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COMMENTARY

The Danger of Interpreting Detection Differences Between Image Categories: A Brief Comment on "Mind the Snake: Fear Detection Relies on Low Spatial Frequencies" (Gomes, Soares, Silva, & Silva, 2018)

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Using breaking continuous flash suppression (b-CFS; a perceptual suppression technique), Gomes, Soares, Silva, and Silva (2018) showed that human observers have an advantage in detecting images of snakes (constituting an evolutionarily old threat) over birds. In their study, images of snakes and birds were filtered to contain either coarse-scale or fine-grained information. The preferential detection of snakes relied on coarse-scale (rather than fine-grained) information, which was taken as support for the existence of an evolutionarily old subcortical pathway dedicated to snake detection. Here, we raise the concern that images of snakes and birds inherently differ in their visual characteristics, which can strongly affect detection times in b-CFS. Images of snakes, for instance, have a larger perimeter-to-surface ratio than images of birds. Importantly, these visual characteristics are not snake specific, as they are shared with many nonthreatening object categories. To illustrate this point, we compared detection times between images of bicycles and cars—nonthreatening image categories that differ in visual characteristics but for which detection is unlikely to capitalize on an evolutionarily old dedicated subcortical pathway. Observers exhibited an advantage for detecting bicycles over cars. Mirroring the snake–bird differences reported in Gomes et al., this advantage was driven by the coarse-scale (rather than fine-grained) information in the images. Hence, differences in visual characteristics between two nonthreatening, semantically matched stimulus categories suffice to produce the exact same pattern of findings as observed with snakes versus birds. We conclude that spatial frequency-specific detection differences in b-CFS cannot be unequivocally attributed to differences in processing pathways.

Keywords: threat perception, unconscious processing, low spatial frequencies, continuous flash suppression, dual-route model

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A key role of our visual system, from an evolutionary stance, is to detect threatening stimuli within our environment. Accordingly, there is ample evidence that stimuli signaling threat are preferentially processed over nonthreatening stimuli (for reviews, see Mather, & Sutherland, 2011; Yiend, 2010). There is less consensus, however, regarding the neural mechanisms that enable this preferential processing of threatening stimuli. A long-standing debate in this regard concerns the role of a subcortical pathway in the fast and automatic detection of potentially threatening stimuli (Pessoa & Adolphs, 2010). This pathway connects the retina to the amygdala via the superior colliculus and the pulvinar, bypassing the cortex (LeDoux, 1998). Many studies investigating the involvement of this subcortical pathway in detecting threatening (or fear-inducing) stimuli capitalize on the fact that it transmits coarse-scale (i.e., low-spatial frequency) information, as opposed to the fine-grained information that is processed in the visual cortex (Pessoa & Adolphs, 2010; Vuilleumier, Armony, Driver, & Dolan, 2003).

Following this approach, Gomes, Soares, Silva, and Silva (2018) recently demonstrated that the preferential detection of

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All experiment files, stimuli, raw data, and analysis files used in the experiment described in this article can be retrieved at https://osf.io/ga2xv (via the Open Science Framework).

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snakes (threatening stimuli) over birds is driven mostly by low spatial frequency information. They presented images of snakes and birds to one eye and suppressed these images from consciousness by presenting a high-contrast dynamic pattern to the other eye (continuous flash suppression; Tsuchiya, & Koch, 2005). The time it takes participants to localize these initially suppressed images provides a measure of detectability, which can be compared between images of birds and snakes (i.e., the so-called breaking continuous flash suppression paradigm [b-CFS]; Jiang, Costello, & He, 2007; Stein, Hebart, & Sterzer, 2011; for a review, see Gayet, Van der Stigchel, & Paffen, 2014). In line with their earlier work, the authors observed faster detection of snake images than bird images, thus showing preferential detection of snake images. Crucially, the spatial frequency content of the images was also manipulated, such that images comprised only low spatial frequency (i.e., coarse-scale) information, only high spatial frequency (fine-grained) information, or both (i.e., unfiltered, broadband images). The preferential detection of snakes over birds was observed for unfiltered images and for images containing only low spatial frequencies but not for images containing only high spatial frequencies (see Figure 1A for a summary of their results). These results were interpreted as evidence for a specialized subcortical pathway dedicated to snake detection based on coarse-scale information.

