# Relevant experiments using mouse-tracking

“Continuous attraction toward phonological competitors” by Spivey et al.

Much of cognitive science theories build on “discrete stage-based theoretical framework[s]”, however Spivey et al. wants to show that “partial activation of multiple lexical representations (“cohorts”) cascading to later stages of processing even just of the way through hearing a word”. Meaning that information about the word being heard are being passed along to the next stage even before “the single correct lexical item is identified”.

In this paper Spivey et al. wants to investigate whether the activation of word representations are updated continuously and cascading the output to later stages or if the process still have parts working in a discrete stage-based like manner.

The confusion has come from that it can be hard to distinguish between a continuous account and discrete account when averaging over the motor outputs.

Mouse-tracking provides a high quality visualisation of the continuous cognitive dynamics, e.g. in real-time spoken-language processing.

A model called TRACE that simulates speech processing show a nonlinear increasing probability function for “beaker”, when “beaker” is the spoken word. The probability function for “beetle” will be rising and then falling over time.

Spivey comes with a good motivation of mouse-tracking over eye-tracking. Eye-tracking is only a semicontinuous record of eye-movement, since the steady fixations are a bit like categorical data since it is a steady fixation of one object over time only making researchers able to approximate the continuous nature. Movement-tracking however will show continuous movements’ graded pull towards other object than the one chosen.

Their first test is a REALLY SIMPLE AND UNINTERESTING statistical test of error rates.

They give a good account of time normalisation of x-, y-coordinates. The method uses linear interpolation to calculate a mouse-coordinate between two discrete samples. This is done for x and y separately.

In their analysis section they seem to do a lot of different t-tests and some linear models. But so far it all seems a bit dumb. None of it is actually answering the question about dynamic or discrete stage-based processing.

They show a stronger effect for rightward movements compared to leftward. The explanation proposed involves kinematics of right arm and position of the mouse to the right of the keyboard.

They use a speech-recognition model called TRACE to simulate the same experiment. The model produces results that are comparable to the experimental results.

List of analysis elements:

* T-test between percentage of incorrect trials in cohort and control
* T-test between total response time (from visual onset to correct mouse click) in cohort and control
* Linear model??? (based on no main effect): time\_initiation\_movement ~ condition
* Linear model??? (based on significant main effect): duration\_of\_movement ~ condition
* T-test between x-coordinates in cohort and control (done for each time slice)
  + Only significant for leftward from 70th to 81st time slice
  + Only significant for rightward from 9th to 92nd time slice
* T-test between proximity to target object and proximity to distractor object for control condition (done for every 10th time slice)
* T-test between proximity to target object and proximity to distractor object for cohort condition (done for every 10th time slice)
* Calculated degree of curvature, converted to z-scores within participants (for both control and cohort), and then pooled across participants. Then they calculate mean, variance, kurtosis, skewness and bimodality coefficient (b) for both cohort and control (“with b > 0.555 being the standard cutoff for multimodality”)
  + Kolmogorov-Smirnov test done to estimate normality of data. Both are either not normal or close to not normal due to high kurtosis, meaning that they are further from bimodality
* Calculate area under the trajectory, converted to z-scores within participants (for cohort and control seperately), and then pooled across subjects
  + Use Kolmogorov-Smirnov test to evaluate differences (since mean and variance is the same (I do not know how???))
  + Since control should be unimodal, then if they are similar cohort is also unimodal

“Mouse tracking as a window into decision making” by Maldonado et al.

They use an “”optimal” analysis of their data and describe this as being the pre-trained LDA. But why is this “optimal”?

They are primarily interested in “extracting a continuous measure of the degree of deviation in mouse paths”, and not to use the LDA for classification. But they are using the LDA for classification, so what do they mean about this?

Reaction time can show whether a decision process was fast or slow.

Mouse-tracking uses the assumption that motor movements are “planned and executed” in parallel with the decision processes that they reflect.

“The Cognitive Dynamics of Negated Sentence Verification” by Dale & Duran

“Using mouse cursor tracking to investigate online cognition: Preserving methodological ingenuity while moving toward reproducible science” by Schoemann et al. (2020)

The article is a review of the mouse-tracking literature, specifically its methodology. In the abstract they say that there is a problem with not having a standardised best practice in regards to reporting, what measures are used, and how the experiment is designed.

Limiting the methodological degrees of freedom of a mouse-tracking experiment will only increase the possibility of reproducibility. In the early days of fMRI it also had to undergo years of scrutiny and critique to establish best practices within the field.

Implementation of mouse-tracking can be different both between and with-in scientific fields. This is the results of both demands from specific paradigms, but also individual intuitions of how collection, analysis and interpretation should be done. Difference in methodological details have high impact on strength of relationship and the reproducibility of the study. This calls on creating new standards in mouse-tracking research.

