Active and Passive Haptic Exploration of Two- and Three-Dimensional Stimuli

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PhD. thesis abstract

Experiments were conducted in three broad areas: 1. haptic exploration of raised line drawings, 2. active versus passive exploration of virtual objects using a Phantom force feedback device, and 3. visual and tactile perception of two-dimensional displays. In addition, Experiment 1 was conducted to ensure that the sounds made by one of the devices used – the Tactile Display System (TDS) – did not provide any assistance to subjects attempting to identify the stimuli.

1. In Experiment 2, passive haptic perception of raised line drawings was studied in terms of four components (a) kinaesthesis, (b) shear forces from relative movement between the skin and a surface, (c) cutaneous input from the presence of a raised line, and (d) the pressure against the sides of the finger exerted by the TDS. It was found that exploration strategies involving kinaesthesis generally resulted in a greater number of correct identifications in the shortest time. Conditions with "minimal" information, such as the shear forces produced when a plain surface is moved underneath a stationary fingertip, resulted in lower levels of performance that were nevertheless quite remarkable. In Experiment 3, the TDS allowed a subject to freely explore a stimulus with one finger, and those movements caused a rotated version of the stimulus to move under the contralateral finger. The stimuli of each pair (i.e., normal and rotated forms) had different meanings (e.g., d and p). Most subjects did not detect that one stimulus was the rotation of the other. The letter or number named by the subject identified the finger to which the subject was attending, and this was influenced more by the presence or absence of a raised line than by whether the finger was moving.

2. The passive exploration of simple, two-dimensional pictures with the Phantom resulted in superior performance compared with active exploration (Experiment 4), consistent with research previously conducted using the TDS. However, active superiority was evident when simple three-dimensional geometric shapes (e.g., sphere or cone) were explored with the Phantom. Active superiority was found whether the active-passive comparison was delayed (Experiment 5, in which the active subject's exploration was recorded and later used to guide the passive counterpart), or the matching was done in real time (Experiment 6, in which two Phantoms were electronically yoked). Results were interpreted in terms of cognitive rather than sensory burdens associated with active and passive exploration.

3. In Experiment 7, subjects were guided around two-dimensional letters using the Phantom and a pre-recorded movement pattern, which was also plotted on a screen in two visual conditions: a 1 cm segment of line moved around the screen, following the movement path (an analogy to moving a 1 cm hole in an opaque surface over a line that represented the movement path); or the 1 cm segment remained in the centre of the screen and seemed to "dance" (analogous to moving the stimulus behind a stationary 1 cm hole in an opaque surface). In Experiment 8, the TDS was used for two haptic conditions: moving a fingertip and moving the stimulus underneath a stationary fingertip (haptic equivalents to a moving and stationary hole respectively). Haptic performance was equivalent to that found with vision in terms of response time. The moving window/moving finger conditions were superior to the stationary window/stationary finger conditions.

Some conclusions were that the haptic system can interpret displays with minimal information, active touch seems to be superior for exploration of three dimensional objects, and touch in general compares favourably with vision if tasks are matched. Results will be useful in guiding the design of haptic virtual environments, and relevant to applications of telepresence, robotics, sensory aids, and simulations.