In this Brief Commentary, we argue that the finding of a detection difference between different images in the b-CFS paradigm cannot be interpreted as evidence for or against the involvement of subcortical processing, even when these differences are driven selectively by low spatial frequency content. Please note that our commentary is neutral about the existence of a putative subcortical pathway for preferential processing of threatening stimuli. Rather, we present a more general limitation in interpreting detection times between different image categories in the b-CFS paradigm, one that similarly applies to other studies investigating the preferential detection of emotionally laden over emotionally neutral stimuli (e.g., Gomes, Silva, Silva, & Soares, 2017; Sklar et al., 2012; Yang, Zald, & Blake, 2007).

It is well known that low-level visual differences between image categories can bring about differences in detection times, particularly so in the b-CFS paradigm (Tsuchiya, & Koch, 2005; Yang & Blake, 2012; for an overview, see Gayet et al., 2014). Accordingly, when previous studies included additional controls to assess the contribution of visual confounds to the difference in detection times between stimulus categories, the difference in detection times was often found to be at least partly driven by these visual confounds (e.g., Chen & Yeh, 2012; Gray, Adams, Hedger, Newton, & Garner, 2013; Stein, Awad, Gayet, & Peelen, 2018; Stein, Peelen, & Sterzer, 2011; Stein & Sterzer, 2012; Tsuchiya, Moradi, Felsen, Yamazaki, & Adolphs, 2009). To account for such differences in visual characteristics, Gomes and colleagues (2018) a priori equated the luminance and contrast between the two image categories and asserted a posteriori that there was no significant difference in spatial frequency energy between the two image categories. Nevertheless, images of snakes and birds inherently differ in terms of visual characteristics. As such, it remains unclear whether the faster detection of snakes reflects a processing advantage for threatening stimuli or a processing advantage for threat-unrelated visual properties that happen to differ between snakes and birds (e.g., curvature, elongation, or perimeter-to-surface ratio).

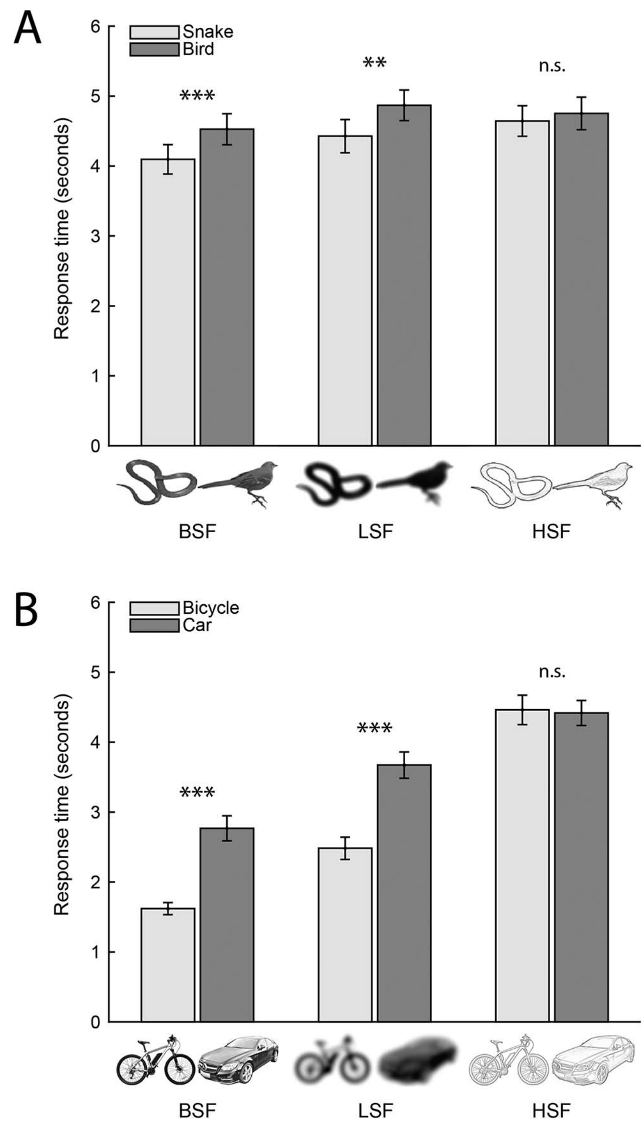

Figure 1. Panel A depicts the results of Gomes and colleagues' (2018) Experiment 1A and is reconstructed on the basis of the means and standard deviations reported in their article. Panel B depicts the results of our experiment (see the online supplemental materials for a complete description of the Methods and Results). The bars depict average response times to initially suppressed snake and bird stimuli (A) or bicycle and car stimuli (B), which were unfiltered (BSF), low-pass filtered (LSF), or high-pass filtered (HSF). Error bars depict the standard error of the mean. n.s. = non-significant. ** $p < .01$. *** $p < .001$. Snake and bird images, as well as data points for Panel A, were retrieved with permission from Gomes et al. (2018); stimuli for Panel B were adapted from copyright-free images (source: www.pxhere.com).

