

Event-based eye blink rate as an index of working memory gating and updating: predictive pre-updating and individual differences in working memory capacity

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Introduction:

Prediction mechanisms in sentence processing

Lau, Holcomb, & Kuperberg (2013) suggested a distinction between two prediction mechanisms:

- **Pre-activation** – activating representations stored in long-term memory (i.e. the knowledge of a word/concept)
- **Pre-updating** – integrating the predicted content into the sentence's representation built online in working memory (WM)

In a recent study we found **evidence from event-related potentials** for predictive pre-updating in highly constraining contexts (relative to low constraint). Additionally, **the tendency to engage in pre-updating was shown to be affected by individual differences in WM capacity** (i.e. individuals with higher WM capacity displayed greater pre-updating effects; Ness & Meltzer-Asscher, 2018).

In the current study we sought additional evidence for pre-updating and its sensitivity to individual differences in WM capacity, from a different methodology: Event Based Eye Blink Rate (ebEBR).

Event Based Eye Blink Rate

Extensive research indicates that spontaneous **eye blink rate (EBR) is an effective indirect measure of dopamine (DA) activity in the striatum** (Jongkees & Colzato, 2016).

Additional work suggests that **phasic DA signals drive gating and updating of WM**, in line with the prefrontal cortex basal ganglia WM model (Hazy, Frank, & O'Reilly, 2006).

