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# Response to Visual Threat Following Damage to the Pulvinar

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## Summary

We present a unique case demonstrating contributions of the pulvinar in response to visual threat. Substantial evidence demonstrates that the amygdala contributes to the emotion of fear and the response to threat [1, 2]. Traditionally, two routes to amygdala activation have been distinguished: a "slow cortical" route through visual and association cortex and a "fast subcortical" route through the thalamus [1]. The pulvinar nucleus of the thalamus is well connected to the amygdala [3], suggesting that pulvinar damage might interfere with amygdala activation and response to threat. We tested this possibility in patient SM, who suffered complete loss of the left pulvinar. We measured interference from threatening images on goal-directed behavior. In SM's ipsilesional field, threatening images slowed responses more than pleasant images did. This interference decreased rapidly over time. In contrast, in SM's contralesional field, interference from threatening images was initially absent and then increased rather than decreased over time. Processing through the pulvinar therefore plays a significant role in generating response to visual threat. We suggest that, with disruption of the subcortical route to the amygdala, briefly presented images were not fully processed for threat. The reemergence of interference over time may reflect contributions of a slower route.

## Results and Discussion

At the time of testing, SM was a 62-year-old male who more than six months earlier had suffered a hematoma centered on the left pulvinar (see Figure 1 for lesion and other details). The lesion destroyed the left pulvinar. There was no evidence of field deficits, neglect, or visual extinction upon confrontation.

We measured the extent to which threatening images, relative to pleasant images, interfered with subsequent goal-directed behavior. Participants responded by pressing the key corresponding to one of two possible colors of an imperative target; they were instructed to make these key-press responses as quickly as possible while minimizing errors. The target was preceded by a task-irrelevant image manipulated according to three factors: image threat (the image was either threatening or pleasant), visual field (the image appeared left or right of central fixation), and image duration (300 or 600 ms). After presentation of the task-irrelevant image, the image was removed and the target appeared in the location of the image (see Figure 2).

We first consider the results of ten age-matched male controls (Figure 3). Controls showed slower mean response time (RT) to targets that followed threatening compared to pleasant images [$F(1, 9) = 8.212$, $p = 0.019$]. This greater cost for threatening relative to pleasant images is consistent with results from previous flanker studies [4] and with the valid conditions of dot-probe-cueing studies [5–7]. Interference from images decreased with time, so that RT for controls was faster for the 600-ms than the 300-ms exposure for both pleasant and threatening images [$F(1, 9) = 6.118$, $p = 0.035$]. There was a trend for RT to show greater reduction with image duration for threatening compared to pleasant images, although this interaction was not significant [$F(1,9) = 1.544$, $p = 0.245$]. There were no other significant effects.

SM's performance was both similar and different from that of controls (Figure 3). His results were submitted to an analysis of variance (ANOVA) with trial number as the random variable. As with controls, there was a main effect of image duration [$F(1, 316) = 7.64$, $p = 0.006$] such that RT was faster after the 600 ms than the 300 ms exposure for both pleasant and threatening images. Unlike for controls, for SM there was no main effect of image threat [$F(1, 316) = 0.302$, $p = 0.583$]. Instead, there was a significant three-way interaction of image duration, image threat, and visual field [$F(1, 316) = 6.615$, $p = 0.011$] (illustrated in Figure 3). In SM's left, ipsilesional field, RT was slower than in controls but showed a very similar pattern of interference. In the right, contralesional field, a very different pattern showing a delay in interference emerged. Instead of the rapid decrease of interference after a threatening image, there was initially sparing interference and then, relative to pleasant images, a greater-increasing interference as exposure duration increased. Importantly, the effects of SM's lesion were specific to threatening images. A separate analysis of just the threatening-image trials revealed a significant interaction, shown by none of the controls, between image duration and visual field [$F(1, 125) = 5.837$, $p = 0.017$]; this interaction verified that the time course of interference from threatening images varied significantly in the ipsilesional and contralesional fields. A similar analysis of pleasant-image trials showed no main effect or interaction involving visual field ($p > 0.25$).

## Conclusions

Our findings from controls and from SM's ipsilesional field demonstrate that, relative to pleasant images, threatening images interfere with subsequent re-

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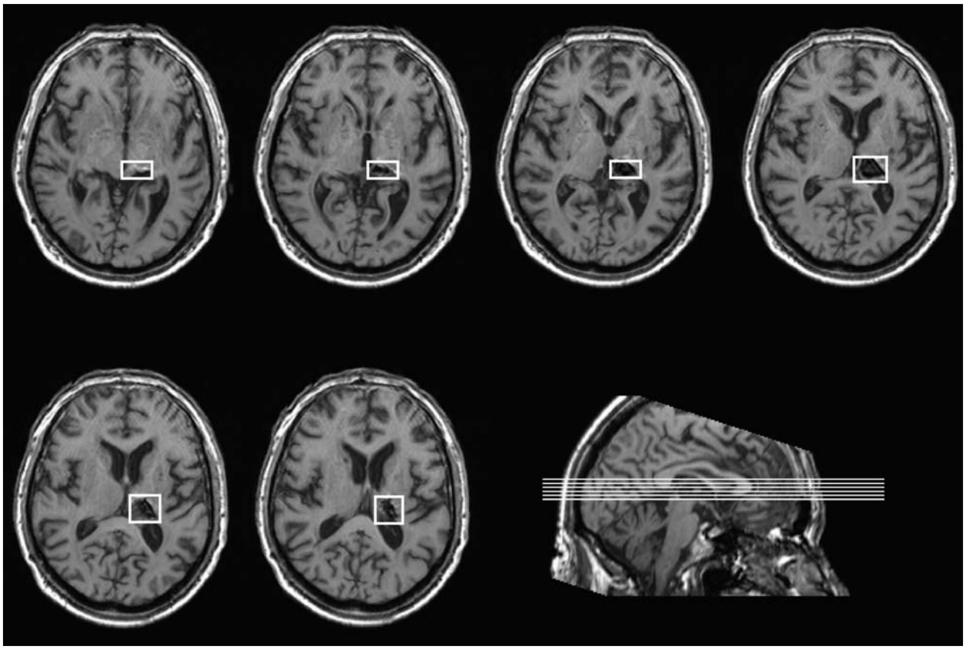