The article compares three different studies that apply three different procedures: static start procedure + click response procedure, deadline start procedure + click response procedure, dynamic start procedure + hover response procedure.

“Hehman et al. (2015) stressed the importance of instructing participants to initiate movements early by introducing a movement initiation deadline. Concerning the mouse

variables, Fischer and Hartmann (2014) discussed the importance of the cursor speed1 settings and recommended the usage of slow cursor speed settings as well as clear reporting of those (regarding cursor speed, see also Huette, 2016).”

“Despite the identification of two prototypical mouse-tracking setup, we revealed substantial heterogeneity with respect to most examined design features.”

“For eye tracking, another more traditional process-tracing method, this challenge has recently been taken by Fiedler, Schulte-Mecklenbeck, Renkewitz, and Orquin (2019), who uncovered a lack of reporting transparency and developed a minimal reporting standard “to promote the cultural shift towards openness and transparency in science to increased reproducibility, because precise, accurate and informative reporting is a prerequisite of reproducibility”

“Pushing forward in embodied cognition: may we mouse the mathematical mind?”

Fischer and Hartmann argue that only trajectories in the wrong hemispace (on the wrong side of x = 0 line I guess) should count as evidence for attraction of the distractor stimuli. But due to the dominating theoretical framework of dynamic competition, also trajectories in the right hemispace express attraction through large curvature (but Fischer and Hartmann mean this is wrong).

A large problem of using average curves to illustrate the movement of a mouse-tracking trial condition is that if the underlying distribution is bimodal, then the averaged curve will not be representative of task performance.

“Lost to translation: How design factors of the…”

“A dCOM (discrete change of mind) results in a trajectory shape that is characterized by a direct movement toward the unchosen option, followed by a horizontal movement to the chosen response box (see Wulff et al., [2019](https://link-springer-com.ez.statsbiblioteket.dk:12048/article/10.3758/s13414-019-01889-z#ref-CR62)). These trajectories are problematic for using mouse movements to trace cognitive processes, as they indicate that the movement does not reflect continuous competition manifesting itself in movement, but instead indicates the sequential execution of two processes that lead to two relatively discrete responses”

“A dCOM is a trajectory shape that is conflicting with core assumptions of the mouse-tracking procedure (Wulff et al., [2019](https://link-springer-com.ez.statsbiblioteket.dk:12048/article/10.3758/s13414-019-01889-z" \l "ref-CR62" \o "Wulff, D. U., Haslbeck, J. M. B., Kieslich, P. J., Henninger, F., & Schulte-Mecklenbeck, M. (2019). Mouse-tracking: Detecting types in movement trajectories. In M. Schulte-Mecklenbeck, A. Kühberger, & J. G. Johnson (Eds.), A handbook of process tracing methods (pp. 131–145). New York, NY: Routledge.)): Mouse tracking is assumed to record cognitive processing through its continuous manifestation into movement (O’Hora et al., [2013](https://link-springer-com.ez.statsbiblioteket.dk:12048/article/10.3758/s13414-019-01889-z" \l "ref-CR39" \o ); Spivey & Dale, [2006](https://link-springer-com.ez.statsbiblioteket.dk:12048/article/10.3758/s13414-019-01889-z" \l "ref-CR53" \o )). In contrast to this assumption, dCOM trials indicate discontinuity in this manifestation, with movement being ahead of processing. More specifically, the initial movement toward the vicinity of the unchosen option in a dCOM trial is not indicative of a continuous progress of the decisional processes. Instead, it represents an overemphasis of an initial tendency, after which the decision process leading to the ultimate choice kicks in, through which the movement direction is abruptly corrected; the velocity profile of dCOM trials also suggests this pattern.”

”Kieslich dissertation”

”Many mouse-tracking studies have performed analyses based on aggregate curvature indices and aggregate trajectories. As I have shown in this dissertation, these are not necessarily representative of what is happening at the trial level and it is, therefore, important to visualize and analyze individual trajectories”

” Relatedly, the results from the design factor studies have shown that there is still a need to better understand how cognitive processes in general and the preference development in particular are mapped onto the mouse movement. It seems that the original assumption of a completely continuous mapping of the cognitive process onto the mouse movement responses (Freeman et al., 2011; Spivey & Dale, 2006) depends on the task and methodological setup of the study, and thus cannot be assumed a priori”

” if one is mainly interested in assessing the overall level of conflict that was present in a decision and is somewhat agnostic about the specific process model, one can still rely on trajectory curvature to test theoretical predictions”

” Thus, a study with a static starting procedure, click response mode, and default mouse sensitivity settings is more likely to produce a mix of straight and change of mind trajectories than a study with a dynamic starting procedure, touch response mode, and reduced cursor speed (and disabled acceleration). In other words, if a mix of straight and change of mind trajectories was observed in the latter setup, this would be more convincing evidence for a dual-system model on a process level than if they were observed in the former setup”