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Effects of emotional intensity under perceptual load: An event-related potentials (ERPs) study

Miriam Müller-Bardorff[a,*], Claudia Schulz[a,c], Jutta Peterburs[a], Maximilian Bruchmann[a], Martin Mothes-Lasch[a], Wolfgang Miltner[b], Thomas Straube[a]

[a] Institute of Medical Psychology and Systems Neuroscience, University of Münster, Germany
[b] Department of Clinical and Biological Psychology, University of Jena, Germany
[c] Department of Psychology, University of Münster, Germany

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ABSTRACT

Effects of emotional intensity and valence on visual event-related potentials (ERPs) are still poorly understood, in particular in the context of limited attentional resources. In the present EEG study, we investigated the effect of emotional intensity of different emotional facial expressions on P1, N170, early posterior negativity (EPN) and late positive potential (LPP) while varying the amount of available attentional resources. A new stimulus set comprising 90 full color pictures of neutral, happy (low, high intensity), and angry (low, high intensity) expressions was developed. These facial expressions were presented centrally, superimposed by two horizontal bars, and participants engaged in a focal bars task. Availability of attentional resources was varied in two conditions by manipulating the difficulty of the focal bars task (low vs. high perceptual load). Our findings demonstrate intensity and valence effects of task-irrelevant facial expressions on early (N170) and intermediate processing stages (EPN). In addition, task-related effects of perceptual load evolved at intermediate processing stages and were full blown in the time window of LPP. In line with limited resource accounts, valence effects on N170 and EPN were reduced under high perceptual load. Interestingly, apart from this valence by load interaction no further interactions between stimulus and task-driven factors were obtained: Effects of emotional intensity were not modulated by the perceptual load of the focal bars task, indicating that emotional intensity was processed even though attentional resources were heavily restricted.

1. Introduction

In recent years there has been a growing interest to investigate effects of emotional intensity instead of dichotomously contrasting ‘neutral’ versus ‘emotional’ stimulus events. Several event-related potential (ERP) components have been found to be sensitive for emotional content and thus might also reflect effects of emotional intensity. In the domain of face-processing, the P1 (Batty & Taylor, 2003; Luck et al., 2009), the face-specific N170 component (e.g., Blau, Maurer, Tottenham, & McCandliss, 2007; Brenner, Rumak, Burns, & Kieffaber, 2014; Caharel, Courtay, Bernard, Lalonde, & Rebaï, 2005), the early posterior negativity (EPN; e.g., Calvo & Beltrán, 2013; Rellecke, Palazova, Sommer, & Schacht, 2011; Wronka & Walentowska, 2011), and the late positive potential (LPP; e.g., Foti, Olvet, Klein, & Hajcak, 2010; Recio, Schacht, & Sommer, 2014; Schupp, Öhman et al., 2004) have been reported to be enhanced by emotion. In addition, P1, N170 and LPP have been directly linked to intensity processing (e.g., Duval, Moser, Huppert, & Simons, 2013; Utama, Takemoto, Koike, & Nakamura, 2009), with more stable activations for the right hemisphere (Utama et al., 2009; see also Abbott, Cumming, Fidler, & Lindell, 2013). While the N170 is often referred to as reflecting structural encoding in the context of face perception (e.g., Eimer, 2002), P1, EPN, and LPP have been linked to initial attention allocation (P1), to enhancements in perception (EPN), and to enhanced working memory representations (LPP) (Hajcak, Weinberg, MacNamara, & Foti, 2012).

Sprengelmeyer and Jentzsch (2006) were the first authors who investigated intensity-driven modulations by facial expression on event related potentials (ERPs): In an emotion-classification task, the authors observed a prolonged temporo-parietal negativity as a function of intensity. Component-specific modulations were not reported. Over the course of the following years mixed findings have been obtained regarding the time course of intensity-driven modulations: Using comparable tasks and stimuli, both early and

* Corresponding author.
E-mail address: m.mueller-bardorff@uni-muenster.de (M. Müller-Bardorff).

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late intensity-driven modulations have been observed (early modulations <300 ms: e.g., Leppänen, Kauppinen, Peltola, & Hietanen, 2007; Utama et al., 2009; late modulations >300 ms: e.g., Duval et al., 2013). Affective ERP research provides good evidence that both positively and negatively-valenced stimuli trigger affective processing (see Olofsson, Nordin, Sequeira, & Polich, 2008 for a review), and it seems probable, that intensity-driven modulations apply for positive and negative stimuli (but see also Leppänen et al., 2007).

