Deciding when to cut your losses: Sympathetic arousal and suboptimal estimation of stopping time

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Abstract

Many of our important decisions have a deadline. We can wait and collect more evidence in order to make a more informed decision, but we run the risk of running up against the deadline and suffering a penalty. Based upon the relative rewards of accuracy and penalties associated with hitting the deadline, one can calculate the optimal time to make a decision. There is good evidence that humans are susceptible to biases that make it difficult for them to choose optimal stopping times. One of these biases might be due to a stress-based deterioration of one's ability to estimate time intervals. For example, as one approaches a decision deadline, a stress response might be correlated with either a collapsing decision threshold (cf. drift diffusion models (Ratcliff, 1978)) or a time-dependent urgency signal that boosts the gain of evidence and noise until a decision is reached (Cisek,2009). In either case, if the perception of time is tied to a decision variable's linear approach to a fixed boundary, that perception would be distorted when either the linearity of the approach or the position of the boundary is changed.

One way of probing the stress response (and general sympathetic arousal) is through the measurement of galvanic skin response (GSR). We asked whether GSR levels would predict the distribution of subjects' decision times in an optimal stopping task. In this task, subjects reported the direction of coherence in a random dot coherence display, where the level of coherence was always 5% of the total number of dots. The onset of this display was selected from a random uniform distribution of onset times, never appearing on 40% of trials. There were two types of trials (blocked in 100 trial sessions each): those that ended after 5 seconds (Easy task) and those that ended after 8 seconds (Difficult task). Subjects received 20 points for correct responses and lost 20 points for incorrect responses. They lost 35 points if the trial ended prior to a response. This forced subjects to estimate a time (their "stopping time") when they should guess instead of risking a timeout.

We computed an optimal stopping policy for each subject based on their speed/accuracy and the payoff structure of our task (figure 1c). Subjects performed quite well on the task, stopping on average within 1 second of their optimal stopping time. Furthermore, galvanic skin response showed a significant correlation to late stopping times (ie showed greater change when a subject waited past their optimal time). This is consistent with an increasing physiological urgency signal but does not appear to induce early decisions. While this finding does not rule out a collapsing bound drift-diffusion or urgency gating model, it suggests that sympathetic arousal is not the physiological mechanism behind the urgency signal.

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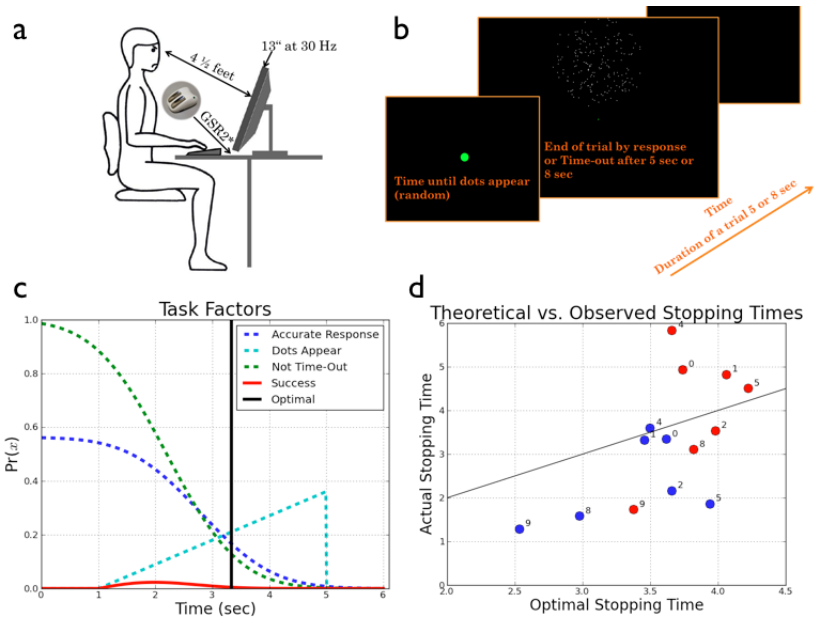

