Individual difference in semantic working memory predicts verb-mediated anticipatory eye movement during sentence comprehension

Introduction

Anticipatory eye movements in the visual world paradigm (VWP) reveal an important role for predictive processing during language comprehension. For example, when participants hear "The boy will eat the cake", they make anticipatory eye movements towards a picture of a cake when the other objects in the scene are inedible[1]. This pattern suggests that we predict features of an upcoming noun based on information about the verb. While the anticipatory eye movement effect has been widely replicated, there is variation across individuals and previous research has been mixed as to whether this variation relates to general cognitive abilities. Huettig and Janse[2] showed that individuals with greater working memory (WM) capacity showing more anticipatory eye movements, but Hintz and colleagues[3] failed to find evidence for these relationships, though the studies differed in how WM was assessed. The current study uses more theoretically informed measures targeting visual-spatial, semantic, and phonological WM to investigate the role of WM in verb-mediated anticipatory eye movements. We hypothesize that semantic WM, the ability to temporarily maintain word-meaning information, plays a key role, as past studies suggest that semantic WM is critical for comprehension[4].

Method

The visual world experiment included 50 sentences, either predictable or unpredictable based on the verb. Sixty-four participants listened to sentences (e.g., "The man peels/draws, at this moment, an apple") while viewing a screen with a target object (e.g., apple) and three unrelated distractors (e.g., candle, radio, owl). Forty experimental sentences were adapted from the Hintz, Meyer, and Huettig's study[5], translated into English, and supplemented with ten filler sentences to vary sentence structure.

Visual-spatial WM was measured with the Corsi block tapping task. Participants saw a set of blocks light up in sequence and were instructed to click the blocks in the same order. Semantic WM was measured with synonym probe. Participants saw lists of 6 words followed by a probe word and judged whether the probe word was a synonym with any list words. Phonological WM was measured with digit matching. Participants listened to two list of 7 digits and indicated whether the lists were the same or different.

Results and conclusion

Eye fixation data were analyzed for the critical period between the acoustic onset of the verb and the onset of the target noun. The difference in fixations to the target vs. distractors was significantly greater in the predictable condition (14.3%) than in the unpredictable condition (1.6%), $t(63) = 13.37$, $p < .0001$, confirming the verb-mediated anticipatory eye movement effect.

A multiple regression analysis was conducted with the three working memory measures as independent variables, and the proportion of fixations on the target object in the predictable condition as the dependent variable. The results showed that only the synonym probe task made a significant unique contribution ($b = .36$, $p < .01$), indicating that individuals with larger semantic WM capacity exhibited more anticipatory eye movements. Our findings highlight the critical role of semantic WM, in contrast to phonological or visual-spatial WM, in verb-mediated predictive processing.

References

1. Altmann, G. T., & Kamide, Y. (1999). Incremental interpretation at verbs: Restricting the domain of subsequent reference. *Cognition*, *73*(3), 247-264.
2. Huettig, F., & Janse, E. (2016). Individual differences in working memory and processing speed predict anticipatory spoken language processing in the visual world. *Language, Cognition and Neuroscience*, *31*(1), 80-93.
3. Hintz, F., Voeten, C. C., Dobó, D., Lukics, K. S., & Lukács, Á. (2024). The role of general cognitive skills in integrating visual and linguistic information during sentence comprehension: individual differences across the lifespan. *Scientific Reports*, *14*(1), 17797.
4. Martin, R. C. (2021). The critical role of semantic working memory in language processing. *Current Directions in Psychological Science*, *30*, 283-291.
5. Hintz, F., Meyer, A. S., & Huettig, F. (2017). Predictors of verb-mediated anticipatory eye movements in the visual world. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *43*(9), 1352.

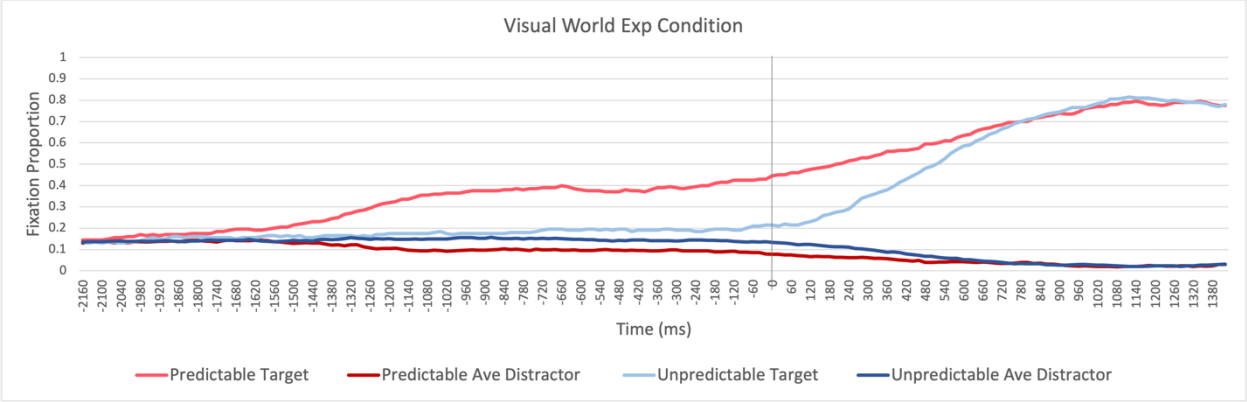

Figure 1. Results of visual world paradigm. The figure plots the fixation proportions for target and averaged distractor objects in the predictable and unpredictable experiment sentence conditions. The critical time window spans between the acoustic onset of verb (the most left end of time axis) and the acoustic onset of the target noun (time zero, vertical grey line).

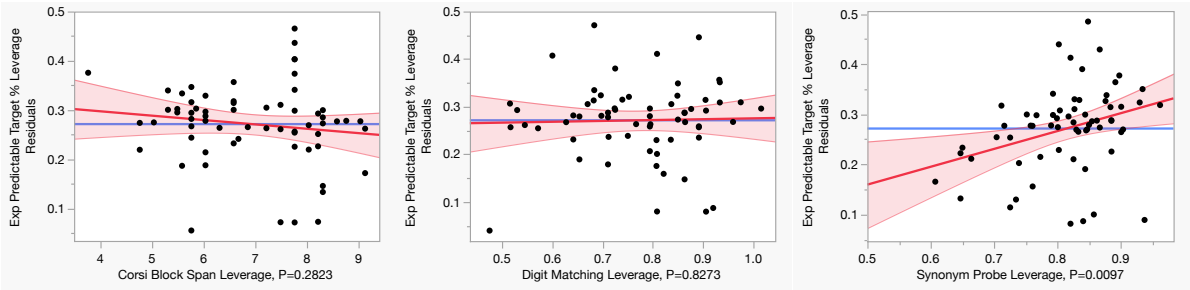

Figure 2. Leverage plots from multiple regression analysis with Corsi block, digit matching and synonym probe as predictors.