National Aeronautics and Space Administration

Effect of Force-Feedback on an Aimed Movement Task

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Introduction

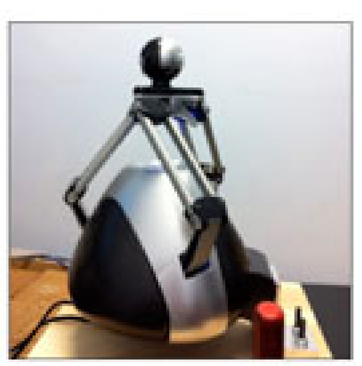
- Trajectory-Based Operations (TBO) will require new onboard avionics (e.g. Cockpit Display of Traffic Information, CDTI) to provide pilots with necessary information about surrounding traffic and terrain
  - There are several constraints on the use and implementation of the CDTI in the near future:
    - Limited space in the cockpit
    - Instability of the cockpit
    - Input method
- Force-feedback has been proposed as a way of improving performance in HCI 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; Hasser 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 (FDDRL) 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 space icons

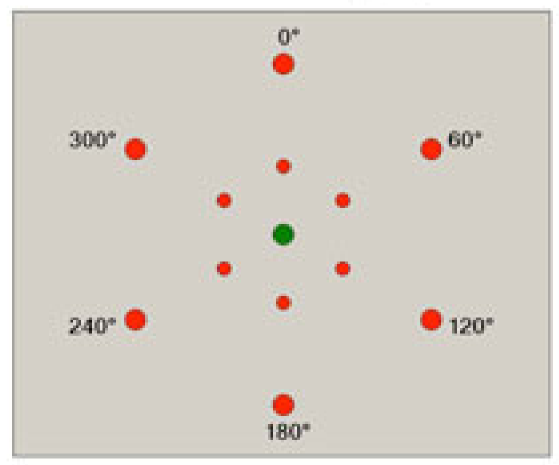
Method

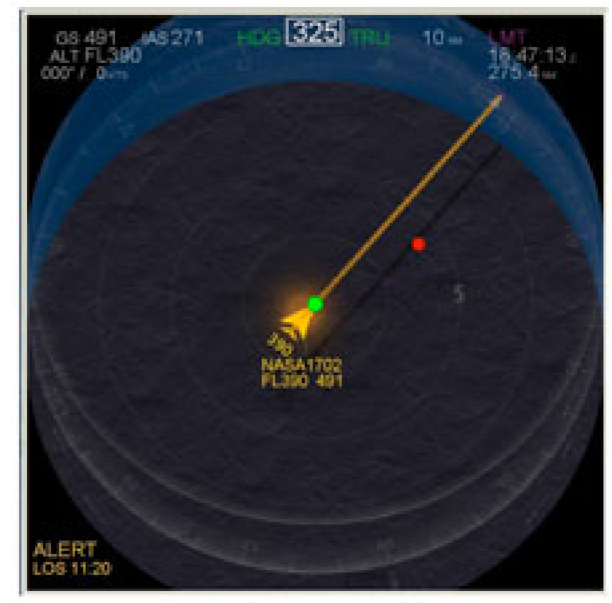
- Subjects
  - 12 students from CSULB; paid $10/hr for 6 hrs of participation
- Apparatus
  - Standard Logitech laser mouse
  - Novint Falcon input device
    - 4" x 4" x 4" operational workspace
      - Programmed to provide force feedback using modified Newton's gravitational law equation



Method

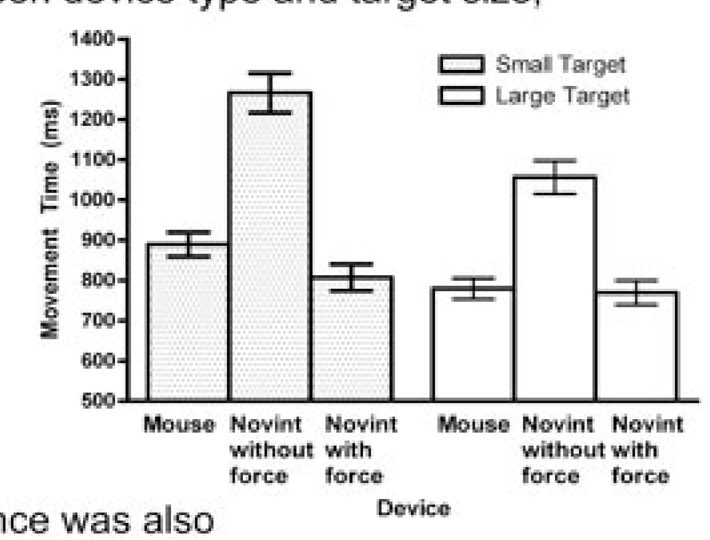
- Procedure
  - Start and target icons displayed over screen shot of an active CDTI display, with no traffic (shown below)
    - Start icon remained constant size (1/4") and location (center)
    - Target position and size varied randomly from trial to trial
    - 8 blocks per device condition, 120 trials per block
- IV's:
  - *Device Type* - mouse, Novint with Force, Novint without Force
  - *Target Size* - 1/6" or 1/4"
  - *Target Distance* - 5/6" or 2 ½"
  - *Target Angle* - 0°, 60°, 120, 180°, 240°, and 300°
- DV: movement time (ms)



