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Decision Making and Movement Planning Under Risk

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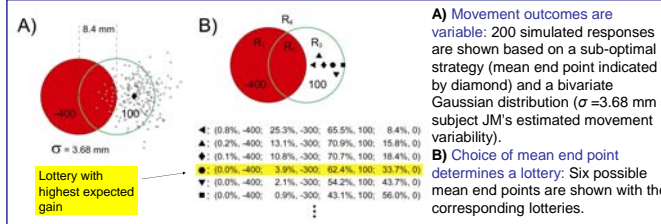
Movement Planning Under Risk



(See Trommershäuser, Maloney, Landy, 2003, JOSA A, 20, 1419 for details on set-up and experimental procedure.)

Movement planning is formally equivalent to decision making under risk or uncertainty. In our experiments, subjects were instructed to rapidly touch a target region (green) on a screen while trying not to hit a nearby penalty region (red). Each target hit yielded a reward; late responses and hits on the red region incurred a penalty. At the end of the experiment, the points scored were converted into a bonus (money or course credit).

Movement Planning is Decision Making



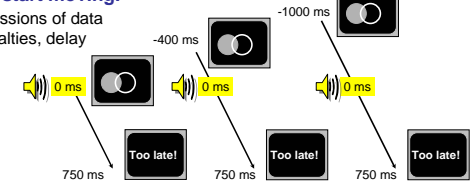
Expt. 3: Separation of Visual Stimulus Display and Go Signal

In this experiment, the information about "where" to move was separated from the information about "when" to start moving.

6 subjects, 1 learning session, 3 sessions of data collection; (3 configurations, 3 penalties, delay until go signal varied trial by trial).

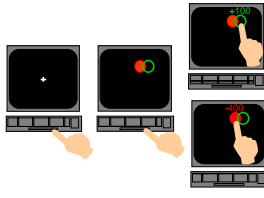
Results:

- No effect of delayed go signal
- Stability of mean end point
- Stability of movement variability
- Stability of performance



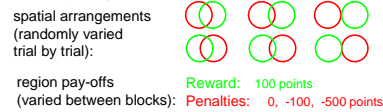
Experimental Task

- Fixate cross
- Begin trial by button press
- Go-signal for movement:
 - Expt. 1: Visual display of stimulus configuration
 - Expt. 2: Sine tone (0 ms, 400 ms or 1s after visual display of configuration)
 - Expt. 3: Sine tone (400 ms after visual display of configuration)
- Feedback about performance after each trial



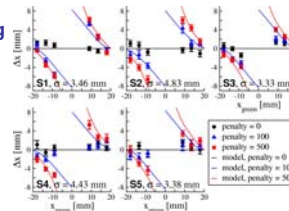
Expt. 1: Optimal Responses to Changes in Value

In this experiment, the expected gain of a configuration was manipulated by varying the value (=points) assigned to the penalty region.



5 subjects; 1 training session, 2 sessions of data collection (40 data points per condition)

Results: Subjects adjusted their movements to compensate for changes in value.

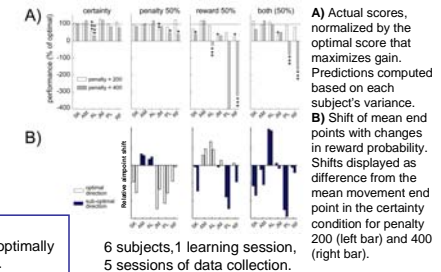


Expt. 4: Stochastic Rewards and Penalties

In this experiment, the receipt of the reward and/or penalty was uncertain for the subject.

certainty: 100% of trials (Lucky 100%)
 penalty 50%: 50% of trials (Lucky 50%, Sorry 50%)
 reward 50%: 50% of trials (Lucky 50%, Sorry 50%)
 both 50%: 50% of trials (Lucky 25%, Sorry 25%)

Results: Subjects failed to adjust their movements to optimally compensate for stochastic rewards/penalties.



Expected Gain of a Movement

Each movement has **four possible outcomes**:

- Landing in the penalty region (R_1),
- Landing in the target/penalty overlap (R_2),
- Landing in the target (R_3),
- Neither / hitting the background (R_4).

The probability of occurrence for each of these outcomes is determined by a subject's **movement variability (σ)** and the choice of **mean end point (μ)**.

The combination of **probabilities (p_n)** and **pay-offs (G_n)**, associated with each of the four outcomes ($n=1, \dots, 4$) forms a **lottery $L(\mu, \sigma)$** (see "Movement Planning is Decision Making"),

$$L(\mu, \sigma) = (p_1, G_1; p_2, G_2; p_3, G_3; p_4, G_4).$$

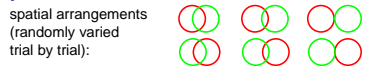
The **expected gain (EG)** of this lottery is: $EG = \sum_{i=1}^4 p_i G_i$.

Our trained subjects had constant movement variability σ . Thus, movement planning consisted of a choice of mean end point μ .

In selecting a movement, subjects must choose among indefinitely many lotteries.

Expt. 2: Compensation for Changes in Uncertainty

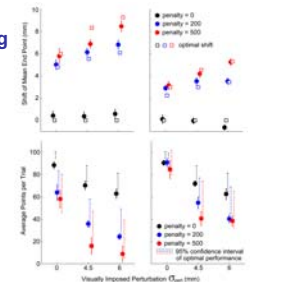
In this experiment, the expected gain of a configuration was manipulated by increasing the task-relevant movement variability σ by perturbation of visual feedback.



visually-imposed perturbation (Gaussian noise, random direction on each trial): σ_{pert} : 0 mm, 4.5 mm, 6 mm

6 subjects, 1 training session per perturbation condition: 1 learning session, 2 sessions of data collection (40 data points per condition)

Results: Subjects adjusted their movements to compensate for changes in uncertainty.



Expt. 5: Choice Between Two Configurations

In this experiment, subjects chose between configurations with different expected gain.

7 configurations: (100), (100/100), (500), (500/100), (500/500), (500/500/100)

Simultaneous display of two configurations drawn from the above 7 (one on the left, one on the right).
 5 subjects, 1 learning session, 1 session (1 configuration)
 2 sessions (2 configurations)

Results:

- Mean end points unchanged when selecting between two configurations compared to pointing at a single configuration.
- Configurations that earned more points and configurations with higher expected gain were chosen more frequently.
- Overall performance was sub-optimal for 3 (right-handed) subjects due to a preference to point at the configuration presented on the right.

Conclusion

We have described movement planning as equivalent to risky decision making. In our experiments, the movement planning task involved a speeded choice among infinitely many lotteries and yet, unlike performance in traditional decision making tasks, subjects' performance was close to that required to maximize expected gain. In addition, we found that subjects managed to compensate for changes in value and uncertainty, independent of the time available to process the visual information about the goal of the movement. Optimal performance was disrupted when information about rewards and penalties became stochastic or when motor constraints interfered with the selection of the goal.