The addition of different spatial filtering conditions might appear to circumvent this problem, under the assumption that non-specific visual differences between images of snakes and birds remain constant across spatial filtering conditions. We make the case, however, that the addition of different spatial filtering conditions simply introduces new image categories, which differ idiosyncratically in their visual characteristics. That is, considering that the snake and bird image categories comprise different visual characteristics, these image categories will also be differently affected by spatial frequency filtering. For example, images with a higher perimeter-to-surface ratio (like snakes) will retain more troughs and peaks once blurred (i.e., low-pass filtered), whereas images with lower perimeter-to-surface ratio (like birds) will mostly comprise a single peak, with a surrounding trough (i.e., a blob). When these same image categories (of high and low perimeter-to-surface ratio) are high-pass filtered, both perimeter edges and within-stimulus edges will be retained, so that the images become more similar between categories (online supplemental Figure S3). Note that this is only one of many possible differences in visual characteristics between stimulus categories and spatial filtering conditions (other examples could include differences in elongation, center of mass, number of gaps, object curvature, etc.). Importantly, these differences are not accounted for by equating variables such as contrast and luminance values, but they could similarly drive differences in detection times.

To illustrate this point, we ran an experiment comparing detection times between (luminance and contrast-equated) images of bicycles and cars, two image categories that arguably do not differ in terms of the fear that they induce and for which detection surely does not rely on an evolutionarily old dedicated subcortical pathway. These image categories do differ, however, in the visual characteristics that they comprise, such as the perimeter-to-surface ratio (see online supplemental materials). Following the exact procedure of Gomes and colleagues (2018), we compared detection times to broadband filtered, low-pass filtered (LSF), and high-pass filtered (HSF) images of bicycles and cars (see Figure 1B; the full methods and results can be found in the online supplemental materials; ethical approval was provided by the Ethical Committee Social Sciences). For broadband (i.e., unfiltered) images, initially suppressed bicycles were detected 1.15 s faster than cars, $t(12) = 9.7$, $p < .001$, $d = 2.7$. For images containing only low spatial frequency content, bicycles were detected 1.19 s faster than cars, $t(12) = 7.7$, $p < .001$, $d = 2.1$. For images containing only high spatial frequency content, however, there was no difference in detection time between bicycles and cars (detection of cars was numerically 0.05 s faster), $t(12) = 0.2$, $p > .8$, $d < 0.1$. Note that absolute response times differed between filtering conditions (as also observed by Gomes and colleagues) because filtering inherently removes visual information from the image, thereby impacting absolute detection times. This is irrelevant to the current findings, in which we compare detection times between image categories, within filtering conditions. In sum, akin to the previously reported difference between snakes and birds, the detection difference between bicycles and cars (as observed with unfiltered images) appears to be fully driven by the low spatial frequency information in the images. In contrast to snakes, however, preferential detection of bicycles yields no clear evolutionary benefit.

Admittedly, the fact that the advantage of (A) detecting images of snakes relative to images of birds and the advantage of (B) detecting images of bicycles relative to images of cars both rely on the low spatial frequency content of these image categories does not prove that both detection differences are underpinned by the same neural mechanism. As such, it is possible that a subcortical pathway to the amygdala causes the advantage for snake detection and that a different (cortical) mechanism causes the advantage for bicycle detection. Considering that humans most probably did not evolve a specialized subcortical route for bicycle detection, our data at least demonstrate that a detection advantage in the low spatial frequency domain for some image category does not require the presence of a specialized subcortical route for processing said image category.

Given that the snake (or bicycle) detection advantage is only found for low spatial frequency content, does that not imply an involvement of the subcortical pathway? No, the reliance of an effect on low spatial frequency information does not provide evidence for subcortical processing. While cortical involvement is indeed required for processing detailed, high spatial frequency information (e.g., Stein, Seymour, Hebart, & Sterzer, 2014), this logic cannot be reversed, as the visual cortex processes a wide range of spatial frequencies. More generally, there is little evidence that stimuli composed of high and low spatial frequencies are effective in isolating magnocellular and parvocellular visual processing (Skottun, 2015).

