Is the P600 linked to phasic noradrenaline release? Relating ERPs to pupil size in a sentence processing paradigm

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Introduction. The P600 event-related component is typically interpreted as a signal of specific linguistic syntactic and combinatorial operations and it continues to inform neurocognitive models of language comprehension (e.g., Brouwer et al., 2017). However, more recently the P600 – just like the earlier P3 – has been proposed to reflect phasic norepinephrine release from the locus coeruleus (LC-NE) to motivationally significant stimuli more generally (Sassenhagen et al., 2014, 2015, 2019). LC-NE activity remains difficult to measure directly in humans, but pupil size has been established as an index of both phasic (task-elicited dilation) and tonic LC activity (baseline pupil size, e.g., Joshi et al., 2016).
Methods. Here, we aim to further test this LC-NE-P600 hypothesis by co-registering pupil size and EEG in a sentence processing task. Thirty-six participants will be presented via rapid serial visual presentation with 240 German sentences (modified from Sassenhagen & Fiebach, 2019, Exp. 2; see examples below), 25% of which contain agreement violations. After each sentence, participants will make a grammaticality judgment. To minimize luminance changes, words, inter-stimulus intervals, and the fixation cross will be enclosed in a continuous, same sized mask.
Expected results. We expect an effect of sentence type on both of our dependent measures: The amplitude of the P600 and the size of the task-elicited pupil dilation should be larger on target words in violation than control sentences. Further, if pupil diameter is a proxy for LC-NE activity and the P600 indeed reflects phasic NE release, P600 amplitude and pupil dilation should be correlated on a trial-to-trial basis in sentences containing violations. Lastly, phasic noradrenaline activity exhibits a non-linear relationship to tonic (baseline) NE activity, with the strongest phasic activity occurring in the medium tonic range, while during very low and very high tonic mode, phasic responses are reduced or completely absent (Aston-Jones & Cohen, 2005). Thus, both the P600 as well as task-elicited pupil dilation should exhibit such an inverted U-shaped relationship with target word-onset baseline pupil diameter, a proxy for tonic LC-NE levels. We will test these hypotheses using mixed effects models, which take into account variability of the effects of interest per participant and item.
Additionally, we will supplement the paradigm with a non-linguistic oddball task replicating previous findings on the relationship between pupil size and the P3 (e.g., Hong et al., 2014; LoTemplio et al., 2020; Murphy et al., 2011). Since the P3 is similarly suggested to reflect phasic LC-NE activity (Nieuwenhuis et al, 2005), we expect the same relationship between the P3 amplitude and pupil size as outlined for the P600 above.
Discussion. The results of this study will contribute to our understanding of the neurobiological basis of the P600 ERP component. Observing a relationship between pupil size and both the P600 and P3 would further support the idea that both ERP components might rely on a shared neural generator and, more specifically, that they may both be linked to phasic NE release. This could further inform the debate on whether language-related ERPs such as the P600 are indeed specific to linguistic processes or whether they reflect more domain-general cognitive processes and should be interpreted as such in neurocognitive models of language comprehension (e.g., Bornkessel-Schlesewsky & Schlesewsky, 2019; van de Meerendonk et al., 2010).

The study has been pre-registered on OSF, data collection is ongoing, and we expect to present first results at the AMLaP conference.

Example sentence stimuli (Target words are underlined.)

*Der schüchterne Schüler **[sitzt/*sitzen]** auf der Bank.*

[The timid student [sits/sit] on the bench]

*Den Kuchen mögen **[sie/*er]** ganz besonders.*

[The cake like [them/he] very much]. (They/he particularly like the cake)

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