8-2013

Using Mouse Tracking to Examine the Time Course of an Auditory Lexical Decision Task

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Abstract

Mouse-tracking studies demonstrate that hand movements reveal the progression of responses over time during psychological tasks. In the present study, we examined the time course of cognitive processing during an auditory lexical decision task. The following predicted results emerged to indicate facilitation for words relative to nonwords: 1) shorter reaction times; 2) fewer direction changes, and, compared to the ideal trajectory; 3) smaller deviation; and, 4) area under the curve for words relative to nonwords. We also found predicted differences between words and nonwords in velocity throughout the trials, providing a greater understanding of the real-time processing dynamics throughout the course of spoken word recognition.

An auditory lexical decision task involves the speeded classification of spoken words and nonwords, usually presented randomly and binaurally over headphones. Because completion of the task involves lexical processing, it has been used in the study of a wide variety of phenomena in laboratory settings. When conducting a standard auditory lexical decision task, the dependent variables typically comprise response accuracy rates for words and nonwords and response latency measured by reaction time (RT), as well as other possible measures (e.g., repetition priming effects). See Goldinger (1996) for a review.

Mouse Tracking

Recent research has shown that hand movements with the mouse can reveal how processing changes over the course of responding to psychological tasks (e.g., Spivey, Grosjean, & Knoblich, 2005; Freeman, Dale, & Farmer, 2011). Mouse tracking allows for the examination and comparison of two-dimensional mouse trajectories during online, continuous competition between multiple response options. In this way, movement toward the correct response reflects facilitation, and movement toward the incorrect response reflects interference. Because many cognitive processes occur rapidly, a continuous measure with considerable temporal resolution such as mouse tracking is optimal. Spoken word recognition is one online cognitive process that occurs quickly and automatically, often examined with the use of RT and accuracy data in tasks such as lexical decision. In addition to these outcomes, the mouse-tracking software used in the current study also provides measures of variables over time. For example, measures of spatial attraction allow for the comparison of trajectories' distances from unselected response options and measures of complexity (smoothness of trajectory) that could indicate the "attraction" of the hand to more than one response option simultaneously. Retaining trajectories in raw time also allows for the analysis of velocity. See Freeman and Ambady (2010) for a full review of the MouseTracker software used in the present study. The current study used mouse tracking in a replication of a relatively difficult lexical decision task from McLennan and Luce (2005) in which participants decided on each trial whether a stimulus heard over headphones was a word or nonword by pressing an appropriate button on a response box. Results of that study (and many others) found facilitation for words compared to nonwords in the form of shorter RTs and higher accuracy rates, known as a lexicality effect.

Consistent with those results, results of the current study were also expected to indicate a lexicality effect. Specifically, relative to nonwords, the following results were expected to emerge in the mouse trajectories for words: shorter RTs, less complexity - as indicated by fewer horizontal direction changes (i.e., x-flips), and less spatial attraction to the incorrect response (i.e., a smaller maximum deviation and a smaller area under the curve compared to the ideal trajectory). We also predicted differences in velocity between trajectories for words and nonwords that would indicate a lexicality effect. In particular, we expected mouse trajectories to be faster earlier during the course of the trial for words relative to nonwords.

Method

Participants

Seventy-two right-handed, English-speaking undergraduate students with no hearing or speech disorders received partial course credit for participation.

Materials

Auditory stimuli consisted of 12 monosyllabic English words spoken by a male and 12 spoken by a female, 12 monosyllabic nonwords spoken by a male and 12 spoken by a female, and eight monosyllabic control items (four words, four nonwords). All words and nonwords were taken from Experiment 2 of McLennan and Luce (2005). Nonwords from this experiment were created by using sequences with low phonotactic probability, determined by positional segment frequency and biphone frequency.

Procedure

For each trial, participants clicked "START" at the bottom center of the screen, cueing the onset of the auditory stimulus over headphones and the response timer. Participants then clicked one of two buttons at the top right and left corners of the screen labeled "Word" and "Nonword", respectively. Figure 1 shows a screenshot during the auditory lexical decision task. The MouseTracker software first rescales all trajectories into a standard coordinate space, which has been used in previous research by Freeman et al. (2011). It represents a 2 X 1.5 rectangle, which retains the aspect ratio of most computer screens, leaving the start location of the mouse (at the bottom center of the screen) with the coordinates (0.00, 0.00; See Figures 1 and 2).

