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Emotionally arousing context modulates the ERP correlates of neutral picture processing: An ERP test of the 'Glutamate Amplifies Noradrenergic Effects (GANE)' model

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Abstract: The timescale of the effects of emotional arousal on neutral information processing is crucial for the predictions of the Glutamate Amplifies Noradrenergic Effects (GANE) model. GANE suggests that when emotional and neutral stimuli are presented in a slow sequence, neutral information processing will change. We review the ERP literature, including our own dataset, to test this prediction.

The timescale of the facilitating versus impairing effects of emotional arousal on the processing of neutral information is an open question for GANE (p.53). The authors assert that "an emotionally salient word that impairs perceiving a subsequent target word flashed in the same location 50 or 100ms later can instead enhance perceiving a target word flashed 1000ms or later" (p.9). The specific timescales are likely to vary across experimental setups,

e.g. depending on the complexity of stimuli and the intensity of the arousal. The problem is that if the impact of arousal is not temporally bound, priority can be used to explain experimental effects in either direction, namely, both the impairing and the

facilitating effects of arousal. Here we discuss how EEG data can provide crucial temporal dynamic

information that can disambiguate GANE's predictions - evidence which the target article did not consider.

According to GANE arousing stimuli capture resources during their processing. Once their own processing is completed the arousal they induce also facilitates the processing of subsequent stimuli. To test GANE we need to know in advance the duration of emotional stimulus processing. Previous work shows that emotional pictures, a stimulus of choice in much of the human emotion-cognition literature, enhance a number of event-related potentials (ERPs). The most robust is the Late Positive Potential (LPP). The LPP is thought to reflect attention allocation and maintenance of stimuli in working memory (Donchin and Coles, 1988). The amplitude of the LPP 400-700ms after stimulus presentation is higher when stimuli are emotional (Schupp et al., 2006), reflecting the additional resources allocated to such stimuli, in line with GANE. Emotion also enhances other components, including the positive slow-wave, where amplitudes are higher up to 6s post-stimulus. We can conclude, therefore, that the processing of neutral information presented within 6s of emotional pictures may be altered.

Only with this temporal information can we put GANE to the test. We do so by comparing the ERPs associated with processing neutral stimuli presented on their own (blocked neutral condition), to those presented alongside emotional stimuli (mixed condition). Not only is the context more arousing in the mixed condition (Long, Danoff & Kahana, 2015), but emotional stimuli also increase arousal locally. When the inter-stimulus interval (ISI) is long emotional and neutral stimuli are unlikely to compete for processing resources and GANE predicts that the higher global arousal in the mixed condition should enhance neutral information processing. By contrast, Pastor et al. (2008) used an ISI of 12s and observed *reduced* LPP for neutral stimuli in the mixed compared to the blocked condition. It is possible, however, that those emotional pictures

were still being processed when the subsequent picture was displayed after 12s. When the ISI is short competition should be pronounced, so GANE predicts that the processing of neutral information should be impaired. By contrast, Schupp et al. (2012) used an interval of 3s and observed a null effect of context (blocked/mixed). It is possible, however, that the effect of emotion on resource allocation in that study was short-lived, e.g. because of the orienting task. If emotional stimuli no longer attract attention when subsequent neutral stimuli were presented the null effect is compatible with GANE's predictions.

In our experiment (Barnacle et al., in preparation) 23 healthy adults viewed 16 lists of 14 pictures: 4 neutral, 4 emotional, and 8 mixed lists (50% emotional pictures). All pictures depicted people; emotional and neutral picture sets were equally semantically related; but the emotional pictures were more negative and arousing. Each picture was presented for 2s with a jittered ISI of 4s +/- 0.5s. Participants were asked to encode these pictures for a free- recall memory test, which followed each study list after a 60s-distractor task. EEG was recorded during encoding with a BioSemi Active Two (BioSemi, Amsterdam) using 64 electrodes conforming to the 10-20 system and pre-processed with SPM (www.fil.ion.ucl.ac.uk). Data were filtered between 0.1-25Hz, downsampled to 125Hz, and epoched between -200ms and 4000ms. Eye-blink artefact was removed using an algorithm implemented in SPM. A threshold of 100μV was used for trial rejection.

Following Schupp et al. (2012) we extracted LPP and slow-wave component amplitude data, averaging across centroparietal electrodes (Cz, CPz, Pz, C1, C2, P1, P2, CP1, CP2) in three time windows: 400ms-700ms, 1000s-2500s and 2500ms-4000ms post-stimulus. We compared emotional and neutral picture processing in the mixed condition at each window to ascertain the duration of the effects of arousal, using three 1-tailed paired samples t-tests (p<.017 controlled for multiple comparisons). Emotion modulated ERPs in the 400-700ms and 1000s-2500s windows but not later (Figure 1). We then compared neutral picture processing in the mixed and blocked

conditions at both these windows with two 2-tailed t- tests (p<.025). The LPP for neutral pictures was attenuated in the mixed, compared to the blocked, condition.