There is an ongoing debate whether affective processing such as the processing of emotional expressions depends on attentional resources. Although there are ERP studies investigating intensity-driven modulations in the context of varying attentional resources (see Norberg, Peira, & Wiens, 2010; Sand & Wiens, 2011; Wiens, Molapour, Overfeld, & Sand, 2012), interactions between intensity and perceptual load have not been studied in the domain of face processing. According to the theory of perceptual load (Lavie, 1995), task-irrelevant processing occurs resource-contingent, with task-irrelevant distractors being processed under conditions of low perceptual load, but not under conditions of high perceptual load, when attentional resources are depleted. This means, that processing of task-irrelevant, emotionally intense expressions – like task-irrelevant processing in general – should be abolished when participants engage in a sufficiently demanding task (see Pessoa, McKenna, Gutierrez, & Ungerleider, 2002; Mothes-Lasch, Mentzel, Miltner, & Straube, 2011; Pessoa, 2005; Wiens et al., 2012; but see also Pourtois, Spinelli, Seeck, & Vuilleumier, 2010). In contrast to that, recent studies provided evidence that emotional distractors can successfully compete for neuronal representation—provided that saliency is high (e.g., Müller, Andersen, & Keil, 2008). Norberg et al. (2010) showed that stimuli related to phobic fears resist manipulations of perceptual load (see also Sand & Wiens, 2011 for similar findings with IAPS pictures). Furthermore, several EEG studies utilizing emotionally and/or motivationally significant stimuli demonstrate that early processing stages are under stimulus-driven control and do not depend on top down attention (e.g., Hickey, McDonald, & Theeuwes, 2006; Holmes, Kiss, & Eimer, 2006; Holmes, Nielsen, Tipper, & Green, 2009). Finally, processing priorities can be efficiently shifted by high emotional significance (see Mohanty, Egner, Monti, & Mesulam, 2009; Pessoa, 2009). Considering this line of evidence, it is unlikely to assume that task factors alone (e.g., the perceptual demand of a focal task) fully determine involuntary stimulus processing. Whether intense facial expressions are strong enough to resist manipulations of perceptual load has not been tested yet.

It is challenging to establish valid manipulations of emotional intensity for facial expressions. Previous research on the effect of emotional intensity relies on intensity-morphed facial stimuli (FEEST, Young, Perrett, Calder, Sprengelmeyer, & Ekman, 2002) derived from the Pictures of Facial Affect (Ekman & Friesen, 1976), which only contains black and white images from a small number of models—some of the pictures may appear dated. To avoid shortcomings of previous studies, a new face-database, the J3DFD, was developed. In contrast to previously used stimuli, emotional intensities of the J3DFD reflected actual emotional states and were not result of a morphing procedure. Positive expressions were expressed in a strong and natural way to reach comparable arousal levels like negative expressions (see Section 2).

With regard to the experimental task, we decided to utilize a perceptual judgement on the length of two horizontal bars. Bars and facial expressions were presented overlapping, since targets (bars) and distractors (facial expressions) were both intended to fall in the spotlight of spatial attention (see e.g., Anderson, Christoff, Panitz, De Rosa, & Gabrieli, 2003). The length judgement allowed controlled manipulations of perceptual load, since the effort for extracting the information of interest was directly related to the physical difference between the bars. For the present study, manipulations of perceptual load had to be strong (e.g., imposing a substantially higher attentional demand in the high load condition) to provide a fair test for interactions between stimulus-driven effects and task related effects of perceptual load.[1] With regard to the temporal succession, it was expected that involuntary face processing would precede and/or overlap with task-related bars processing. This is in line with several other EEG studies demonstrating that involuntary processing of salient distractors precedes more controlled, goal-directed processing (e.g., Hickey et al., 2006; Holmes et al., 2006; Pourtois et al., 2010; see also Hopfinger & West, 2006).

The following three hypotheses were tested:

1. First, it was tested whether visual ERPs vary as a function of emotional intensity, with amplitudes largest for highly intense positive and negative expressions (as reflected in a main effect of intensity). According to the literature P1, N170, EPN and LPP might be affected.
2. Second, it was tested whether the perceptual load itself modulated visual ERPs. Although effects of perceptual load have been reported for early (e.g., Rauss, Pourtois, Vuilleumier, & Schwartz, 2009) and late processing stages (e.g., Sand & Wiens, 2011), we expected load effects to dominate at late processing stages, reflecting effects of voluntary processing and top-down attention.
3. Finally, if the theory of perceptual load applies for high intense, facial distractors, an additional intensity by load/valence by load interaction should emerge, indicating suspended distractor processing under high perceptual load. If the theory of perceptual load is not applicable in the case of high intense facial distractors these interactions should be absent.

2. Method

2.1. Participants

Twenty four healthy volunteers participated in exchange for course credit or money. Since only correct responses were considered in the ERP analysis, five participants had to be excluded due to technical problems with response markers, and one participant was excluded due to incomplete data collection. The remaining sample consisted of twelve females and six males aged between 21 and 36 years (mean age, M = 25.17, SD = 4.31), all but one participant were students of the University of Jena. All participants were Caucasian, right-handed, had normal or corrected-to-normal vision, and did not have neurological or psychiatric disorders. All subjects gave written informed consent prior to participating. The study conforms to the Declaration of Helsinki and has received ethical clearance by the Ethics Board of the University of Jena.

2.2. Stimuli

2.2.1. The Jena 3D face database (J3DFD)

The J3DFD was specifically developed for the current study and future studies. It contains 608 three-dimensional (3D) objects portraying 32 Caucasian models (16 female, 16 male) posing happy, angry, fearful, sad, surprised and disgusted facial expressions at three emotional intensity levels plus neutral expressions. All models were part of an amateur acting group (M = 22.58 years; range, 21–25 years, 1–10 years of acting experience). The models

[1] Please note that there is a difference between perceptual and attentional load—attentional load refers to inducing load at the level of working memory (e.g., 1-back versus 2-back tasks see Holmes et al. (2009)).