Multisensory Integration and Noise in Decision-Making
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INTRODUCTION
Technology increasingly utilizes vibrotactile signals for communication purposes. For example, vibrations delivered to the skin can alert drivers to potential dangers. They can also notify a cell phone user that a call or message has arrived, with the vibrations’ temporal pattern identifying the message’s sender. Unfortunately, vibrotactile signals are easily corrupted; changes in finger position, phone position, or pressure can degrade the quality of the signal received.

Using a rate discrimination task with human subjects, we examined the following main questions. First, how might rate discrimination fail when noise (random signal variation) is added to vibrotactile, visual, and visuotactile (combined simultaneous visual and vibrotactile) signals? Additionally, how might rate discrimination benefit from bimodal (visuotactile) signal presentation, and could the effect of noise negate such a benefit?

In our task, subjects were given trains of stimulus pulses and made a binary decision for each train, judging whether pulses were delivered at a slower rate (3 Hz) or a faster rate (6 Hz). In addition to describing results in terms of accuracy and speed of judgment, we examined performance within an accumulation framework, the Drift Diffusion model.

In this framework, decisions result from a probabilistic accumulation, over time, of evidence supporting the two competing alternatives (1). The model commits to a decision when evidence reaches a threshold for one of the alternatives.

From the model, we extracted two key parameters: accumulation rate and threshold (amount of evidence needed when evidence reaches a threshold for one of the alternatives). The speed of judgment, we examined performance within an accumulation framework.

METHODS
Subjects
N=25; ages ranged from 18 to 22 years.

Stimuli
Delivered by a Samsung tablet, handheld at a viewing distance of ~40 cm.

Pulse trains comprised 33 ms pulses separated by interpulse intervals (IPI). IPI was set to produce pulses at rates of 3 Hz or 6 Hz.

Vibrotactile (T) pulses were produced by gating tablet vibration on and off. Visual (V) pulses were made by turning on and off illumination of a small area at the tablet display’s center. Visuotactile (VT) pulses were generated by combining concurrent T and V stimuli.

Randomization of IPI produced three levels of noise in pulse rate: none, low, and high. Figure 2 shows the degree to which potential rate confusion varies with noise.

Task
Subjects judged the rate of each pulse train as “slow” (3 Hz) or “fast” (6 Hz). Testing was blocked by type: T, V, or VT.

Analysis
Conducted using R and Python. Modeling used HDDM (2).

RESULTS
Fig. 1. The Drift-Diffusion model
- Evidence accumulates fastest in the VT condition (Fig. 4a).
- T signals generate the highest decision thresholds (Fig. 4b).
- Noise reduces rates of evidence accumulation and decreases decision thresholds in all modalities.
- Because subjects did not know a trial’s noise level before it began, this result indicates that thresholds are set rapidly, during the course of a trial.

Fig. 2. Modality (a-c) and noise (d-f) conditions for stimuli
- a. Vibrotactile (T)
- b. Visual (V)
- c. Visuotactile (VT)
- d. No Noise
- e. Low Noise
- f. High Noise

Fig. 3a. Overall accuracy
- Responses to T and VT signals are more accurate than responses to V signals (Fig. 3a).
- Response times to VT signals are faster than in either unimodal condition (Fig. 3b).
- Noise decreases accuracy and increases response times in all modalities.
- Performance with bimodal (VT) signals is faster and more accurate.

Fig. 3b. Response time (correct trials)
- Noise and modality interact to evoke the fastest and most accurate responses.

REFERENCES

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