Results

See Table 1 for descriptive statistics. Results showed that RTs to words were shorter than RTs to nonwords, $t(71) = -10.30$, $p < .0001$. Participants also made fewer direction changes (i.e., x-flips) in response to words compared to nonwords, $t(71) = -3.03$, $p = .002$. Trajectories for words had smaller maximum deviations from the ideal trajectory (a straight line from the center of the start button to the center of the correct response alternative) compared to nonwords, $t(71) = -12.42$, $p < .0001$. See Figure 2, which displays the mean online mouse trajectories for words and nonwords (after responses to nonwords were remapped 90 degrees to the right for comparison). Trajectories for words also had smaller area under the curve compared to the ideal trajectory relative to nonwords, $t(71) = -11.31$, $p < .0001$.

A 2 (Stimuli: word, nonword) x 6 (Time Bin: 100-300 ms, 300-500 ms, 500-700 ms, 700-900 ms, 900-1100 ms, 1100-1300 ms) repeated measures ANOVA on velocity showed significant main effects for stimuli, $F(5, 355) = 11.87$, $p = .001$ and time bin, $F(5, 355) = 103.53$, $p < .001$, qualified by a significant Stimuli x Time Bin interaction, $F(5,355) = 39.92$, $p < .001$. Based on the significant interaction, separate ANOVAs were conducted for each time bin. As predicted, results of the ANOVA showed that participants moved the mouse faster for words than nonwords during first three time bins, faster for nonwords during last two time bins, and converge during the last time bin. Table 2 displays differences in mean velocity of the mouse trajectories for words versus nonwords during six successive time bins.

Discussion

As predicted, RTs to correct responses to words were significantly shorter than to nonwords. In addition, compared to the ideal trajectory (a straight line from "START" to the correct answer), the area under the curve for correct responses to words was on average significantly smaller than for that of nonwords. These results are consistent with previous research using a visual lexical decision task and mouse tracking (Barca & Pezzulo, 2012), suggesting that spatial attraction to the incorrect response was larger for nonwords compared to words. Finally, analyses of velocity over time provided information regarding the real-time dynamics of the perceptual processing over the course of a trial. Velocity results suggest that participants moved the mouse faster sooner on average for words compared to nonwords, providing evidence for an effect of facilitation on velocity for words relative to nonwords. Thus, a lexicality effect, reflecting differential processing of words and nonwords, was evident as early as 100 ms into a mouse movement. This evidence of a lexicality effect emerges much earlier using mouse tracking during an auditory lexical decision task relative to what has been reported previously with RT data in studies using traditional button-push responses. It is possible that end-point measures, such as RT and accuracy, may be providing an incomplete picture – or even leading researchers to miss effects altogether. Continuous measures, like that of mouse trajectories, may be more appropriate for examining some aspects of spoken word recognition, as well as other cognitive psychological phenomena.

The results of the current study contribute to the understanding of the online processes involved in spoken word recognition. Moreover, the results provide a solid base from which to examine additional issues (e.g., priming effects) in spoken word recognition.

References

Barca, L. & Pezzulo, G. (2012). Unfolding visual lexical decision in time. *PLoS ONE* 7(4): e35932. doi:10.1371/journal.pone.0035932.

Freeman, J.B., Dale, R., & Farmer, T.A. (2011). Hand in motion reveals mind in motion. *Frontiers in Psychology, 2,* 1-6.

Goldinger, S.D. (1996). Auditory lexical decision. Language and *Cognitive Processes, 11,* 559-567.

McLennan, C.T. & Luce, P.A. (2005). Examining the time course of indexical specificity effects in spoken word recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31,* 306-321.

Spivey, M. J., Grosjean, M., & Knoblich, G. (2005). Continuous attraction toward phonological competitors. *Proceedings from the National Academy of Science, 102* (29), 10393-10398.

