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Absence of a gender difference in a haptic version of the water-level task

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The present experiment studied horizontality representation among men and women submitted to a haptic version of the water-level task. Without seeing the display, the subjects positioned a magnetic rod corresponding to the water line. It was found that the women performed as well as the men did, in contrast to the systematic male superiority under the standard visual version. Similarly, there was no gender effect when the subjects were instructed to set the rod horizontally in tilted containers. The absence of misleading visual information and the beneficial contribution of salient proprioceptive cues through haptic activity were suggested as possible determinants for the canceling of typical gender differences.

Among visuospatial tasks, the water-level task calls for both the mastery of the Euclidean system of coordinate axes and some knowledge of the physical behavior of liquids. Failure on this task has been repeatedly measured in a significant proportion of adults, mostly women, who do not represent the water line as horizontal irrespective of the container's tilt (Liben, 1991; Linn & Petersen, 1985).

Various visual formats of the task have been tested. Under a selection or recognition format, the subject is shown a series of tilted containers (one with a horizontal line and each of the others with a differently oriented oblique line), among which the correct orientation of the water surface must be identified. Line drawings of the containers may be employed (Harris, Hanley, & Best, 1977). Real containers may also be presented on stereoscopic slides (Howard, 1978) or on a computer screen through digitalized photographs (McAfee & Proffitt, 1991). Under a production format, the subject generally uses a pencil to draw the water line in containers outlined on sheets of paper (Liben & Golbeck, 1986). Working with the Thomas apparatus (Thomas & Jamison, 1975), he or she may also have to adjust the orientation of a straight line as if it were the water line in a tilted bottle. A positive correlation has been found between success with each of these two production variants and correct selection from line drawings (Wittig & Allen, 1984). More importantly, the typical gender difference occurs under both the production and the selection formats (Liben, 1991; Linn & Petersen, 1985).

Interested in how spatial concepts develop, Piaget and Inhelder (1948) devised the water-level task along with several other tasks. However, having asked children to draw the water line as well as to gesture its orientation with their hands, these authors observed that correct gestures outnumbered correct drawings. Such a response gap has been recently replicated by Ackermann-Valladão (1987), who emphasized that the gesture response involves relevant kinesthetic information that stresses the child's own body position in relation to the ground. This information may compensate for the misleading visual information provided by the container's orientation, whereas such information is unavailable in the drawing situation. However, the possibility of a greater gesture-drawing gap among girls than among boys was not investigated.

As the partial canceling of visual input through motoric assistance appeared to facilitate mastery, the purpose of the present experiment was to devise a version of the water-level task that would preclude any visual perception while favoring proprioceptive involvement. It was conceived that such a version should involve both haptic exploration of the container and haptic setting of the water line.

Indeed, the haptic perceptual system incorporates both cutaneous and kinesthetic inputs that are derived through manual exploration and from which knowledge is extracted about objects, their properties, and spatial layout (Loomis & Lederman, 1986). The strength of the anatomical and proprioceptive coding characterizes performance in tactile motor tasks, since the axis of gravity and the plane of the ground supply the basic references for haptic perception (Gibson, 1962; Kennedy, 1978). Such body-centered functioning has been contrasted with the prevalence of environmental references in visual motor tasks (Hasbroucq & Guiard, 1986). It is noteworthy that no gender differences have been found in the haptic identification of planar stimuli (Flannery & Balling, 1979; Witelson, 1976) or three-dimensional objects (Summers & Lederman, 1990). Moreover, when the orientation of a bar within a tilted grid had to be either horizontally or vertically adjusted in either tactual or visual perception conditions, accuracy was not related to gender under the tactual condition, whereas men surpassed women under the visual condition (Walker, 1972).

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It was reasoned that, in the visual format of the water-level task, a number of subjects, mostly women, might erroneously focus on the container's shape and orientation, instead of relying on appropriate internal cues as to the direction of gravity. Since the shape and contour of objects are considerably less salient under haptic exploration than under visual inspection (Klatzky & Lederman, 1987), it was thought that the typical female handicap might not develop with a haptic version oriented toward body-centered references.

