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Spatial frequency filtered images reveal differences between masked and unmasked processing of emotional information ☆

Michaela Rohr *, Dirk Wentura

Department of Psychology, Saarland University, Germany

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ABSTRACT

High and low spatial frequency information has been shown to contribute differently to the processing of emotional information. In three priming studies using spatial frequency filtered emotional face primes, emotional face targets, and an emotion categorization task, we investigated this issue further. Differences in the pattern of results between short and masked, and short and long unmasked presentation conditions emerged. Given long and unmasked prime presentation, high and low frequency primes triggered emotion-specific priming effects. Given brief and masked prime presentation in Experiment 2, we found a dissociation: High frequency primes caused a valence priming effect, whereas low frequency primes yielded a differentiation between low and high arousing information within the negative domain. Brief and unmasked prime presentation in Experiment 3 revealed that subliminal processing of primes was responsible for the pattern observed in Experiment 2. The implications of these findings for theories of early emotional information processing are discussed.

1. Introduction

Emotional information has been shown to be processed in a prioritized fashion, compared to neutral or less relevant information, requiring less attentional or cognitive resources (for reviews, see, e.g., Brosch, Pourtois, & Sander, 2010; Yiend, 2010). Aspects of emotional stimuli are extracted even if the emotional stimulus is not task-relevant for the participant, such as a prime stimulus in a priming paradigm. This fact is especially true for short and masked presentation conditions, as participants are unlikely to consciously access the processed information (e.g., Rohr, Degner, & Wentura, 2012; for a review, see Barrett, Niedenthal, & Winkielman, 2005).

Specifically, Rohr et al. (2012) presented target faces with happy, angry, fearful, or sad expressions that were preceded by briefly flashed and sandwich-masked prime faces expressing emotions varied orthogonally to the target emotions (for an unmasked version, see Carroll & Young, 2005). Rohr et al. found congruency effects, with response times being faster in congruent trials (i.e., prime emotion matched target emotion) compared to incongruent trials (i.e., prime emotion did not match target emotion; see also Neumann & Lozo, 2012). The effects produced by brief exposure to primes coupled with the presence of a mask for the primes indicated that participants processed the primes effortlessly, non-strategically,

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* Corresponding author. Address: Department of Psychology, Saarland University, Campus A2.4, D-66123 Saarbruecken, Germany.
E-mail address: m.rohr@mx.uni-saarland.de (M. Rohr).

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unintentionally, and non-consciously. In the following, we will use the established term *automatic process* for this set of features (see Moors & De Houwer, 2006, for a critical discussion of the term).

Yet, it is still debated, first, what information can be automatically extracted under which conditions (see, e.g., Murphy & Zajonc, 1993; Pessoa, 2005; see below), and, second, which mechanisms and processes account for the automatic processing of emotional information (Pessoa & Adolphs, 2010; Tamietto & de Gelder, 2010). Abundant evidence suggests that the valence of the emotional stimuli is processed under automatic processing conditions (see, e.g., Klauer & Musch, 2003), but recent evidence also points towards a more specific differentiation beyond valence (Neumann & Lozo, 2012; Rohr, Degner, & Wentura, 2014; Rohr et al., 2012). In addition, the content contained in various spatial frequencies contributes differentially to the processing of specific emotional information (for a recent review, see de Cesarei & Codispoti, 2013). Specifically, the processing of emotional information, in particular under automatic pre-attentive or non-conscious presentation conditions, is presumed to rely primarily on low spatial frequencies (LSF; Langner, Becker, & Rinck, 2012; Tamietto & de Gelder, 2010; Vuilleumier, Armony, Driver, & Dolan, 2003). It is still unclear, however, which information in terms of emotional meaning can be extracted from low spatial frequencies under automatic processing conditions. With regard to extraction of specific emotional meaning from spatial frequency filtered emotional faces, there is only evidence from studies employing *explicit* instructions to decode the emotional meaning and clearly visible presentation conditions (Kumar & Srinivasan, 2011; Schyns & Oliva, 1999; Smith & Schyns, 2009). Thus, the masked presentation of primed spatial frequency filtered emotions of varied valence can shed light on the differentiation of emotional information under non-strategic, unintentional, non-conscious processing conditions, and the assumed special role of low spatial frequencies for such processing.