Figure 1. MRI Scan of Patient SM

SM was a 62-year-old, right-handed, hypertensive man who suffered a hematoma centered in the left pulvinar. This figure shows axial slices parallel to the AC-PC plane and spaced at 3 mm; the figure shows complete destruction of the pulvinar nucleus, with lateral extension of the lesion into the periventricular white matter. The lesion is outlined in boxes. There was no evidence of field deficits, neglect, or visual extinction on confrontation. See [12] for further details.

sponses. Previous findings have found activation of the pulvinar during presentation of emotional stimuli [8], but our results show, for the first time, the behavioral significance of the pulvinar and thus demonstrate its role in the rapid processing of visual threat. Interference did eventually emerge even in the absence of the pulvinar, consistent with either slowed transmission in the degraded channel or the influence of a slower alternative route for response to threat, perhaps through cortical pathways to the amygdala.

Beyond their direct connection, the amygdala and the pulvinar may be involved in multiple potential circuits. Although the pulvinar is a subcortical structure with connections to many other subcortical structures, its most distinguishing feature is its vast, reciprocal connectivity throughout all major divisions of the cortex [9]. This connectivity leaves the pulvinar well placed to modulate cortico-cortical communications [10, 11]. Thus, the pulvinar may be a crucial locus of contact between the "fast subcortical" and "slow cortical" routes to the amygdala. As a consequence, the cortical route to the amygdala may be subject to subcortical modulation via the pulvinar, and, likewise, activation of the amygdala via the subcortical route could reflect the

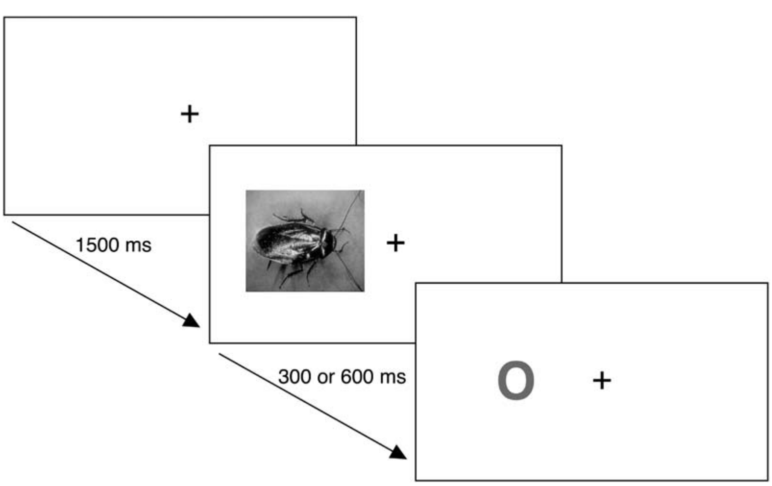


Figure 2. A Sample Trial

Each trial began with the fixation screen displayed for 1500 ms. The pleasant or threatening image then appeared in the left or right visual field. Images were selected from the IAPS picture set [13]. The mean valence rating was 2.56 for the 80 threatening images and 7.14 for the 80 pleasant images. Mean arousal rating was 6.13 (6.04 for pleasant, 6.23 for threatening). The image was presented for 300 or 600 ms. The image was then removed and replaced by a blue or green "O" that appeared in the same location. The "O" remained visible until a speeded response indicating its color was made. Responses were made with the index and middle fingers of the left hand. SM performed the task twice in each of two sessions a month apart and completed 324 trials.

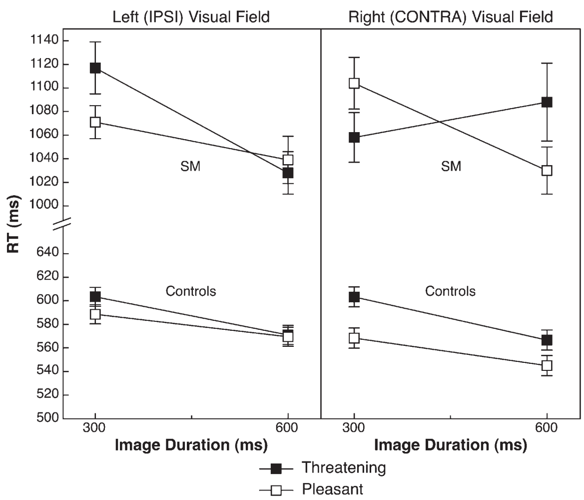


Figure 3. Interference from Pleasant and Threatening Images in Controls and SM

The upper two lines in each panel are the results for SM; the lower two lines are the results for ten age-matched male controls. Error bars indicate standard error of the mean.

influence of cortical computation. Of relevance here may be the fact that pulvinar connections with cortical areas known to be important for emotional processing, such as orbitofrontal and cingulate cortex, are in the medial pulvinar, in close proximity to the pulvinar's connections with the amygdala [3]. Although the pulvinar's connectivity therefore blurs the anatomical distinction of the two routes to the amygdala, our results demonstrate a functional distinction showing that, even given the presence of an intact cortex, rapid (<300 ms) processing of visual threat requires an intact subcortical processing stream.

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