determined from zero-crossings in the acceleration function) per submovement (determined from zero-crossings in the velocity function). The locus of maximum displacement (*overshoot*) was used as an index of movement accuracy.

Cursor orientation (crosshair, leftward, rightward), direction of movement (leftward, rightward) and distance (near, far) were varied to produce 12 conditions. Participants performed 10 trials in each condition. Kinematic indices were calculated for each trial and averaged over the 10 trials in each condition. These indices were then subjected to separate $3 \times 2 \times 2$ repeated-measures analyses of variance (ANOVAs).

RESULTS

Total Time

It took on average 1554 ms to position the cursor on the computer screen. In this study it took significantly longer to position cursors in far targets ($M = 1697$ ms) than in near targets, ($M = 1412$ ms), $F(1, 11) = 73.182$, $p < .001$. This is noteworthy when considering motions with similar indices of difficulty. For example, our task had indices of difficulty of 4.25 and 5.25, associated with times of 1412 ms and 1697 ms, respectively, whereas one might expect times of 528 ms and 608 ms for simple positioning movements with comparable precision requirements (Fitts & Peterson, 1964). Nevertheless, there was no significant difference among crosshairs ($M = 1560$ ms), leftward ($M = 1532$ ms), or rightward ($M = 1571$ ms) pointing cursors; $F(2, 22) = 0.530$, $p > .05$. There were no other effects on total time, providing little indication as to mechanisms responsible for the prolonged times associated with the performance of this task.

Reaction Time

Reaction time is used as an index of the ability to plan movements. The mean reaction time was commensurate with that expected in visual choice reaction time tasks (Welford, 1980). Participants required less time to plan movements to near targets ($M = 271.8$ ms) than to far ones ($M = 280.6$ ms), $F(1, 11) = 5.225$, $p < .05$. Evidence of S-R compatibility effects was provided by the interactive effects of cursor orientation and movement direction, $F(2, 22) = 4.903$, $p < .05$ (see Figure 1). An analysis of simple main effects indicated that for *rightward movements*, response initiation was superior for a crosshair ($M = 264.1$ ms) compared with the compatible rightward-facing ($M = 279.3$ ms) or the incompatible leftward-facing ($M = 279.4$ ms) cursors, $F(2, 22) = 3.519$, $p < .05$. However, this interaction was not symmetric because participants were not significantly faster at initiating *leftward movements*; the compatible leftward-facing cursor ($M = 270.0$ ms) was only marginally faster than rightward-facing ($M = 280.6$ ms) and crosshair ($M = 283.7$ ms) cursors, $F(2, 22) = 2.365$, $p > .05$.

The effects of movement amplitude on reaction time were also modified by movement direction. There was a significant interaction between movement direction and amplitude, $F(1, 11) = 9.731$, $p < .05$. Simple main effects indicated that movement amplitude had a greater impact on the initiation of rightward movements (mean difference = 19.2 ms, $F(1, 22) = 16.561$, $p < .05$) than leftward movements (mean difference = 1.6 ms, $F(1, 22) = 0.117$, $p > .05$).

Movement Time

Movement time is used as an index of the difficulty of response execution. In this task the mean movement time required to position the cursor ($M = 838.4$ ms) was demanding compared with that expected for ordinary positioning movements with similar indices of difficulty (264 and 338 ms; Fitts & Peterson, 1964). Indeed, the positioning of the cursor was more difficult than the planning of any response, because participants took three times longer to position the cursor than to initiate the response. As might be expected, participants took longer to position a cursor in a far target ($M = 929.8$ ms) than a near ($M = 747.0$ ms) one, $F(1, 11) = 35.835$, $p < .05$, but such effects should be considered in the context of two significant interactions. There was a significant Direction of Movement × Cursor Orientation interaction, $F(2, 22) = 6.111$, $p < .05$, which can be seen in Figure 2. Simple main effects found that cursor orientation had a significant effect on movement times for leftward, $F(2, 22) = 8.251$, $p < .05$, but not rightward movements, $F(2, 22) = 0.532$, $p > .05$.

Although there was some expectation of superior positioning performance with cursor orientations compatible with movement direction, this was not the case: A rightward-facing cursor was the fastest when moving in a leftward direction. Given that movements tended to be faster for cursor orientations that were

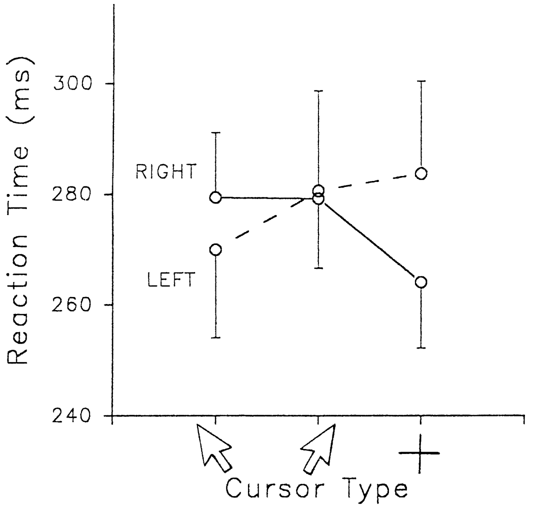

Figure 1. Interactive effects of cursor shape (leftward- or rightward-pointing arrowheads, or crosshairs) and direction of motion (right, left) on reaction time (ms).