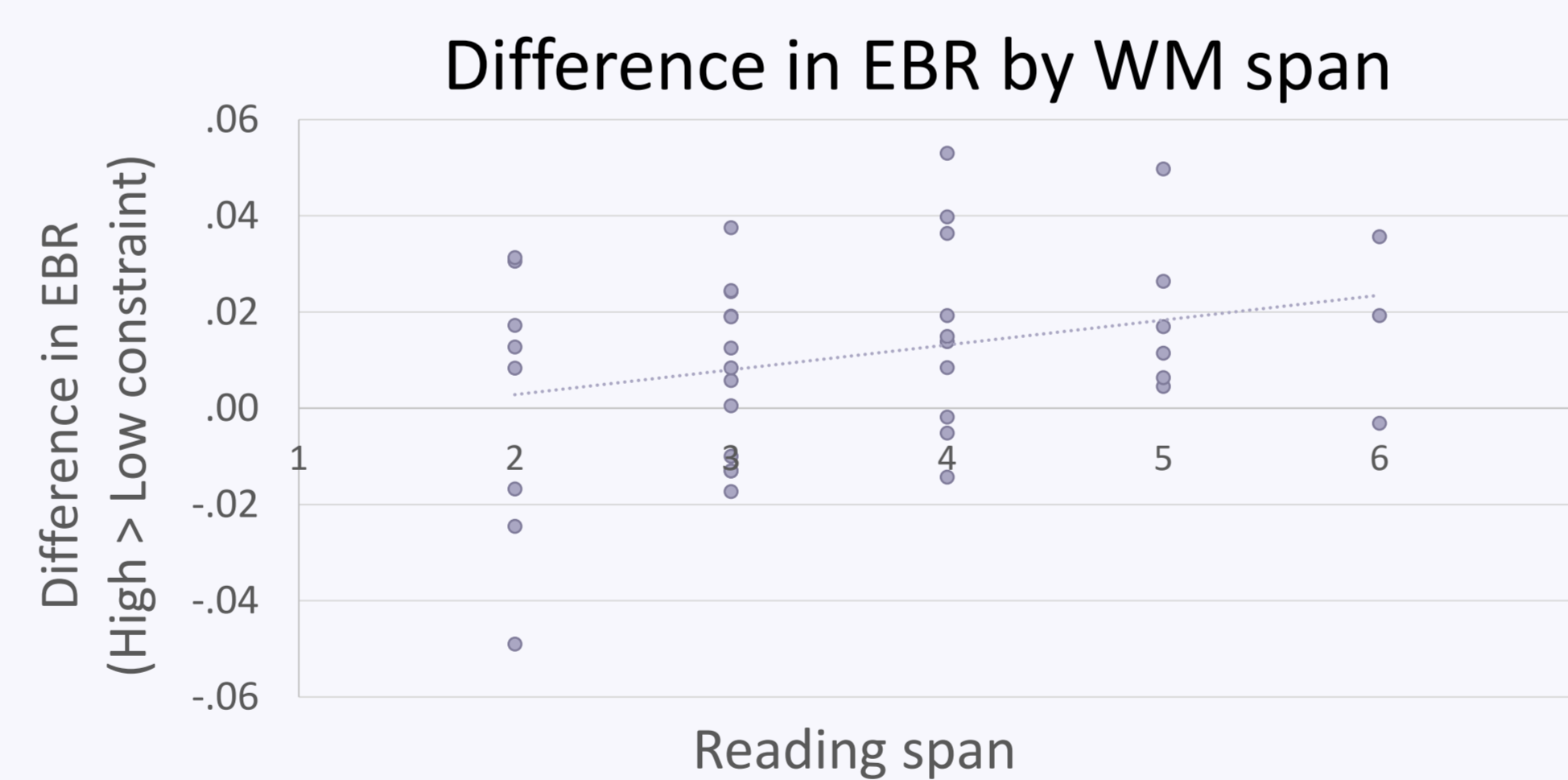
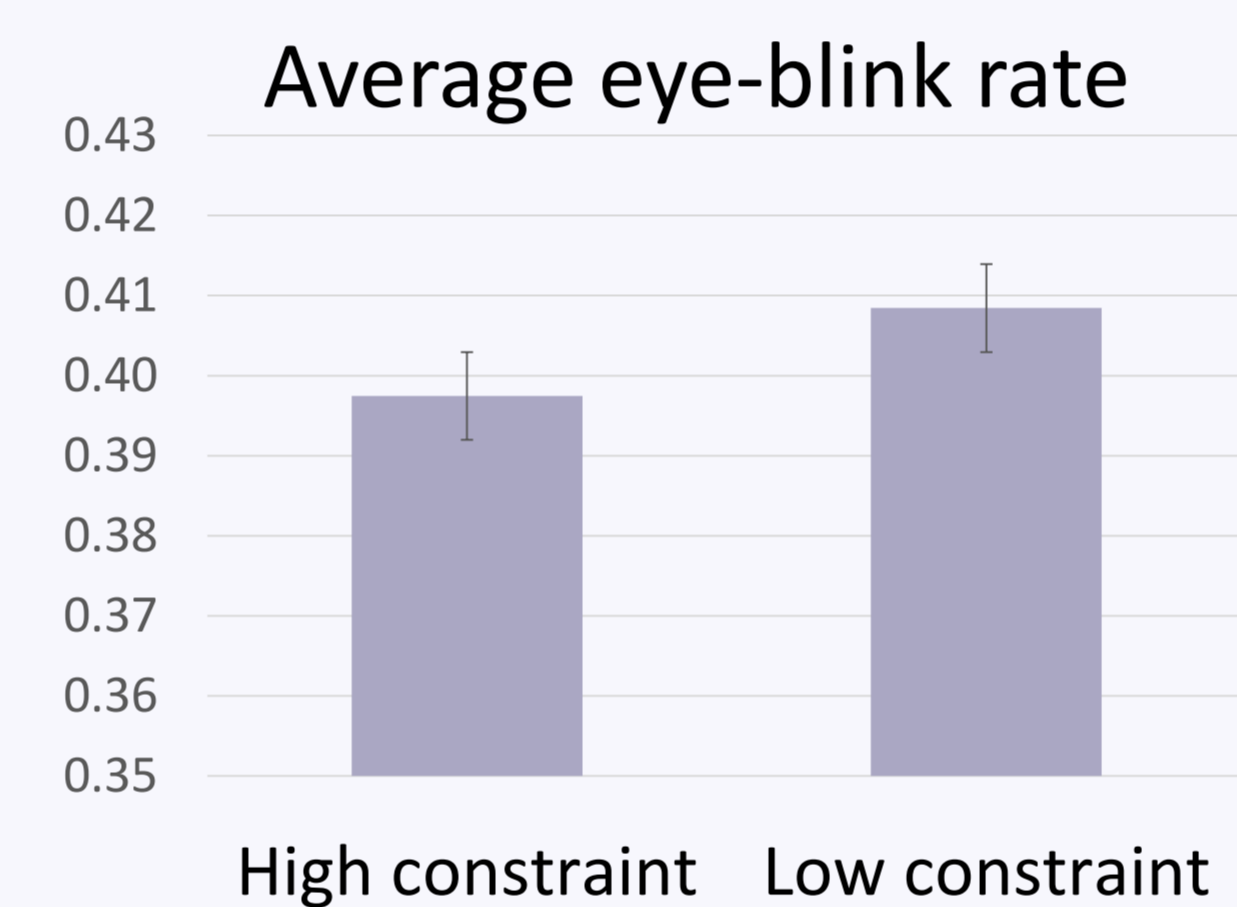
In a recent event-based eye-blink rate (ebEBR) study, **blink rate was shown to increase when WM was updated** in a non-linguistic, reference-back task (Rac-Lubashevsky & Kessler, 2017).