A control task involving the production of horizontal lines within tilted rectangles was included in order to assess the subjects' capacity to haptically locate the horizontal plane. No gender differences have been measured in the visual format of this task (Liben & Golbeck, 1986).

METHOD

Subjects

Aged between 19 and 34 years (mean age = 23.9 years), 18 women and 15 men with normal or corrected vision were recruited for the experiment and paid $5 each. All were French-speaking students from the Université de Montréal majoring primarily in social sciences and humanities. These programs were selected, given that, in a much larger sample drawn from the same population, approximately equal numbers of men and women had volunteered to participate in a similar study after all members of several classes had been invited to do so (Robert, 1989). None of the departments involved had a subject pool policy.

Materials

The device used for the haptic version of the water-level and horizontal tasks comprised the following elements. Rectangular shapes (7.6 cm high × 5 cm wide) representing containers had been cut out in the bottom halves of five metal plates (48 cm long × 35 cm wide × 0.2 cm thick).[1] On both surfaces of each plate, a plastic strip (0.6 cm wide × 0.35 cm thick) served as the container's contour on three sides, whereas the lid was indicated by a wider (1.3 cm) strip covered with sandpaper. Parallel to the plate's bottom edge, a plastic strip (20 cm long × 0.6 cm wide × 0.35 cm thick) served as the table on which the container was set. In different positions on different plates, the container was either upright or tilted at 30°, 60°, 300°, and 330° (0° corresponding to the horizontal on the right-hand side). Figure 1 (top) illustrates a 60° tilt. On the underside of the plate, all four sides of the container were calibrated in millimeters; these references could not be haptically felt. A wooden rod (22 cm long × 0.2 cm wide) had a small block (3.2 cm long × 1.4 cm wide × 2.2 cm thick) fixed at each end, with a strip of magnetic plastic (3.2 cm long × 1.4 cm wide × 0.5 cm thick) glued on one face of each block. Figure 1 (bottom) illustrates the magnetic rod adhering to the underside of the plate.

Two wooden boards were used to maintain the plate in a fixed position. Board A (91 cm long × 5.7 cm wide × 2 cm high) was fixed with C clamps across the full width of a rectangular table, 1 cm from the tabletop and 18 cm from the edge of the table on the subject's side; board B (18 cm long × 1.3 cm wide × 1 cm high) was glued onto the table, perpendicular to board A. The boards and clamps were covered with cardboard. A large block (22 cm long × 17 cm wide × 28 cm high), with a small cardboard right angle (7.2 cm long × 4.5 cm wide × 2.3 cm high) glued on top, was placed at each end of board A on the subject's side.

Additionally, a wooden stick (76.5 cm long × 5.7 cm wide × 2 cm thick) and an opaque hairdressing cape (110 cm long × 150 cm wide), with Velcro strips around the neck opening, were part of the equipment. The stick maintained the cape in position, screening the display from the subject's view during each item from either the water-level or the horizontal task. A piece of cardboard (20.2 cm long × 22.7 cm wide), with a magnetic plastic strip glued to its upper and lower edges, served the same purpose between items.

Procedure

A male or female experimenter examined each subject individually. The subject was informed that he or she would complete two unconnected types of tasks, using a different table for each type. Sitting in a swivel chair, the subject alternately performed one item from either the water-level or the horizontal task on table 1 and, following a 180° turn, completed a filler task on table 2. The filler (visual) tasks were unrelated to either the water-level or horizontal tasks and involved, for instance, reversible figures and paper mazes. Alternating between tables 1 and 2, the subject could not see table 1 while the experimenter was recording the answer after each item or arranging the display in preparation for the next item.

Before the subject entered the experimental room, the plate with the upright container was set under board A on table 1, its left side adjacent to board B. On the subject's side of table 1, the plate was covered with the magnetic cardboard, its lower end projecting 30 cm from the table. The subject put on the hairdressing cape and sat in the swivel chair. The experimenter rolled up a few centimeters of the cape on the stick that was then set against the cardboard right angles on top of the blocks, preventing the subject from seeing the materials that were later touched or manipulated. This option was preferred to that of blindfolding, which might have favored visual imagery.