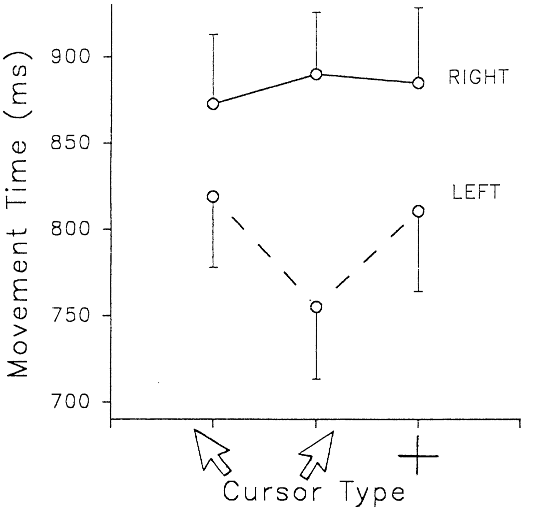

Figure 2. Interactive effects of cursor shape (leftward- or rightward-pointing arrowheads, or crosshairs) and direction of motion (right, left) on movement time (ms).

incompatible with direction of movement, this is unlikely to be a direct effect of compatibility. The effect is also unlikely to be a result of illusory processes; an arrow pointing away from the direction of motion is likely to lead to an underestimate of the distance and hence slower movements (not faster ones, as observed in this study). Instead, the data suggest that people at first move the center of the cursor to the center of a target icon before repositioning the hotspot in the correct location.

Because movement duration was measured up to the point of maximum extent (overshoot), it is a simplification of typical computer usage but is nevertheless informative. There was a significant interaction between movement amplitude and cursor orientation, $F(2, 22) = 15.956$, $p < .05$ (see Figure 3). Simple main effects indicated that cursor orientation had a significant effect for far targets, $F(2, 22) = 16.741$, $p < .05$, but not near targets, $F(2, 22) = 2.571$, $p > .05$. Tukey's Honestly Significant Difference (HSD; Gravetter & Wallnau, 2000) revealed that a rightward-pointing arrow was faster than either a leftward-pointing arrow (mean difference = 64.5 ms) or a crosshair (mean difference = 84.2 ms). This result implies that cursor orientation has a greater effect on full-screen movements, whereas a

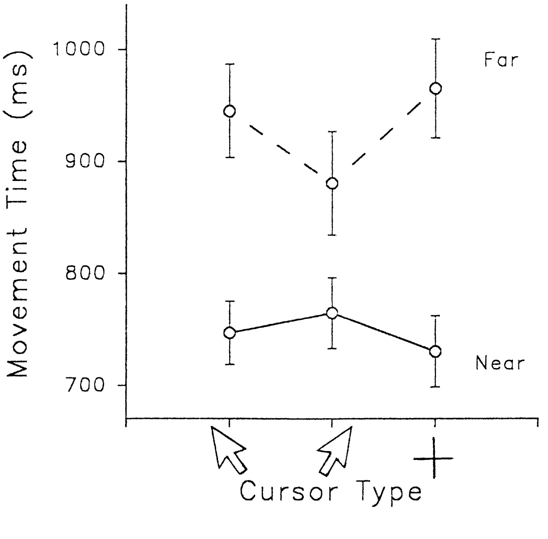

Figure 3. Interactive effects of cursor shape (leftward- or rightward-pointing arrowheads, or crosshairs) and movement amplitude (near, far targets) on movement time (ms).

direction-neutral cursor such as a crosshair can be appropriate when interacting with closer target icons.

Trajectory Efficiency

If cursor orientation was responsible for problems of cursor positioning, one might expect there to be effects of cursor orientation on the efficiency of cursor trajectories. However, there was no effect of cursor shape on the number of accelerative and decelerative impulses per submovement, $F(2, 22) = 0.008$, $p > .05$. Even so, there was a trend for rightward movements ($M = 4.65$) to require fewer cycles of acceleration and deceleration than for leftward movements ($M = 5.03$), $F(1, 11) = 4.046$, $p < .07$. Similar effects have been observed in simple positioning tasks (Morgan et al., 1994), but any biomechanical differences that have contributed to such effects are likely to be diminished in graphical user interfaces when motions of the controller are reduced in scope. Nevertheless, movement amplitude did influence the efficiency of movement; movements to farther targets ($M = 5.155$) required more accelerative/decelerative impulses per submovement than did those to nearer targets ($M = 4.525$), $F(1, 11) = 5.728$, $p < .05$.