Figure 1: a) Subjects sat at a computer station during the experiment while a GSR2 device recorded skin conductance from their index and middle fingers. b) The dot display onset occured after a variable fixation period ranging from 1 to 5 sec (Easy task) or 1 to 8 sec (Difficult task). On 40% of both the Easy and Hard tasks, the dot display never appeared. c) The probability of success as a function of time was calculated as the joint probability of dots appearing, correct response overall, and response before time out. The black line marks the optimal stopping time for this theoretical subject, as it is the point past which a correct response becomes impossible (due to reaction time limitations). d) Theoretical optimal stopping times plotted against observed stopping times. Red dots represent difficult trials and blue dots represent Easy trials.

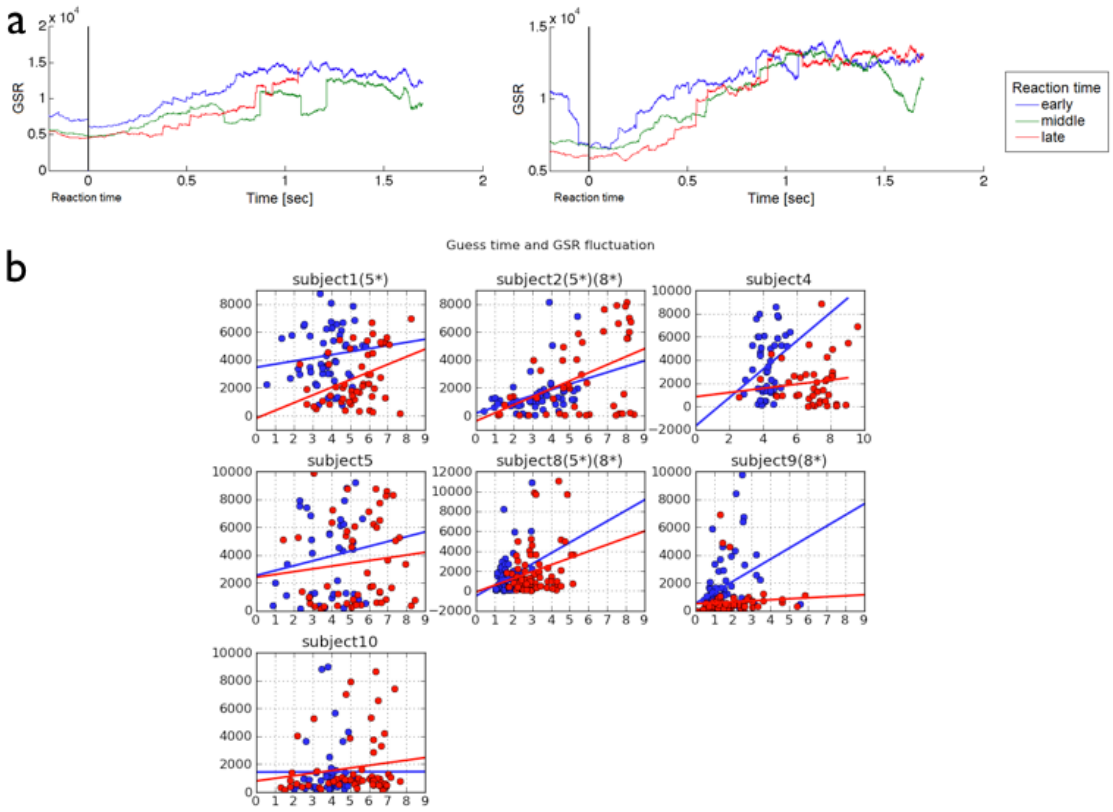

Figure 2: Observed GSR and its relation to stopping times. a) GSR waveforms time-locked to response time demonstrate a robust response (to either the response or the following feedback) across subjects. b) Absolute GSR signal fluctation magnitudes correlated with stopping time.