Effect of Force-Feedback on an Aimed Movement Task

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Introduction
- **Trajectory-Based Operations** (TBO) will require new onboard avionics (e.g., Cockpit Display of Traffic Information, CDTI) to provide pilots with necessary information about surrounding traffic and terrain
- There are several constraints on the use and implementation of the CDTI in the near future:
  - Limited space in the cockpit
  - Instability of the cockpit
  - Input method

- Force-feedback has been proposed as a way of improving performance in HCl tasks that have a high degree of difficulty (Griffiths and Gillespie, 2005)
- Force-feedback works by either assisting or resisting operator movement
- The use of an attractive force basin (or virtual fixture) has been found to decrease target selection time by 20-25% (e.g., Eberhardt, Neverov, West, and Sanders, 1997; Hassler and Goldenberg, 1998)

- Movement direction (relative to the starting position) is also important to evaluate, since the CDTI will accommodate a wide range of movement
- Fitts’ law research has largely investigated one-dimensional movements, with some exception:
  - MacKenzie and Buxton (1992) and Whisenand and Emurian (1996) noted that movements with a computer mouse along the horizontal and vertical axes resulted in faster movements than those along diagonal axes.

- Relevance to NASA—study used force feedback to determine potential benefits in operator performance with the Cockpit Situated Display (CSD)
- CSD was developed by the Flight Deck Display Research Center (FDDRC) at NASA Ames

Purpose
- This study examined the effect of force-feedback in a Fitts’ law task using a variety of movement directions
- It also utilized a task environment that roughly mirrored a future flight deck environment:
  - Small display size
  - Small and closely spaced icons

Method
- **Subjects**
  - 12 students from CSULB; paid $10/hr for 6 hrs of participation

- **Apparatus**
  - Standard Logitech laser mouse
  - Novint Falcon input device
  - 4” x 4” x 4” operational workspace
  - Programmed to provide force feedback using modified Newton’s gravitational law equation

- **Procedure**
  - Start and target icons displayed on screen shot of an active CDTI display, no traffic (shown below)
  - Start icon remained constant size (1/4”) and location (center)
  - Target position and size varied randomly from trial to trial
  - 8 blocks per device condition, 12 trials per block
  - IVs:
    - Device Type: mouse, Novint with force, Novint without force
    - Target Size: 1/8” or 1/4”
    - Target Distance: 5/8” or 2 1/2”
    - Target Angle: 0°, 60°, 120°, 180°, 240°, and 300°
  - DV: movement time (ms)

Results
- **Target Size**:
  - Main effect of target size, $F(1, 11) = 386.68, p < .001$
  - Significantly longer to select small target
  - Significant interaction between device type and target size, $F(2, 22) = 204.82, p < .001$
  - Novint with force was quicker than Mouse when selecting the small target size only ($p < .01$)

- **Target Distance**:
  - A main effect of target distance was also found, $F(1, 11) = 652.69, p < .001$
  - Significantly longer to select far target
  - Significant interaction between device type and target distance, $F(2, 22) = 20.51, p < .001$
  - Novint with Force was faster than the Mouse when participants were selecting the near target only ($p < .01$)

Conclusion
- Force-feedback led to significantly faster performance than the mouse when the demands of the task required small, fine movements (small and near targets)
- Supports previous findings (e.g., Akamatsu and MacKenzie, 1996): force-feedback largely eliminates the need for the fine motor movements required by smaller targets and close target distances
- Force-feedback was found to produce significantly faster movements along all four diagonal axes

Proposed Future Work
- Thesis will expand on previous study with 3 main changes:
  - Multiple force values will be used (Low Force vs. High Force)
  - Goal is to determine the extent to which the level of force feedback impacts operator performance
  - There are twice as many movement directions, including movements along both the vertical and horizontal planes
  - Cursor trajectories will be recorded to analyze path of approach
- Data is currently being collected here at NASA Ames