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Journal Club

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Latencies Associated with Neuronal Pathways of Visual Emotional Processing

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Review of Wang et al.

Identification of external threats is of paramount importance for survival. However, the neuronal circuits that govern visual discrimination of emotional stimuli remain poorly characterized. Two neural pathways have been proposed, mainly based on their distinct anatomy (Pessoa and Adolphs, 2010). The first pathway is the classical cortical visual pathway that travels from the retina to the lateral geniculate nucleus of the thalamus and then to the visual areas of the occipital lobe; this pathway is expected to be relatively slow (Pessoa and Adolphs, 2010). The second pathway relies on a subcortical pathway from the retina, connecting the superior colliculus to the pulvinar nucleus of the thalamus and then to the amygdala. This pathway is called the low road, and it is thought to rapidly carry coarse information from visual emotional stimuli (Tamietto and De Gelder, 2010). Although the structural connectivity of both pathways has been well documented, the very existence of multiple pathways for visual emotional perception still remains under debate. What is critically missing are functional studies

investigating the latencies and the physiological dynamics supporting emotional visual perception (Pessoa and Adolphs, 2010). Intracranial electroencephalography (iEEG) recordings of epileptic patients undergoing neurosurgery are a unique approach to discover the spectrotemporal profile of these pathways in humans. They may therefore directly inform the debate on the existence and functional significance of both circuit models (Pessoa and Adolphs, 2010; Tamietto and De Gelder, 2010).

Wang et al. (2023) reported the results of a study with epileptic patients implanted with deep electrodes who performed a face discrimination task. The participants were presented with faces carrying different emotional content (neutral, happy, and fearful) with different visual spatial frequencies (low and high). Low spatial frequencies of faces convey coarse emotional cues and are supposed to elicit a stronger amygdala response than high spatial frequencies, and high spatial frequencies convey fine-grained information and are expected to elicit a stronger occipitotemporal regions response than low spatial frequencies. Importantly, this study used a backward masking procedure with a face presented for a short enough duration (33 ms) to limit visual awareness. The authors found an increase of activity in the amygdala during an early stage of perception starting ~80 ms in the raw iEEG local field potential (LFP) signal, with greater response to fearful faces

carrying low spatial frequency information in comparison with faces carrying high-frequency information (Méndez-Bértolo et al., 2016). Importantly, spectral iEEG analyses revealed that this effect was driven by a specific increase of low gamma activity (~30 Hz) starting as soon as 45 ms after stimulus onset. Crucially, recording directly from visual cortices did not produce any evidence for early-stage emotional discrimination during, for example, the P100 or N170, two important electrophysiological markers of visual perception occurring 100 and 170 ms after stimulus onset, respectively. Greater activation of visual cortex in response to fearful compared with neutral faces occurred only later, ~400 ms after stimulus onset, and solely for stimuli carrying high spatial frequency information.

By producing robust evidence in support of the subcortical pathway for processing emotional images, this study confirmed earlier results showing that the human amygdala responds preferentially to fearful faces in comparison with other emotional faces because of specific physical properties of the stimulus (Méndez-Bértolo et al., 2016). Furthermore, the results support the hypotheses that two visual pathways process visual emotional information and characterize the latency of activation of each pathway. Using such an empirical approach with epileptic patients undergoing neurosurgery is important as it is the only way to

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directly measure LFP in humans to discover the latencies associated with cognitive processes. Further research should investigate how information carried by the two pathways converge during emotional perception and investigate their influence on each other.

It should be noted that the results presented by Wang et al. (2023) are somewhat contrary to recent results reported in other studies. These new results provide direct proof of low spatial frequency visual information being processed early by the amygdala and high spatial frequency visual information being processed by the visual cortex later. In contrast, recent findings found activation of the visual cortex occurring ~70 ms after presentation of emotional stimuli that were unconsciously perceived (Carretié et al., 2022). Moreover, such early activation of visual cortex is also observed with nonaffective stimuli (~60 ms after stimulus onset; Pessoa and Adolphs, 2010), suggesting that the classic cortical visual pathway may also participate in the early stages of visual perception. On the other hand, the subcortical pathway has only been associated with the processing of affective stimuli, with no response to, for example, the shape of task-relevant objects (Guex et al., 2020). Together, these different results converge to a model where both pathways contribute to emotional perception at different stages (Pessoa and Adolphs, 2010). These results suggest that early amygdala activation is associated with the processing of low spatial frequencies of affective stimuli in general, independently of stimulus type, in support of the subcortical pathway model (Vuilleumier et al., 2003; Méndez-Bértolo et al., 2016). Regarding high spatial frequencies and the discrepant latencies of activation found in the visual cortex, further investigation needs to disentangle these results by directly comparing spatial frequencies (low and high) with different stimulus type. Together, these results suggest that different pathways temporally coexist during emotional visual perception, which may increase the probability of detection of external threat and may bind physiological activities

between a low level of sensory processing such as the amygdala and the visual cortex with a higher level of neuronal processing in the prefrontal cortex to achieve optimal behavior (Pessoa and Adolphs, 2010).

Although the study by Wang et al. (2023) provides some important insights, there also exist some limitations. In this study, patients had to discriminate the emotional content of faces that were presented very briefly. Based on the behavioral results, from which one patient was excluded because he was able to discriminate the emotion of the faces above chance level, the authors concluded that the stimuli were invisible. However, nondiscriminable does not imply that the stimuli used here could not be detected and therefore that they were indeed invisible. Moreover, it was previously shown with a similar experimental approach using fearful faces that the amygdala is not activated during trials where subjects were unable to detect the presence of the stimulus (Pessoa et al., 2006). Previously it has been suggested that stimulus visibility needs to be evaluated throughout the duration of the experiment (Kouider and Dehaene, 2007); single-trial behavioral responses may be a useful classifier of awareness in this context (Guex et al., 2023). Finally, neuroscience studies mostly use direct comparison between two experimental conditions, varying independently one parameter to characterize precise cognitive processes. Ideally a study on invisible stimuli should use a visible condition to determine which neuronal activity corresponds to one level of awareness (Kouider and Dehaene, 2007). Conceptual framing is also important here as it relates to specific neurologic conditions such as hemineglect or blindsight, which are typically defined by behavioral deficits in visual awareness (Tamietto and De Gelder, 2010). Nevertheless, these considerations do not undercut the main findings of this study, and it is obvious that clinical settings do not offer the same level of experimental control as laboratory experiments with healthy participants.

In conclusion, this work offers a time-frequency description of early activation of the subcortical pathway during emotional perception, which is compatible with the view of a temporal advantage of the subcortical over the cortical visual pathway (Pessoa and Adolphs, 2010) while indicating that both pathways may be contributing to the perception of emotional faces at different temporal stages.

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