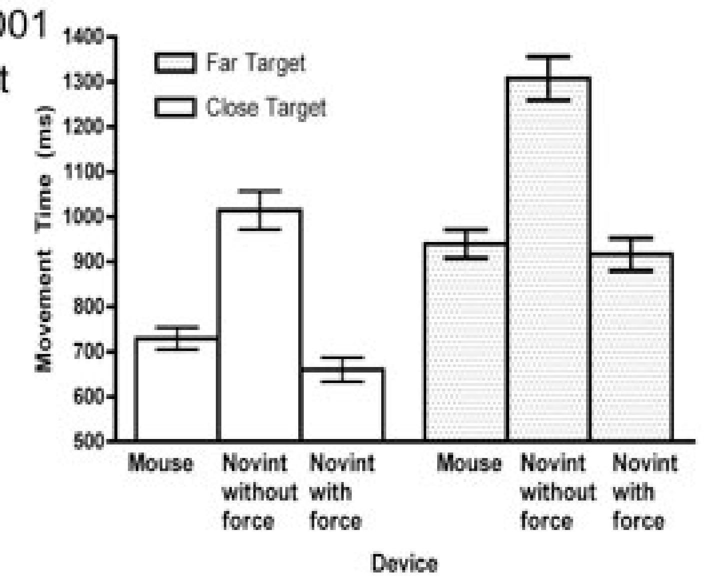


Results

- 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** ($p < .01$)

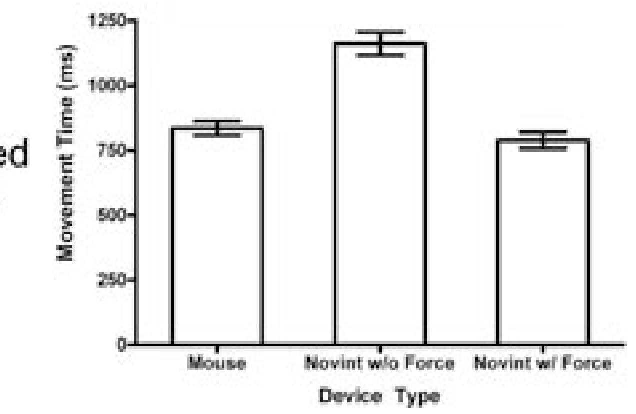


- Target Distance:
  - A main effect of target distance was also found, $F(1, 11) = 652.86$, $p < .001$
    - Significantly longer to select far target
  - Significant interaction between device type and target distance, $F(2, 22) = 20.51$, $p < .001$
    - Novint with Force was faster than the Mouse when participants were selecting the near target **only** ($p < .01$)

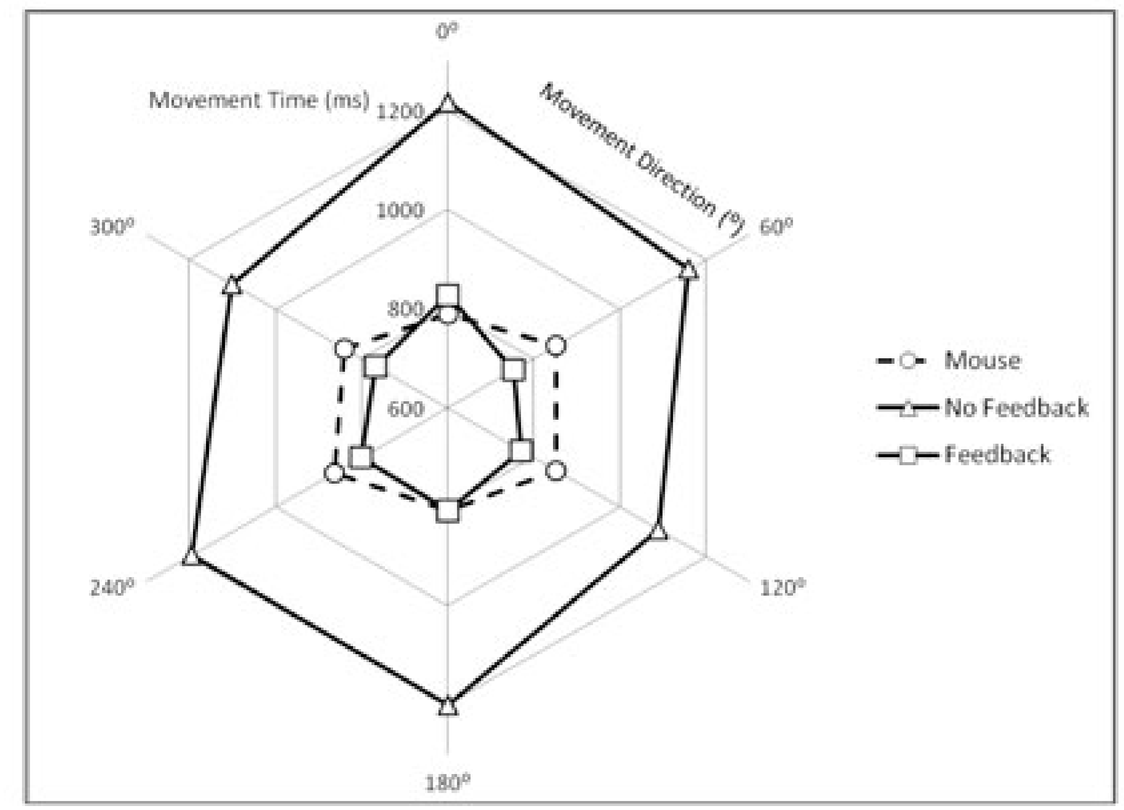


Results (cont.)

- Device Type
  - Main effect of device type, $F(2, 22) = 120.44$, $p < .001$
    - The Novint with force and Mouse conditions performed significantly faster than the Novint without Force ($p < .001$)



- Target Angle:
  - Significant effect of target angle, $F(5, 55) = 9.32$, $p < .001$
  - Significant interaction between device type and target angle, $F(10, 110) = 13.98$, $p < .001$
    - The Novint with Force condition resulted in significantly faster performance than the Mouse condition at diagonal angles



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