Co-registration of mouse cursor and eye movements reveals comparable sensitivity of mouse and eye-tracking to prediction during language comprehension

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Mouse cursor tracking is becoming a popular tool for psycholinguistic research, but it is unclear whether it is as sensitive as other methods such as eye tracking. In this study, we tested whether listeners of Mandarin Chinese can use nominal classifiers and tonal information in pre-classifier numerals to make predictions about upcoming words by registering listeners' eye- and mouse cursor-movements simultaneously. We replicated existing eye-tracking results that listeners used nominal classifiers [1,2], but not numeral tones [3], to predict, and obtained highly comparable results from mouse cursor tracking.

Methods. Participants (n=47) viewed pairs of images on the top corners of the screen while listening to simple instructions such as (1), which contain the sentence frame "Please click on…" and a critical NP consisting of a numeral, a classifier, and a noun (Fig. 1). Participants started each trial by clicking on a black circle at the bottom centre of the screen. Once they started moving the cursor upwards, the instruction was presented auditorily with a syllable onset asynchrony (SOA) of 500ms. Participants were instructed to maintain continuous mouse movements throughout the trial and click on the target as quickly as possible.

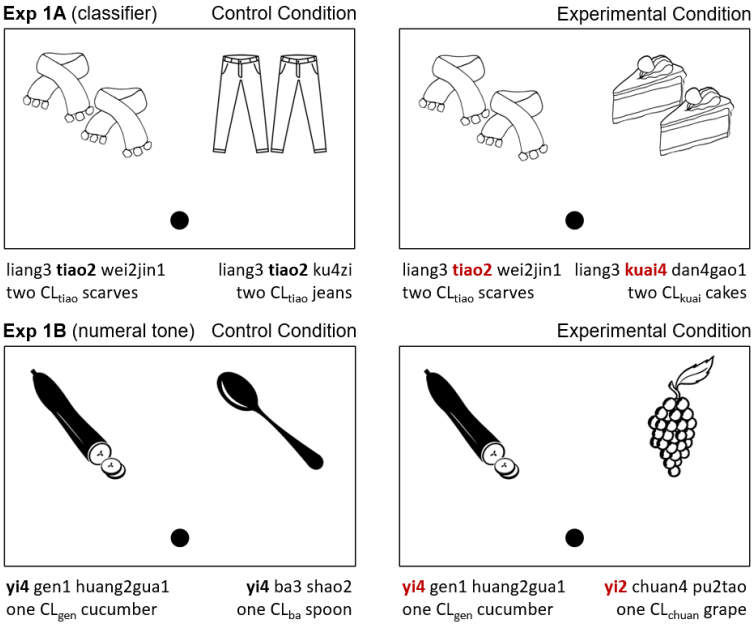
(1) qing3 dian3ji1 yi2 chuan4 pu2tao5
Please click one$_{NUM}$ bunch$_{CL}$ grape$_{N}$ ("Please click on one bunch of grapes.")

In **Exp 1A**, the target and competitor were associated with different nominal classifiers in Mandarin Chinese in the Experimental condition, but they shared the same classifier in the Control condition, such that the classifier was informative of the target's identity in the Experimental condition only. The materials in **Exp 1B** were designed in the same way, except that the two object labels always required distinct nominal classifiers and they differed in whether they triggered a change in the lexical tone (aka tone sandhi) in the preceding numeral (or not). As such, the tone of the pre-classifier numeral was informative about the upcoming classifier and noun in the Experimental condition but not in the Control condition. We tested the T3 sandhi using the numeral *liang3* ('two'), and the *yi* sandhi using the numeral *yi1* ('one'). If listeners can use classifier (Exp 1A) and tone sandhi (Exp 1B) information to predict upcoming language, they should be able to direct their eye gaze and mouse cursor towards the target image earlier in the Experimental conditions than the Control conditions.

Results. Divergence point analysis [4] revealed that in **Exp 1A**, participants showed significantly faster looks to the target object in the Experimental condition (mean = 874ms, 95%CI = [860, 880]) than Control (mean = 1282ms, 95%CI = [1260 1320]; Fig. 2A). Similarly, they were also faster to direct their mouse cursor towards the target in the Experimental (mean = 920ms, 95%CI = [880, 960]) than the Control condition (mean = 1382ms, 95%CI = [1320, 1440]; Fig. 3A). Results suggest that listeners used classifiers to predict the upcoming noun. In **Exp 1B**, no significant differences in divergence points were found between conditions in either eye or mouse cursor movements (Fig. 2B, 2C, 3B, 3C), suggesting that listeners were not able to use tone sandhi in the numeral to predict the upcoming classifier and noun. **In all of our analyses, divergence points in eye movements and mouse movements were highly similar (mean mouse-eye difference = 74.2ms, max = 107ms).** Results from a follow-up Exp 2 (n=31) with the same materials and an 800ms SOA were also highly similar to those of Exp 1 (mean mouse-eye difference = 107ms, max = 156ms).