Hazy, T. E., Frank, M. J., & O'Reilly, R. C. (2006). Banishing the homunculus: making working memory work. *Neuroscience*; Jongkees, B. J., & Colzato, L. S. (2016). Spontaneous eye blink rate as predictor of dopamine-related cognitive function—A review. *Neuroscience & Biobehavioral Reviews*; Lau, E. F., Holcomb, P. J., & Kuperberg, G. R. (2013). Dissociating N400 effects of prediction from association in single-word contexts. *Journal of Cognitive Neuroscience*; Ness, T., & Meltzer-Asscher, A. (2018). Predictive pre-updating and working memory capacity: Evidence from event-related potentials. *Journal of cognitive neuroscience*; Rac-Lubashevsky, R., Slagter, H. A., & Kessler, Y. (2017). Tracking real-time changes in working memory updating and gating with the event-based eye-blink rate. *Scientific reports*.

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Methods and results:

Constraint	Phrase
High	<i>hitxamemut globalit</i> warming global 'Global warming'
Low	<i>marak yerakot</i> soup vegetable 'Vegetable soup'



Hypothesis:

Participants read two-word phrases, in which the first word was either highly predictive of the next (i.e. highly constraining) or not.

In high constraint phrases, upon updating the first word into WM, if pre-updating occurs then the predicted second word is also updated, and no gating or updating is expected upon presentation of the second word. Therefore, a reduction in EBR is expected in the high relative to the low constraint condition.

Participants' WM capacity was assessed via a reading span (RS) task. The aforementioned effects should be greater for participants with high WM capacity, reflecting a higher tendency to engage in pre-updating.

Methods:

40 native Hebrew-speaking students participated.

160 two-word phrases, half in each condition. Mean constraint was 88.6% in the high constraint condition (all above 70%), and 24.3% in the low (all below 35%). 40 anomalous word phrases were used as fillers.

Phrases were presented word-by-word in the middle of the screen (SOA = 1000ms). Participants were instructed to press a button as quickly as possible if a phrase is anomalous.

Blinks were measured using EOG electrodes above and below the eye. ebEBR was calculated as the average amount of blinks per second in the 4 seconds following the presentation of the second word in the phrase.

Results:

Constraint ($p = .002$)

Constraint * Span ($p = .032$).

Conclusion:

In the highly constraining phrases, a decreased ebEBR was observed after the presentation of the predicted word, indicating that **upon encountering a pre-updated word, gating and updating was not needed**, presumably as this was already performed at the first word.

This effect was greater for participants with higher reading span, indicating a higher tendency to engage in pre-updating by participants with higher WM capacity.

These results are in line with the previous ERP results, providing corroborating evidence for pre-updating and for the influence of WM capacity.

By finding ebEBR results that are consistent with the ERP results, we also provide validation for this technique as a tool to study other linguistic phenomena.