Having withdrawn the cardboard, the experimenter invited the subject to explore the plate using one or both hands while listening to the description of the container (and lid) set in the upright position on a table. The subject also became familiarized with handling the rod and having it adhere under the plate. The experimenter then covered the plate with the cardboard and handed the stick at the bottom of the cape to the subject who put the stick in his or her lap and turned toward table 2. In preparation for the filler tasks, the subject read the instructions in the booklet on table 2. These instructions indicated that a limited time was devoted to each filler task and that when asked to, the subject should go back to table 1 even though he or she had not finished a filler task. In the meantime, the experimenter set the rod horizontally under the plate, approximately at the container's midheight. Upon returning to table 1, the subject put the stick against the cardboard right angles on top of the blocks. The water-level task was always performed prior to the horizontal task so as to avoid any beneficial carryover resulting from first performing the horizontal task.

In the water-level task, he or she was asked to imagine that some water was in the container and that the rod represented the water surface. The experimenter withdrew the cardboard and the subject haptically explored the container, water surface, and table line. The cardboard was put back on, and the subject turned around for the first filler task. The experimenter installed a plate with a tilted container. Returning to table 1, the subject was instructed that from then on the container would be tilted in various positions and that his or her task was to set the rod under the plate as if it were the water surface, using one or both hands, above or beneath the plate (see Figure 2). It was specified that although the exact amount of water in the container was unimportant, one could imagine that the container was approximately half full. The subject was asked to inform the experimenter when he or she had finished setting the rod. During rod positioning, the experimenter did not look at the subject's face. Unobtrusively, he or she observed whether one or both hands were used and recorded all information that might reveal the strategy employed by the subject. Once the rod was positioned, the cardboard was put back on the plate. While the subject was working on the second filler task, the experimenter carefully turned the plate over and registered where the upper edge of the rod crossed the two sides of the container. The next plate was then set in place and covered with the cardboard; the subject was asked to come back to table 1. Four tilted containers were presented in four different random orders across subjects within each gender.

In the horizontal task, the subject was informed that he or she would now have to set the rod horizontally within the container in various tilted positions, the setting height being unimportant. Except for the fact that exploration of the plate with the upright container was not repeated, the above-mentioned procedure was replicated. The containers were presented in the same random order as that used in the water-level task.

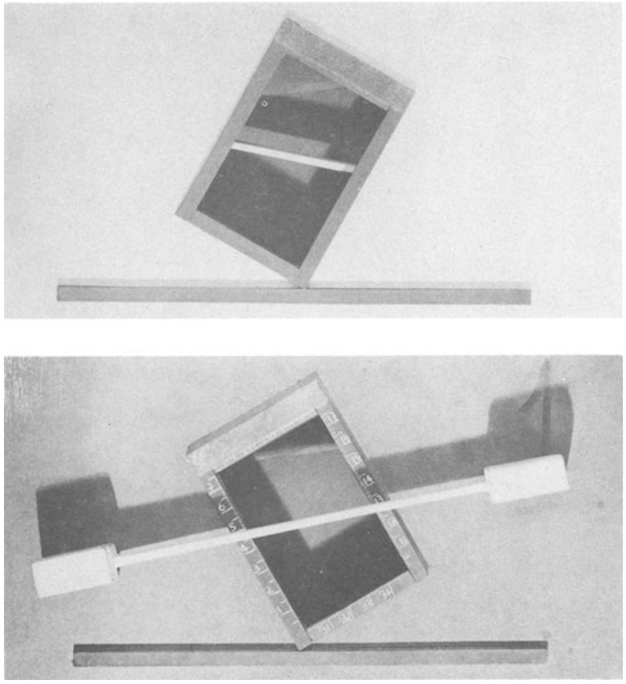

Figure 1. Tilted (60°) container on a table, with rod positioned by subject. Top: upper face of the plate in which the container's contour has been cut out. Bottom: underside of the plate onto which the rod with magnetic blocks adheres. Deviation from the horizontal is determined using the calibrated scale around the container.

