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# Force-Direction Discrimination
## – Effect of the Congruency of Visual Information

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## 1. Motivation

- Threshold measurements for displacement, force, stiffness/compliance and viscosity are well documented in the literature, but force-direction discrimination thresholds do not exist.
- Force-direction discrimination thresholds are needed for designing haptic rendering algorithms, especially when sensor/actuator configurations are asymmetric.
- Understanding how visual information influences our perception of force-direction can improve multimodal perceptualization systems.

## 2. Experiment Design

- 20 participants
- Each participant was tested with 1 of the 5 reference force ($F_{ref}$) directions (Fig.1)
- Each participant was tested in 3 conditions: haptics only (H), haptics with congruent vision (HVcong), and haptics with incongruent vision (HVincong)
  - Haptic force stimuli were delivered to participants' index finger by a PHANToM device (hand motion restricted by resting on a ball; Fig.2)
  - Visual stimuli consisted of blue arrows shooting out from the center of a white cube displayed on a computer monitor (Fig.2)
- Force magnitude was ramped up and down to avoid device instability (Fig.3)
- 3-interval 1-up 3-down adaptive procedure
- Independent variable α is the angle between $F_{ref}$ and the test force direction (Fig.4)
- The participants' task was to indicate the odd *haptic* test force from amongst three forces ($F_{ref}$ twice, test force once, in randomized order) presented in each trial (Fig.5)
- Training effect was eliminated by interleaving the three test conditions

## 3. Results & Conclusions

**Table 1. Estimated discrimination threshold α (in °) and its standard error (in parenthesis)**

| | Condition | | |
|---|---|---|---|
| $F_{ref}$ direction | HVcong | H | HVincong |
| Up | 12.7 (0.8) | 28.4 (1.2) | 26.8 (1.8) |
| Right | 11.9 (3.1) | 23.4 (2.1) | 26.0 (1.2) |
| Left | 19.5 (9.2) | 20.0 (1.2) | 27.2 (3.8) |
| Diagonal right | 21.9 (5.2) | 21.0 (3.1) | 35.3 (7.3) |
| Diagonal left | 26.0 (3.3) | 35.5 (4.8) | 44.3 (8.0) |
| ***Mean*** | ***18.4 (2.4)*** | ***25.6 (1.7)*** | ***31.9 (2.6)*** |

- Average force-direction discrimination threshold was 18.4° (HVcong), 25.6° (H), and 31.9° (HVincong)
- Significant main effect of Condition, with congruent visual information (HVcong) resulting in *lower* threshold than haptic alone (H) or incongruent visual information (HVincong)
- Therefore, vision influences the perception of haptic force direction
- Thresholds did not depend on $F_{ref}$ direction

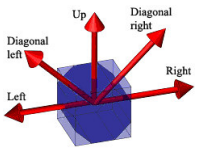


*Fig.1: $F_{ref}$ directions*

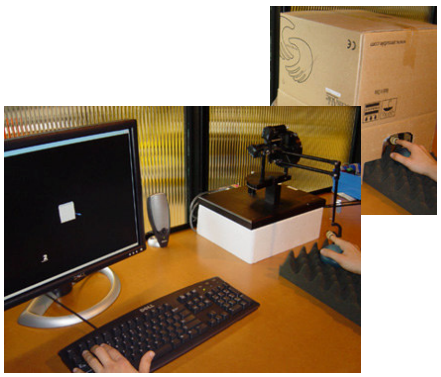

*Fig.2: Experimental setup*

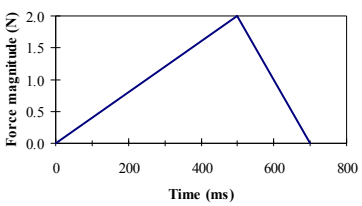


*Fig.3: Force magnitude profile*

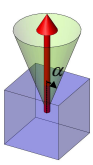


*Fig.4: Independent variable α*

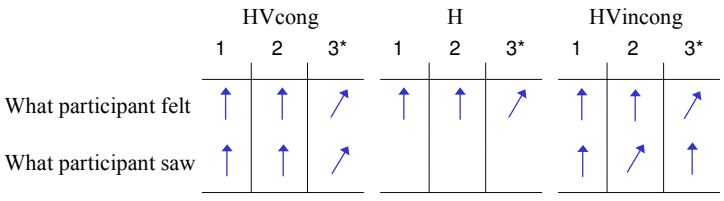


*Fig 5: Illustration of a sample trial in each of the 3 conditions (where test force direction occurred in interval 3; indicated by*)*