Conclusion. Results showed that Mandarin Chinese listeners could use nominal classifiers, but not tone sandhi in a numeral, to predict upcoming language. Crucially, divergence points detected in mouse movements and those detected in eye movements showed remarkably similar results,

indicating that mouse cursor tracking has comparable sensitivity to prediction during language comprehension to eye tracking.



References

[1] Chow, W. Y., & Chen, D. (2020). *Language, cognition and neuroscience*, 35(9), 1149-1161.

[2] Klein, N. M., Carlson, G. N., Li, R., Jaeger, T. F., & Tanenhaus, M. K. (2012). In *Count and mass across languages*, 261-282.

[3] Huo, Y. & Chow, W.Y. (2022) Poster presented at the Architectures and Mechanisms of Language Processing (AMLaP) 2022.

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Fig. 1. A sample visual display of materials.

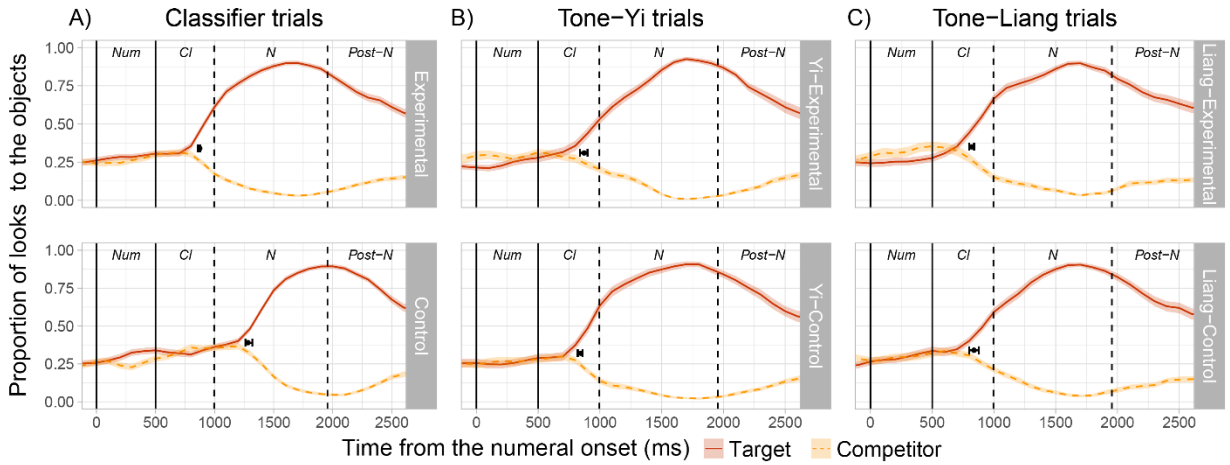

Fig. 2. Change of proportion of **eye fixations** on the target and competitor object across all conditions.

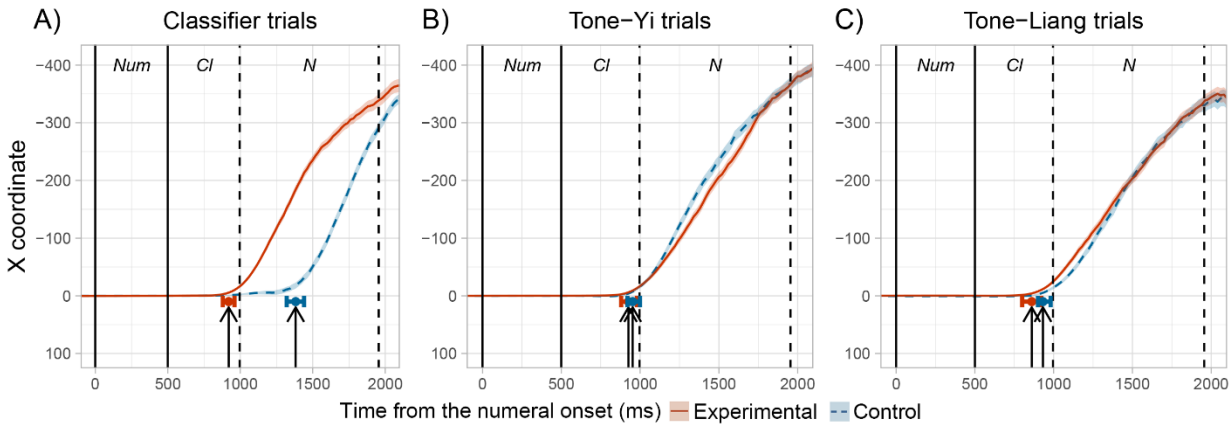

Fig. 3. Change of the cursor's x-coordinate in **mouse cursor positions** across all conditions.