Therefore, the goal of the present study was to investigate the extraction of emotional meaning from spatial frequency filtered primes in an emotion priming paradigm under various presentation conditions. We report three emotion priming studies using the paradigm of Rohr et al. (2012), which employ spatial frequency filtered prime faces under unmasked (Experiments 1 and 3) and masked (Experiment 2) presentation conditions. We assumed that variations of time and conscious accessibility would have an impact on the role of spatial frequencies in emotional meaning extraction. Concretely, we hypothesized that under clearly visible presentation conditions, each specific emotion should be automatically recognized via both high and low spatial frequencies, based on the assumption that several pathways contribute to processing under such conditions. Under shorter presentation conditions, we expected that (1) people would be able to extract only specific aspects of emotional meaning (Rohr et al., 2012), and, most importantly, that (2) the short and non-conscious processing of emotional aspects, such as valence or arousal, should critically involve low spatial frequencies, hence revealing the assumed special link between LSF and emotion processing. This link should only be found under short and masked processing conditions because these conditions provide—in the context of the present experiments—the purest approach to investigate the effects of fast and non-conscious processes.

In the following, we will delineate the relevant theoretical and empirical background from which our hypotheses and the design of our study were derived.

1.1. The differentiation of automatic emotional information processing

As mentioned earlier, the differentiation of automatic emotional information processing is a matter of debate. With regard to non-conscious processing, the specificity of masked processing has been investigated using different methodologies: Evidence from neuroimaging or neurophysiological studies points to distinct brain activation patterns in response to the presentation of masked emotional information (see Tamietto & de Gelder, 2010; Vytal & Hamann, 2010; Zald, 2003), suggesting not only non-conscious processing of stimuli, but also differentiation of meaningful aspects. However, researchers do debate whether these patterns reflect a distinction of stimuli according to their valence, arousal, or relevance, or whether the specific emotional content (e.g., "something threatening", "something sad") can already be assessed at a non-conscious level of processing (Lindquist, Wager, Kober, Bliss-Moreau, & Barrett, 2012; Panksepp, 2005; Vytal & Hamann, 2010). Studies with blindsight patients have demonstrated that non-conscious recognition of specific emotional facial expressions is possible (de Gelder, Vroomen, Pourtois, & Weiskrantz, 1999). The empirical evidence with healthy subjects, however, primarily supports only a differentiation of valence under masked presentation conditions (see Klauer & Musch, 2003; but see Rohr et al., 2012).

Likewise, studies using physiological measures have found that participants can react with increased skin conductance (Esteves, Dimberg, & Öhman, 1994), cardiovascular responses (Freydefont, Gendolla, & Silvestrini, 2012), and facial muscle responses (Dimberg, Thunberg, & Elmehed, 2000) to masked emotional stimuli, suggesting that non-conscious processing can trigger rudimentary affective responses as well. The kind of differentiation that is achieved on this level of processing is, however, debated as well (Freydefont et al., 2012; Stemmler, 2004). Thus, behavioral measures and their outcomes in terms of meaning assessment provide important information regarding this topic.

Behavioral studies exploring the early masked processing of emotional stimuli have yielded mixed results. Studies using *explicit* detection or discrimination tasks have revealed emotion-specific differences in the detection or discrimination of emotional stimuli (Fox et al., 2000; Maxwell & Davidson, 2004; Milders, Sahraie, & Logan, 2008). However, it is unclear whether these differences are due to non-conscious emotional processing or whether they reflect differences in the perceptual discriminability of stimuli (Horstmann, 2009; Milders et al., 2008; Zeelenberg, Wagenmakers, & Rotteveel, 2006).

Behavioral paradigms exploring the *implicit* extraction of evaluative information (e.g., variants of affective/evaluative priming), by contrast, have in general only found support for a differentiation of valence under masked presentation conditions (e.g., Murphy & Zajonc, 1993; see also Clore & Colcombe, 2003). In contrast to discrimination or detection studies, these