Study Information

Title

Mental chronometrics of decision making

Authors

Kitty Lui, Michael D. Nunez, Ramesh Srinivasan, and Joachim Vandekerckhove

Research Questions

Many common models of speeded decision-making assume that cognitive processing required occurs in three sequential time periods: 1) a period of visual encoding, 2) a period of decision-making (decision-making time), and then 3) a period of motor response time. The sum of visual encoding and motor response time is labeled non-decision time. Our overall objective is to find estimates of these three time periods in milliseconds for each subject using a mixture of human behavior observations (choice and reaction time) and evoked electroencephalographic (EEG) measures, and how specific processes contribute to these time periods. In this study, the specific aim is to examine how perceptual categorization and response selection processes contribute to the period of decision-making (decision-time).

Hypotheses

All subjects will perform a two-alternative forced-choice task by discriminating the spatial frequency and/or orientation of a gabor patch presented foveally and embedded in noise. The subjects will provide responses with their index finger and ring finger of the right hand. There will be two task manipulations administered. 1) Signal task: three different levels of spatial frequency difference between the two classes of Gabors will vary between blocks 2) Stimulus-response mapping task: the mapping between the stimulus category and response will be varied between 0 and 2 stimulus dimensions. In each task there are three levels of task difficulty and we expect reaction times to get longer as the blocks get harder. We also make specific hypotheses about diffusion model parameters and EEG signals, and their relationship in each task. Signal task: As the task gets more difficult, the P300/CPP (an event-related potential possibly reflecting perceptual categorization) to be positively correlate to decision time. The duration of the readiness potentials (RP) will increase between the conditions and have a 1-1 relationship with decision time. S-R mapping task: Decision-time will increase as the number of stimulus-dimensions used to select a response increases. There will not be any change in P300/CPP peak latency between the conditions. The duration of the Readiness potentials (RP) will increase between the conditions and have a 1-1 relationship with decision time.

Sampling Plan

Existing Data

Registration prior to creation of data

Explanation of existing data

No behavioral or EEG data has yet been collected to test our hypotheses. Pilot data has been viewed and analyzed in order to conduct exploratory research and help generate hypotheses. However the pilot data will not be used in any dataset resulting from this experiment.

Data collection procedures

Participants will be recruited by word-of-mouth and email on the main campus of the University of California, Irvine. Participants must be at least 18 years of age, have no prior history or family history of epilepsy, and be right-handed. Participants will be paid $30 for two session of EEG data collection while they perform a visual decision making experiment, multiple trials of a simple video game built using Psychtoolbox 3 in MATLAB (attached). A protocol for the data collection procedure is attached. Evoked-EEG measures, reaction times, and choices were calculated using MATLAB scripts.

Sample size

Our target sample size is 48 subjects. They will come in for 2 sessions to perform both tasks. Each subject will complete 120 trials of each experimental condition in the task they were assigned, resulting in 5,760 trial-observations for 4 different experimental conditions. One of the 3 conditions in each task involves identical stimuli and response contingencies, and will be jointly analyzed as a 5th experimental condition that is shared across the 2 tasks with 11,520 trial-observations.

Sample size rationale

The sample size for both trials and number of participants is constrained by time. We do not wish to keep participants in the experiment room for longer than 2 hours because participants will become fatigued. Empirically it was found that 360 trials of data could be collected with 60 trials per block and 120 trials per experimental cell in each EEG session. In our experience, this is adequate to estimate EEG measures, and to estimate drift diffusion model parameters in individual subjects.

Stopping rule

We will terminate our data collection when we have both EEG and behavioural data from 48 participants who participated in 2 sessions

Variables

Manipulated variables

There are two different tasks each of which manipulates a property of the task (i.e., target spatial frequencies, or number of stimulus target dimensions) in order to elucidate different cognitive processes. Within each task there will be 3 different block types (easy = E, medium = M, and hard = H difficulty) that will have 60 trials for each block. There will be 6 blocks total in an experiment. There are 6 different orderings of the blocks which are: E M H E M H, M H E M H E, M E H M E H, H M E H M E, H E M H E M. Each subject will see one of the orders, and an equal number of subjects (8) will see each of the order of blocks in each task. Signal Task: E) Task is to discriminate 2.35 cpd Gabor from 2.65 cpd Gabor. Gabor is randomly presented with random phase and at an orientation of either 45 degrees or 135 degrees with added noise. M) Task is to discriminate 2.4 cpd Gabor from 2.6 cpd Gabor. Gabor is randomly presented with random phase and at an orientation of either 45 degrees or 135 degrees with added noise. H) Task is to discriminate 2.45 cpd Gabor from 2.55 cpd Gabor. Gabor is randomly presented with random phase and at an orientation of either 45 degrees or 135 degrees with added noise. S-R Mapping Task: Task is to discriminate 2.4 cpd Gabor from 2.6 cpd Gabor. Gabor is randomly presented with random phase and at an orientation of either 45 degrees or 135 degrees with added noise. E) respond with one button whenever you detect either stimulus M) respond with one of two buttons based only on spatial frequency 3) with one of two buttons based on spatial frequency - response contingency reverses based on orientation of the gabor (45 or 135 degrees) All subjects will respond with their right hand (using their ring and index fingers for two buttons).

