What if we change your motor variability?

Experiment: Increase “Motor Noise”
Changes in movement endpoints in response to visually-imposed changes in movement variability

Experimental set-up:


Idea:
- Finger visually represented by red point
- On each trial: unpredictable perturbation of the visual feedback of the finger tip by
  \[
  \begin{bmatrix}
  \Delta x \\
  \Delta y
  \end{bmatrix} = \text{Gaussian}
  \begin{bmatrix}
  \sigma_{pert}^2 & 0 \\
  0 & \sigma_{pert}^2
  \end{bmatrix}
  \]
- Points are scored based on the perturbed finger position

⇒ Increase of subject’s effective movement variability \( \sigma_{eff}^2 \)


Prediction

\( \sigma_{eff} = 3.48 \text{ mm} \)


Prediction

\( \sigma_{eff} = 3.48 \text{ mm} \)
\( \sigma_{eff} = 6.19 \text{ mm} \)

**Design**

- Configurations: 4
- Reward: 100
- Penalties: 0, -200, -500
- Added noise: $\sigma_{pert} = 0$ mm, 4.5 mm, 6 mm

**Penalties**

- Reward: 100
- Penalties: 0, -200, -500

**Added noise**

- $\sigma_{pert} = 0$ mm, 4.5 mm, 6 mm


**Results**

- **“New” effective variability**
- **Additivity of Variances**

**Shift in end points: average subject data**

- **Shift in end points: actual vs. optimal shifts**

Results
Scores: average subject data

Results
Scores: actual vs. optimal performance

What if we change your motor variability, making it anisotropic?

Experiment: Training: No-Drift Trials

Experiment: Training: Drift Trials

Experiment: Test: No-Drift Trials
Results

What if we change your outcome variability, trial-by-trial during a task? Will you learn the new variability? How?

Experiment: Task

Experiment: Variance Variation
Experiment: Trial-by-Trial Data

Experiment: Raw Data vs. Optimal

Experiment: Raw Data vs. Optimal

Experiment: Lagged Regression

Do cue weights depend on local viewing conditions?

Stimuli – Disparity-only
Methods

- Task: 2IFC slant discrimination
- Single-cue and two-cue blocks
- Opposite-sign slants mixed across trials in a block to avoid slant adaptation
- One stimulus fixed, other varied by staircase; several interleaved staircases
- Analysis: fit psychometric function to estimate PSE and JND

Outline

- Background: Optimal cue combination
- Methods: slant discrimination
- Single-cue results
- Two-cue results: perceived slant
- Two-cue results: JNDs
- Conclusions
Outline

- Background: Optimal cue combination
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Improvement in Reliability with Cue Combination

If the optimal weights are used:

\[ w_i = \frac{1/\sigma_i^2}{1/\sigma_i^2 + 1/\sigma_d^2} \quad \text{and} \quad w_d = \frac{1/\sigma_d^2}{1/\sigma_i^2 + 1/\sigma_d^2} \]

then the resulting variance

\[ \frac{\sigma_i^2 \sigma_d^2}{\sigma_i^2 + \sigma_d^2} \]

is lower than that achieved by either cue alone.
Conclusion

- The data are consistent with optimal cue combination
- Texture weight is increased with increasing distance and increasing base slant, as predicted
- Two cue JNDs are generally lower than the constituent single-cue JNDs
- Thus, weights are determined trial-by-trial, based on the current stimulus information and, in particular, the two single-cue slant estimates

Experiment: Priors and Likelihoods

Training:
- Subject shown ‘splash’
- Task is touch where coin landed
- Feedback provided
- 150 Trials

See also: Körding & Wolpert (2004). Nature, 427, 244-247.

Teaching Subjects the Prior

HIT!!! You have $2.95

Experimental Stimuli

- 2 dots
- 4 dots
- 8 dots
- 16 dots
- 32 dots


Experimental Trials

- 900 Trials
- Task is touch where coin landed
- Only hit/miss feedback is given
- Hits worth $0.05

Gain Landscape

2 Dot condition:

32 Dots:

Results

Learning a prior on stimulus distribution, hence reliability

Cue-combination data from one representative subject.

Seydell et al. J Vis 2010

Adaptation predictions and data.

Ernst & Di Luca (2011). In Körding et al.

Wei & Körding (2009). J Neurophys

Relevant Visual Error  Irrelevant Visual Error

World

CNS

X\text{prop} \rightarrow X\text{vis}

X\text{vis} \rightarrow X\text{hand}

X\text{prop} \rightarrow X\text{hand}

X\text{hand}

X\text{hand}

\Delta t = 1
\Delta t = 2
\Delta t = 3
\Delta t = 4

Wei & Körding (2009). J Neurophys

Srimat et al. (2008). J Neurophys