Positioning Accuracy

If arrowhead cursors elicit geometric illusions, we would expect that arrows pointing in the direction of movement might cause overshooting (because the distances are overestimated), whereas arrows pointing away from the direction of movement might cause undershooting (because the distances are underestimated). Any problems in the estimation of distances might manifest in participants' movement trajectories at the point of overshoot. The significant interaction between direction of motion and cursor orientation, $F(2, 22) = 11.336$, $p < .05$, is therefore of interest and can be seen in Figure 4. An analysis of simple main effects revealed a significant effect of cursor orientation on rightward, $F(2, 22) = 17.689$, $p < .05$, but not leftward movements, $F(2, 22) = 0.536$, $p > .05$; the rightward-pointing arrow produced the greatest overshoot ($M = 2.14$ mm).

The superior positioning performance when moving leftward is also reflected in the

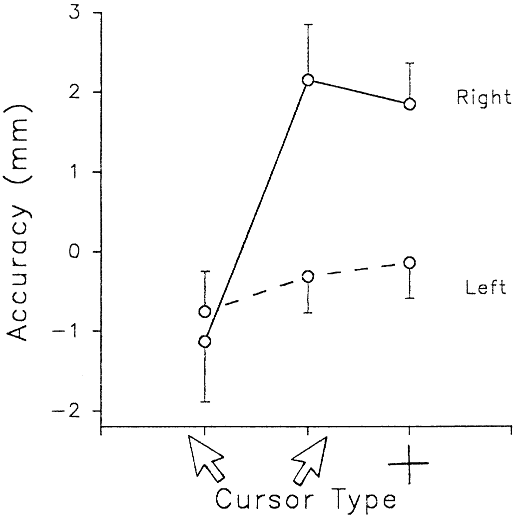

Figure 4. Interactive effects of cursor shape and direction of motion on target overshoot (mm). Cursor shape has a greater effect on the overshooting of rightward movements.

significant Direction × Movement Amplitude interaction, $F(1, 11) = 8.385$, $p < .05$. There was a significant simple main effect of movement amplitude when moving to the right (mean difference = 1.6 mm), $F(1, 22) = 10.955$, $p < .05$, but not when moving to the left (mean difference = 0.4 mm), $F(1, 22) = 0.617$, $p > .05$. This result provides some indication that geometric illusions can affect cursor positioning performance, but directional effects suggest a differential sensitivity as a function of cursor location on the screen.

DISCUSSION

Because the arrowhead cursors in graphical user interfaces provide implicit directional cues, this study considered whether the effectiveness of cursor positioning was influenced by S-R compatibility, illusory processes, or both. Cursor positioning was certainly inefficient, and although reaction times were relatively normal, we observed that participants required about three times as long to position a cursor on a computer screen relative to simple pointing movements with comparable precision requirements. Cursor orientation affected the execution of movements to the left of the computer screen, whereas movement amplitude was more likely to influence the initiation and accuracy of movements to the right. However, although cursor orientation affected cursor positioning, these effects are unlikely to be a product of S-R compatibility or geometrical illusions.

It was difficult to explain performance in terms of compatibilities between direction of arrow and direction of motion, as neutral cursors provided the only significant facilitation to reaction times. Indeed, arrowheads appeared to offer an irrelevant stimulus dimension that operators had to ignore. Instead, the directional dependence of our findings seems to indicate functional specializations associated with left and right visual fields, as cursor orientation affected movements into the left hemispace that has superiorities in visuospatial processing (Bryden, 1988), whereas movement amplitude affected initiation and overshooting of movements into the right hemispace.

The absence of clear illusory effects of cursor shape on judgments of distance or cursor positioning may reflect the reported tendency to judge distances between objects in terms of their centroids, which has been suggested to underlie some illusory effects of geometric figures (Morgan & Glennerster, 1991; Morgan, Hole, & Glennerster, 1990). In the present study, the observation that participants tended to move the center of the cursor to the center of the target is in keeping with this hypothesis.

The prolonged periods required for cursor placement during human-computer interaction lead to a number of recommendations. When speeded responses are required, more direct and natural interfaces (e.g., touch-sensitive screens) might be appropriate, and orientation-neutral cursors could prove useful if reaction time is important. In addition, graphical user interfaces could reduce the distances between target icons and the requirements for rightward movements by using larger icons on the right or by placing icons closer together on the left side of the screen.