Measured variables

We will be collecting reaction time and accuracy from each experimental trial. We will also be collecting EEG session-level event-related potential (ERP) P300 latencies and readiness potential (RP) duration. EEG will be mitigated from electrical and muscle artifact using Independent Component Analysis (ICA) and automatic artifact classification.

Indices

10th reaction time percentiles and reaction time medians will be computed to compare to P300/CPP latencies and RP duration with linear regression analysis. Reaction time and accuracy will be placed into hierarchical Bayesian drift-diffusion models in order to compare cognitive parameter estimates of decision time to RP duration and P300/CPP latencies.

Design Plan

Study type

Experiment - A researcher randomly assigns treatments to study subjects, this includes field or lab experiments. This is also known as an intervention experiment and includes randomized controlled trials.

Blinding

- No blinding is involved in this study.

Study design

The two experiments will be analyzed as a within-subject design with 1 fixed factor manipulating the difficulty of the task, the levels being easy, medium, and hard difficulty in each task. Data will be analyzed treating Subject as a random factor. The medium level condition across both of the experiment is in fact the same task. Here there are 48 subjects performing the same condition which will be subject to an individual differences analysis.

Randomization

There will be 3 different block types (easy = E, medium = M, and hard = H) that will have 60 trials for each block. There will be 6 blocks total in an experiment. There are 6 different orderings of the blocks which are: E M H E M H, M H E M H E, M E H M E H, H M E H M E, H E M H E M. Each subject will see one of the orders, and an equal number of subjects (5) will see each of the order of blocks in each task. As each subject enrolls in the study they will be assigned to a task and block order according to the sequence of block orders given above, which will repeat 8 times.

Analysis Plan

Statistical models

The hypotheses are that 1) decision time and P300 peak-latency positive have a linear relationship and 2) decision time and RP duration have a positive 1 to 1 linear relationship. Embedded in a hierarchical Bayesian framework, we will use 1) the linear model DT = b0 + b1*P300, to test if b1 > 0, and we will use 2) the linear model DT = g0 + g1*RP, to test if g1 = 1. We will also test these linear relationships using simple linear regression with subjects as observations.

Transformations

For the proposed confirmatory hypotheses, the defined variables do not require any transformations. Exploratory analyses may require transformations of the defined variables.

Follow-up analyses

If evidence is discovered for the two hypotheses, we will test the linear relationships between P300 latency and RP duration, and their predictive ability of reaction time using cross-validation.

Inference criteria

In the simple linear regression analyses, statistics reported will be 95% confidence intervals of the slope parameters as well as the Bayes Factors which describe the amount of relative evidence (probability in the Bayesian definition) of a model which has a non-zero regression slope over a model which has a regression slope of zero. Bayes Factors which describe the relative evidence of a model with a slope parameter of 1 (reflecting 1-to-1 relationships) over a model with an

undetermined regression slope will also be reported. Adjusted R^2 will be reported that describes the fraction of variance of the dependent variable (RT statistics) explained by the regressor variables (N200 latencies, P300 latencies, and RP duration). The posterior distributions of the linear effect parameters in the hierarchical Bayesian models will be evaluated using Bayes Factors calculated using the Savage-Dickey ratio to 1) indicate evidence of a 1-to-1 linear effect of N200 latency on non-decision time in all of the tasks, 2) indicate evidence of a positive correlation of RP duration on decision time in the signal-response mapping task and 3) indicate evidence of a positive correlation of P300 latency on decision time in the signal task, 4) indicate evidence of null effects (i.e. slope parameters of zero indicating no effect) of additive effect parameters in exploratory analyses.

Data exclusion

In order to remove "fast error" trials that do not contain decision-making processes, reaction times less than 250 ms will be removed. EEG trials deemed to contain too much "artifact" by visual inspection (high amplitude or high frequency electrical activity that is impossible for cortex-generated activity) will be removed. Single-trial N200 latencies that are found to be on the boundary (either 150 ms or 275 ms post-stimulus; indicating a failure of the simple windowing algorithm to find a stimulus-related peak) will be removed. Trial-averaged N200 latencies that are found to be on the same boundaries will also be removed for the same reasons. Test data will be removed from each block of the data such that 25% of trials will be marked as test data for use in out-of-sample posterior predictive distribution evaluations in exploratory analyses.

Missing data

Missing data will be treated as missing at random (MAR). Out-of-sample predictions will be generated with test data.

Exploratory analysis

We will explore the linear relationships between P300 latency and RP duration, and their predictive ability of reaction time using cross-validation. We will also test if the N200 peak latency and the beta desynchronization time course will total to non-decision time.

Scripts

Upload an analysis script with clear comments

- pdmfinal_cleaningsteps.m
- pdmfinal protocol.docx
- pdmfinal protocol (1).docx

Other

Other

Data and code will be released online in support of the greater scientific community and in an effort to promote ``open science." Specifically, raw EEG data from a few example subjects and sessions, behavioural data and preprocessed EEG measures for all subjects and sessions, generated visual stimuli written in MATLAB with Psychtoolbox 3, simple MATLAB scripts to perform computations of any newly discovered analysis techniques, and MATLAB code needed to generate results presented in published work will be released online.