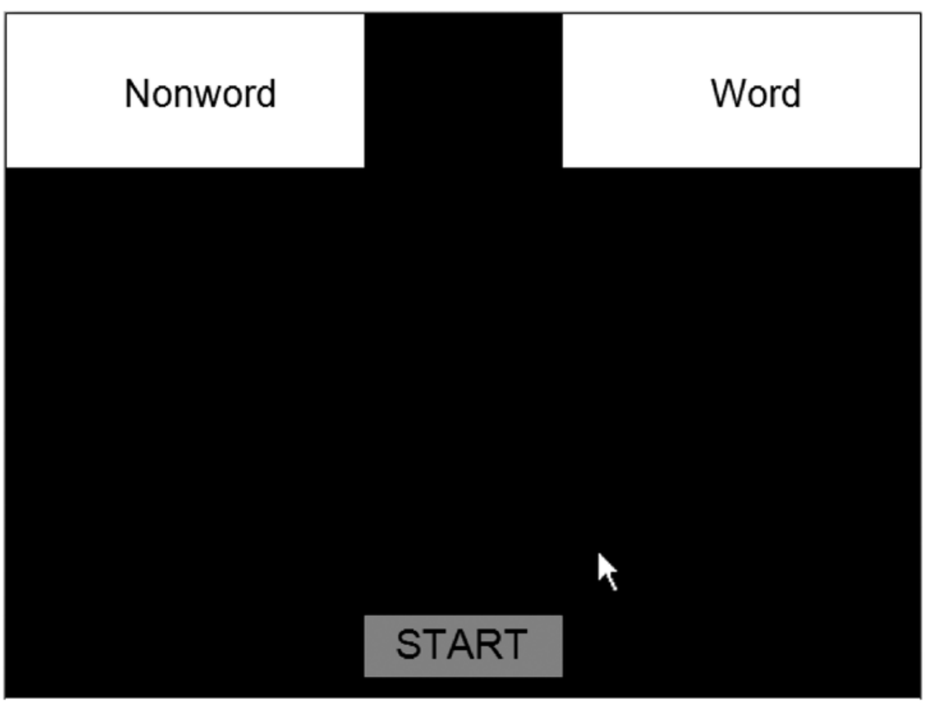

Figure 1. Screenshot during auditory lexical decision task.

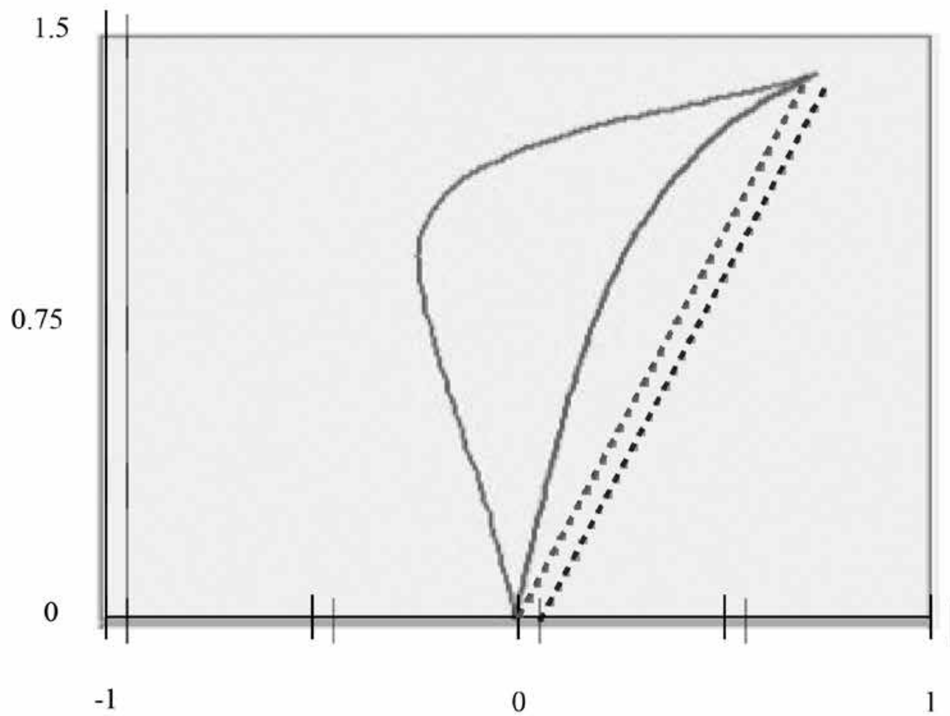

Figure 2. Average mouse trajectories for words (in purple) and nonwords (in blue) after remapping all nonword trajectories 90 degrees to the right. Dotted line represents the ideal trajectory used to compute maximum deviation and area under the curve measures.

Table 1

Descriptive Statistics for Words and Nonwords (n = 72)

Measure	**Word Mean (*SE*)**	**Nonword Mean (*SE*)**
RT *	1040 (23) ms	1261 (27) ms
x-flips *	7.5 (0.2) flips	8.1 (0.2) flips
Maximum Deviation *	0.25 (0.03)	0.81 (0.03)
Area Under the Curve *	0.51 (0.05)	1.91 (0.10)

Note. * $p < .01$.

Table 2

Differences in Mean Velocity of Mouse Trajectories for Words and Nonwords for Six Equal Time Bins (n = 72)

Time Bin (ms)	Word Mean (*SE*)	Nonword Mean (*SE*)	$F(1, 71)$	p
100 to 300	.026 (.006)	-.022 (.004)	26.51	< .001
301 to 500	.085 (.010)	-.065 (.009)	75.70	< .001
501 to 700	.113 (.009)	.025 (.013)	23.10	< .001
701 to 900	.092 (.008)	.218 (.014)	47.46	< .001
901 to 1100	.067 (.009)	.171 (.012)	39.95	< .001
1101 to 1300	.040 (.009)	.048 (.010)	0.333	.566

About the Authors

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