One could argue that a specialized subcortical pathway that evolved for preferential snake detection incidentally causes preferential detection of all image categories that share visual similarities with snakes, including bicycles (for a similar argument in the comparison between manipulable and nonmanipulable objects, see Almeida, Fintzi, & Mahon, 2013; Almeida et al., 2014). It is difficult to establish empirically whether the advantage for detecting bicycles is caused by a specialized pathway that was initially dedicated to detecting snakes. Nonetheless, if a specialized subcortical pathway exists that favors snakes and thereby generalizes to bicycles, we can conclude that this pathway capitalizes on *shape* detection (as argued here) rather than *fear* detection.

Discussion

It is well established that certain types of threatening stimuli are preferentially processed over nonthreatening stimuli (e.g., Öhman, & Soares, 1994; Schmack, Burk, Haynes, & Sterzer, 2016). While it is true that differences in visual characteristics between threatening and nonthreatening stimuli could allow for the employment of an alternative (either cortical or subcortical) processing pathway that favors threatening over nonthreatening stimuli, such conclusions cannot be inferred from the current experimental approach. This follows from the fact that comparing differences in detection times between threatening and nonthreatening image categories does not allow for disentangling the causal role of "fear" from that of nonspecific visual characteristics that constitute the threatening stimuli. The addition of different spatial filtering conditions does not circumvent this problem, as it introduces new image categories with new image confounds and is thus equally uninformative vis-à-vis the role of fear in snake detection.

Nonetheless, we do not argue against the usage of the b-CFS paradigm to investigate the preferential detection of emotionally laden stimuli per se. The b-CFS paradigm can be valuable as long as the difference in emotional content between image categories is not confounded with a difference in visual characteristics. One promising approach to achieve this is by capitalizing on image manipulations like inversion and/or polarity reversal, which partly disrupt the extraction of meaning while preserving most visual characteristics (Rock, 1974). Because these manipulations selectively disrupt the extraction of meaning, the difference in detection time between normal and (say) polarity inverted versions of an image is proportional to the contribution of nonvisual factors to image detection (for a similar approach, see Hedger, Adams, & Garner, 2015; Stein et al., 2018). Image inversion and polarity reversal are of particular interest for the present purpose, because they are orthogonal to spatial filtering (unlike the main differences in visual characteristics between snakes and birds). Hence, if the advantage for detecting normal over polarity inverted snakes increases after applying low spatial compared to high spatial frequency filtering, one can conclude that there is something about the meaning (rather than the visual characteristics) of the snake that is preferentially extracted from low spatial frequency information. Another way to isolate the influence of emotional content when comparing detection times between image categories is to capitalize on between-subjects differences. For instance, Schmack et al. (2016) showed that the preferential detection of spiders relative to flowers depends on the degree of spider phobia. Whereas the detection difference between images of spiders and flowers itself is confounded by differences in visual characteristics, these visual characteristics were identical for all participants despite their varying degrees of spider phobia. Hence, the authors could conclude that fear of spiders drives the preferential detection of spider images. Along similar lines, Tsuchiya et al. (2009) tested whether the advantage for detecting fearful over happy faces, as observed in a matched control group, was preserved in a patient with bilateral amygdala lesions, thus isolating the influence of visual characteristics on detection times. Finally, one can also consider Pavlovian conditioning as a tool to investigate the preferential detection of emotionally laden stimuli within the b-CFS paradigm. For instance, it was shown using classical fear conditioning that initially neutral stimuli are preferentially detected when they signal threat (i.e., when they were previously associated with an aversive event) compared to when they do not (Gayet, Paffen, Belopolsky, Theeuwes, & Van der Stigchel, 2016).

Conclusion

Because the b-CFS paradigm is extremely sensitive to differences in visual characteristics, it poses a challenge when investigating differences in nonvisual attributes (such as threat or fear) between different image categories. Although the comparison of preferential detection of one image category over the other *between* spatial filtering conditions appears to circumvent this issue, this is not the case because spatial filtering (i.e., HSF and LSF) produces idiosyncratic differences in visual characteristics between image categories. As a result of this, the addition of spatial filtering conditions results merely in a larger number of image categories that are all confounded with differences in visual characteristics. This argument is supported by our data, which show that strong differences in detection times between image categories (and across spatial filtering conditions) exist even for nonthreatening, semantically matched stimuli.

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