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<RH>*Commentary/*Pessoa: Précis of *The cognitive-emotional brain*

<CT>How arousal influences neural competition: What dual competition does not explain

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<C-ABS>**Abstract:** We argue that although the "dual competition" model is useful when considering interactions between emotional and neutral stimuli, it fails to account for the influence of emotional arousal on perceptual or goal-directed behavior involving neutral

stimuli. We present the "arousal-biased competition" framework as an alternative that accounts for both scenarios.

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In chapter 7 of *The Cognitive-Emotional Brain*, Pessoa (2013) presents his dual competition model to explain how emotion-cognition interactions determine the flow of information processing in the brain. A significant limitation of the dual competition model is that it focuses exclusively on the competition between processing emotional versus nonemotional information and ignores the question of how emotional arousal influences competition processes more generally in the brain. In our commentary, we contrast Pessoa's "dual competition" framework to another recent emotion-cognition framework, "arousal-biased competition" (Mather & Sutherland 2011), which posits that not only do emotional stimuli compete with nonemotional stimuli, but that emotional arousal influences how nonemotional stimuli compete with each other for neural representation.

Pessoa's framework is dual natured in that it emphasizes competition in both *perceptual* and *executive* processing. Although Pessoa notes that these two systems interact, he discusses them largely independently of one another in the book. The dual competition framework accounts for how *emotionally significant objects* compete with other information, winning greater attention and memory or impairing goal-directed behavior. Certainly, emotionally arousing things like guns or naked bodies draw attention and compete with other stimuli for both perceptual (e.g., Amting et al. 2010) and

executive resources (e.g., Choi et al. 2012). Pessoa does an excellent job detailing the neural pathways and networks that are potentially involved in these competitive processes. But how does an *emotionally aroused state* influence the processing of otherwise benign information? For example, why do most people recall where they were, or who they were with, when they first heard about the 9/11 attacks, despite the nonemotional nature of such information? This type of enhanced memory of neutral details of arousing events is not predicted by the dual competition framework.

Critically, where Pessoa's dual competition framework, as well as most other theories of emotion-cognition interactions, comes up short is when having to account for how emotionally arousing stimuli sometimes enhance, rather than suppress, perception and memory for the *neutral* things that happen *nearby* in space or time. For example, fear-related cues have been shown to enhance both the perception of (Phelps et al. 2006), and the neural response for (Padmala & Pessoa 2008), simple visual features such as Gabor patches. Additionally, the presence of a task-irrelevant emotionally evocative image during encoding can produce either retrograde amnesia (Strange et al. 2003) or retrograde enhancement (Anderson et al. 2006) of neutral images. The dual competition framework can account for cases in which the processing of neutral stimuli is impaired by arousing stimuli (e.g., Amting et al. 2010), or when emotional distracters impair goal-directed behavior (e.g., Dolcos & McCarthy 2006). It does not account for cases in which arousing stimuli enhance perceptual processing of neutral stimuli (e.g., Padmala & Pessoa 2008; Phelps, et al. 2006). Nor does it account for cases in which emotional arousal facilitates executive processes (e.g., Knight & Mather 2009). In contrast, the

arousal-biased competition model accounts for both arousal's enhancement and impairment effects by positing that arousal increases the gain on biased competition processes. Stimulus representations with high priority, either because of top-down goals or bottom-up salience, are further activated under arousal, while representations of competing, lower-priority stimuli, are further suppressed (Lee et al. 2014; Sutherland & Mather 2012).

In terms of perceptual competition, Pessoa reviews findings that demonstrate the competitive advantage held by emotionally significant objects, like emotional faces. However, recent findings indicate that emotional arousal also increases the gain on competition between nonemotional stimuli (Lee et al. 2014; Sutherland & Mather 2012). For example, on each trial in their study, Sutherland and Mather (2012) presented participants with a sound that was emotionally arousing or a neutral sound, and then 750 to 3000 ms later, briefly flashed eight letters on a white background and asked participants to report as many of the letters as they could. Some of the letters were light gray and some dark gray. Everyone reported a greater number of the more salient dark gray letters than the light gray letters, but this advantage for the salient letters was significantly greater after hearing emotionally arousing sounds. A similar pattern has been observed in the brain when participants were shown one salient stimulus next to a less salient stimulus, preceded by a tone previously conditioned to predict shock or a neutral tone (Lee et al. 2014). Lee et al. (2014) found that while neural activity in the fusiform face area (FFA) corresponding to the perceptually salient face images was enhanced, activity in the parahippocampal place area (PPA) corresponding to the

nonsalient item was attenuated on fear-induced arousal trials. This enhancement of processing salient stimuli and inhibition of processing competing less salient stimuli exemplifies the type of interaction of emotional arousal and perceptual priority accounted for by arousal-biased competition.

When Pessoa considers "executive competition," he reviews findings in which a task-irrelevant emotional stimulus produces impairments in executive behavior and neural inhibition. However, his dual competition perspective cannot account for other findings demonstrating that the presence of a low-priority emotionally arousing stimulus can facilitate goal-directed (or executive) behavior (Anderson et al. 2006; Knight & Mather 2009; Steidl et al. 2006). For example, recently Sakaki et al. (2014) found that when participants' goal was to encode items preceding a potentially emotional oddball item (i.e., oddball-1 items), memory was greater for goal-relevant items on emotional oddball trials compared to nonemotional oddball trials. This observation of retrograde enhancement demonstrates that task-irrelevant emotional arousal can facilitate the execution of task-relevant behavior, which is contrary to the predictions made by the dual competition framework. Additionally, when participants' goal was to encode the oddball item itself, the presence of an emotional oddball led to worse memory for oddball-1 items than the presence of an emotionally neutral oddball. Together, these findings demonstrate that emotional arousal can either *enhance* or *impair* memory for neutral items depending on how goal-relevant information is prioritized.

In conclusion, although Pessoa provides an informative take on how emotional stimuli influence resource competition within the brain, his dual competition model addresses only one subclass of how emotion influences neural competition. To understand how emotion influences cognition more generally, one must consider how emotional arousal can either enhance or impair processing of stimuli that are not inherently emotionally arousing. We argue that emotion influences competitive processes in the brain in general, regardless of whether the mental representations in competition are themselves inherently arousing.

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<RFT>References[Steven G. Greening and Mara Mather]

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