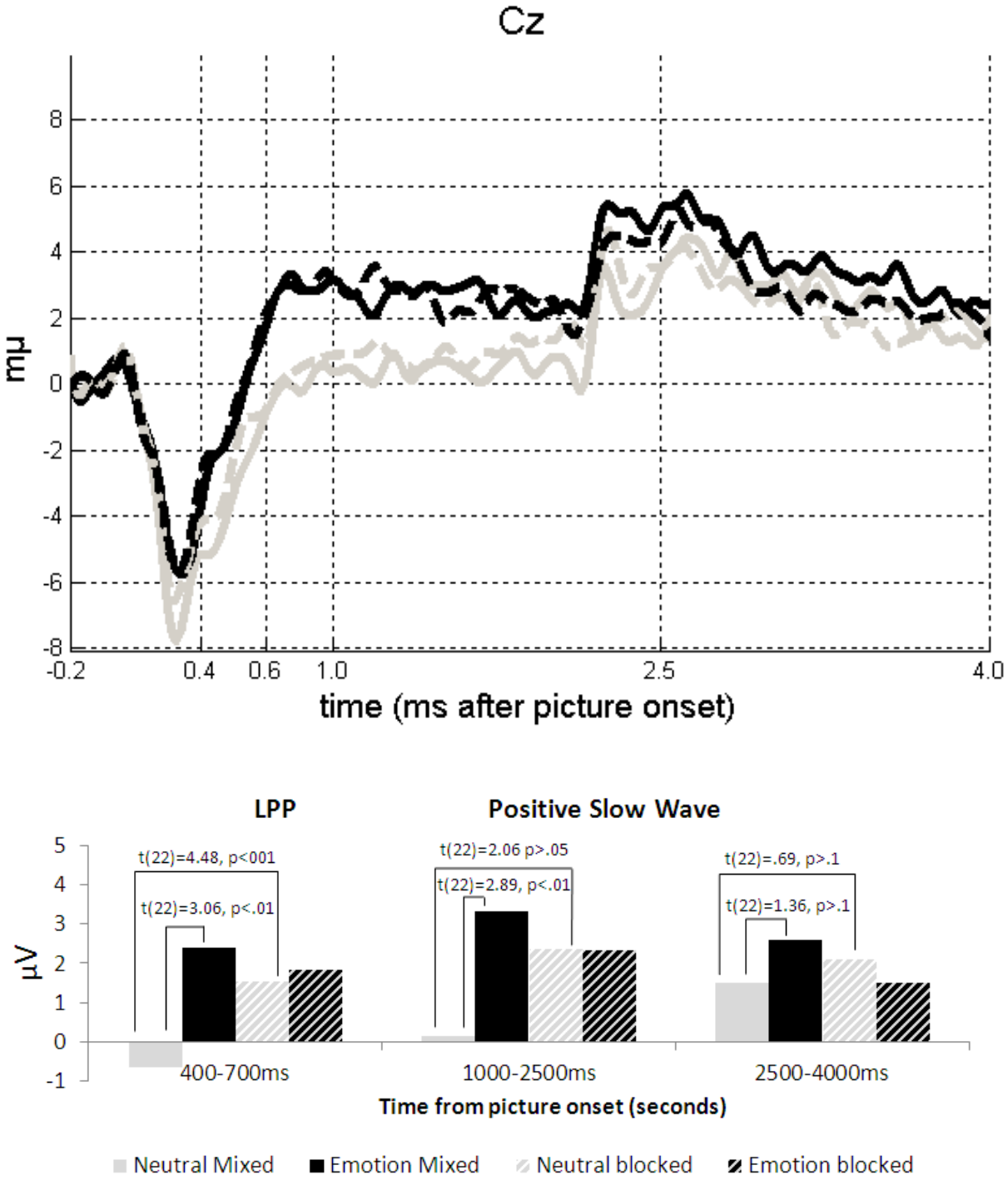

Figure 1. *(Top) ERPs from Cz. (Bottom left) LPP amplitude is higher for emotional than neutral pictures in the mixed condition and lower for neutral in the mixed compared to blocked condition. (Bottom right) Average ERP amplitude in*

time windows corresponding to the early portion of the positive slow-wave. Emotion modulation lasts up to 2500ms post- stimulus.

Our data show that the duration of the effect of arousal is key for testing GANE in novel experimental setups. EEG data allowed us to determine how long emotional pictures attracted extra processing resources. Here the modulation lasted up to 2.5s from stimulus onset, evident in the modulation of the early portion of the LPP and positive slow-wave, but not later. This pattern suggests that arousing stimuli are no longer in competition for resources when neutral pictures are presented in the same sequence. Because of the increased global arousal in the mixed condition, GANE predicts that neutral picture processing should be enhanced. In fact, our data provided robust evidence for *attenuated* processing of neutral information in that situation.

The three ERP datasets we reviewed appear to contradict GANE's predictions. The mature electrophysiological literature on the effect of emotion on perception, attention and memory (e.g. Hajcak, MacNamara & Olvet, 2010; Schupp et al., 2006) can provide crucial data for GANE until data on the timescales of NE-Glutamate interactions are available.

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