RESULTS

Water-level and horizontal rod positionings were dealt with in the following fashion. The two points at which the rod crossed the sides of the container were entered on line drawings of the containers with the same size and orientation as those used on the plate. A straight line was drawn across these two points, and its deviation from the horizontal was scored with a protractor. During scoring, the experimenters were blind as to the subjects' gender. Both the water-level and the horizontal tasks were scored using the customary water-level criterion (Rebelsky, 1964) requiring deviations of 5° or less for success in adults. Under visual conditions, some incorrect responses are expected from subjects considered to have mastered the water-level task (Wittig & Allen, 1984); therefore, successful subjects here were defined as those who produced at least three correct answers out of four. The level of

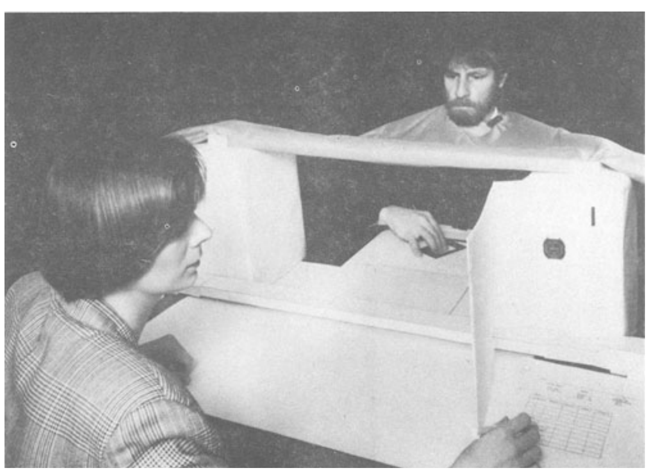

Figure 2. The subject performs the haptic version of the water-level task wearing a hairdressing cape screening the display. He or she sets the rod under the plate as if it were the water's surface, haptic activity being unrestricted.

significance was set at .05. In the water-level task, 61% of the women and 60% of the men were successful [$\chi^2(1, N=33) = 0.00$]. This lack of gender difference was replicated in the horizontal task [$\chi^2(1, N=33) = 1.78$], the corresponding percentages being 67 and 87. Using a combined gender pool, application of McNemar's test showed that success was as frequent in the water-level task as in the horizontal task [$\chi^2(1, N=33) = 0.27$]. The observational data disclosed that nearly all men and women worked with both hands when positioning the rod in either task. However, no specific positioning strategies could be identified.

DISCUSSION

Performing the water-level task under a haptic condition thus eliminated the robust male superiority that is invariably recorded with the typical visual format of this task (Liben, 1991; Linn & Petersen, 1985), matching the absence of a gender effect in various other haptic tasks (Flannery & Balling, 1979; Summers & Lederman, 1990; Walker, 1972; Witelson, 1976). The irrelevant cues originating from the container's shape and contour were not as salient haptically as they would have been visually in the usual situation (Klatzky & Lederman, 1987). As this information was haptically accessible only through successive steps, this also imposed memory demands on input integration. Moreover, it is likely that the haptic setting enhanced saliency of both the gravity axis and the ground plane, thereby facilitating a body-centered functioning in lieu of a display-centered strategy (Gibson, 1962; Hasbroucq & Guiard, 1986; Kennedy, 1978). Indeed, the subjects were equally proficient when setting the rod in the horizontal task as they were when representing the water surface, suggesting that they relied on the same references in both cases.

There were no gender differences in the horizontal task, thus replicating Liben and Golbeck's (1986) finding. The present data indicate that the difficulty that some women experience in the typical version of the water-level task may not be attributed to their inability to draw horizontal lines. It would seem that in such a task context the power of distracting visual information drives a proportion of women into a misleading processing strategy, which they avoid under haptic conditions.

It remains unclear whether the lack of a gender difference in the present haptic version of the water-level task, which excluded visual perception, was because the women caught up with the men or because absence of visual cues was, rather, detrimental to the men, bringing their performance down to the usual female level. With the purpose of clarifying this issue, an experiment comparing the standard visual version of the task with the present haptic version, as well as with a partially haptic version, is now in progress.

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NOTE

1. We had first experimented with several other haptic settings, all of which were more or less appropriate for various reasons. The idea of using plates in which the container's contour would be cut out was that of Richard St-Onge.

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