Given that extended periods spent in placing arrowhead cursors are not a product of S-R incompatibilities or illusory effects, cursor orientation serves merely as a distraction that operators need to ignore. An orientation-neutral cursor, such as a crosshair or annulus, should be used for precise positioning in near space, although the shape (e.g., × or +) should be chosen to enhance visibility during specific tasks (e.g., icon selection versus text editing). Alternatively, there should be an attempt to make the direction of the arrowhead cursor more relevant, perhaps by dynamically orienting it to the most likely direction of use.

ACKNOWLEDGMENTS

The authors acknowledge the assistance of Lauren Saling and Mike Durham.

REFERENCES

Baber, C. (1997). *Beyond the desktop: Designing and using interaction devices*. San Diego, CA: Academic.

Bradshaw, J. L., Bradshaw, J. A., & Nettleton, N. C. (1990). Abduction, adduction, and hand differences in simple and serial movements. *Neuropsychologia, 28*, 917–931.

Bryden, M. P. (1988). Cerebral specialisation: Clinical and experimental assessment. In F. Boller & J. Grafman (Eds.), *Handbook of neuropsychology* (Vol. 1, pp. 143–159). Amsterdam: Elsevier.

Daprati, E., & Gentilucci, M. (1997). Grasping an illusion. *Neuropsychologia*, *35,* 1577–1582.

Day, R. H., & Knuth, H. (1981). The contributions of F. C. Müller-Lyer. *Perception, 10,* 126–146.

Dix, A. J., Finlay, J. E., Abowd, G. D., & Beale, R. (1998). *Human-computer interaction.* London: Prentice-Hall.

Fitts, P. M., & Peterson, J. R. (1964). Information capacity of discrete motor responses. *Journal of Experimental Psychology*, *67,* 103–112.

Fogleman, M., & Brogmus, G. (1995). Computer mouse use and cumulative trauma disorders of the upper extremities. *Ergonomics*, *38,* 2465–2475.

Gravetter, F. J., & Wallnau, L. B. (2000). *Statistics for the behavioral sciences.* Belmont, CA: Wadsworth.

Greene, E., & Nelson, B. (1997). Evaluating Müller-Lyer effects using single fin-set configurations. *Perception and Psychophysics*, *59,* 293–312.

Kantowitz, B. H., Triggs, T. J., & Barnes, V. E. (1990). Stimulus-response compatibility and human factors. In R. W. Proctor & T. G. Reeve (Eds.), *Stimulus-response compatibility* (pp. 365–388). Amsterdam: North-Holland.

MacKenzie, I. S. (1992). Fitts' law as a research and design tool in human-computer interaction. *Human-Computer Interaction*, *7,* 91–139.

Maraj, B. K. V., Elliott, D., Lyons, J., Roy, E. A., & Winchester, T. (1998). Influence of spatial mapping on manual aiming asymmetries. *Perceptual and Motor Skills*, *86,* 967–975.

Morgan, M., Bradshaw, J. L., Phillips, J. G., Mattingley, J. B., Iansek, R., & Bradshaw, J. A. (1994). Effects of hand and age upon abductive and adductive movements: A kinematic analysis. *Brain and Cognition*, *25,* 194–206.

Morgan, M. J., & Glennerster, A. (1991). Efficiency of locating centres of dot-clusters by human observers. *Vision Research*, *31,* 2075–2083.

Morgan, M. J., Hole, G. J., & Glennerster, A. (1990). Biases and sensitivities in geometrical illusions. *Vision Research*, *30,* 1793–1810.

Proctor, R. W., Van Zandt, T., Lu, C.-H., & Weeks, D. J. (1993). Stimulus-response compatibility for moving stimuli: Perception of affordances or directional coding? *Journal of Experimental Psychology: Human Perception and Performance*, *19,* 81–91.

Spijkers, W. A. C. (1990). The relation between response-specificity, S-R compatibility, foreperiod duration and muscle-tension in a target aiming task. *Acta Psychologica*, *75,* 261–277.

Weeks, D. J., & Proctor, R. W. (1990). Salient-features coding in the translation between orthogonal stimulus and response dimensions. *Journal of Experimental Psychology: General*, *119,* 355–366.

Welford, A. T. (1980). *Reaction times.* London: Academic.

Worringham, C. J., & Beringer, D. B. (1998). Directional stimulus-response compatibility: A test of three alternative principles. *Ergonomics*, *41,* 864–880.

James G. Phillips is a senior lecturer of psychology at Monash University, Clayton, Victoria, Australia. He received a Ph.D. in psychology from Flinders University in 1987.

Tom J. Triggs has a personal chair within the psychology department of Monash University and is deputy director of the Monash University Accident Research Centre. He received a Ph.D. in psychology from the University of Michigan in 1968.

James W. Meehan is a senior research scientist in the Air Operations Division at the Aeronautical and Maritime Research Laboratory, Fishermans Bend, Melbourne, Australia. He received a Ph.D. in psychology from Monash University in 1990.

Date received: June 13, 2000
Date accepted: October 17, 2000