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Different time course of emotion regulation towards odors and pictures: Are odors more potent than pictures?

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ABSTRACT

The present study assessed emotion regulation in response to chemosensory and visual stimuli. Using cognitive reappraisal, 40 female participants regulated their emotions in response to disgusting pictures and odors, while the startle reflex was elicited and emotion ratings were assessed. Participants reported feeling less negative, and less aroused, while down-regulating their emotions towards both odors and pictures. Although being rated as equally negative and arousing, odor presentations were accompanied by larger startle responses than picture presentations. Furthermore, as compared to pictures emotion regulation towards odors followed a strikingly different time course suggesting less effective emotion regulation in response to disgusting odors. Questionnaire data show that differences between emotion regulation outcome towards odors was not attributable to different regulation strategies used. Thus, the current data suggest a unique role of olfaction in emotion perception, and show that cognitive emotion regulation – although being generally effective – may also be limited.

1. Introduction

In everyday life, people experience many strong emotions, and in order to effectively adjust to the social environment people must often control these emotions. Thus, they are frequently confronted with the task to decide which emotions they have, when they have them, and how they experience and express them (Gross et al., 2006). Emotion regulation accomplishes this. To date, no study explored whether the sense modality of an emotion-eliciting stimulus has an influence on people's ability to regulate the elicited emotion. However this is important. Emotions can be elicited by a large variety of situations and stimuli belonging to all sensory modalities, including vision, audition, touch and olfaction. Although in general emotions promote the individuals' survival and adaptation to changing environmental demands (Frijda, 1994; for an overview see Keltner and Gross, 1999; Levenson, 1994, 1999; Smith and Lazarus, 1990), emotional reactions can also be maladaptive. For example, olfactory stimuli as well as visual stimuli are described to trigger panic attacks (Hinton et al., 2004) and serve as traumatic reminders in post-traumatic stress disorder (Vermetten and Bremner, 2003; Vermetten et al., 2007). Inadequate emotional responding is at least in part attributable to maladaptive emotion regulation (Barlow et al., 2004). Thus, it is important to evaluate whether emotion regulation is effective for emotions evoked by stimuli of different sensory modalities. Therefore, the present study aimed to investigate whether a well-investigated emotion regulation strategy – cognitive reappraisal – is comparable towards emotions elicited by stimuli of different sensory modalities, namely pictures and odors.

Emotion regulation itself is defined as the extrinsic and intrinsic processes responsible for monitoring, evaluating, and modifying emotions and can be subdivided in automatic and voluntary emotion regulation processes. Automatic emotion regulation is defined as goal-driven changes of the emotional response without voluntary control of or attention to the regulation process itself (Bargh and Williams, 2007; Mauss et al., 2007). Voluntary emotion regulation is a deliberate process that depends on attentional resources. It can be accomplished using various emotion regulation strategies with one example being the cognitive reappraisal of emotion eliciting situations (Gross and Thompson, 2007). Cognitive reappraisal involves the process of intentionally reinterpreting an emotionally evocative scene or single stimulus in an unemotional way, thereby reducing the emotional impact of the stimulus.

To-date numerous studies have demonstrated that self-reported emotions to threatening pictures can be significantly enhanced or reduced using cognitive reappraisal. The same is true for physiological responses, including brain electrical activity (e.g., Moser et al., 2006, 2009; Hajcak et al., 2006), and the affect modulated startle-reflex (e.g., Dillon and LaBar, 2005; Driscoll et al., 2009; Hagemann et al., 2006; Jackson et al., 2000). Furthermore, several

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brain imaging studies found that activation in lateral prefrontal cortex areas is inversely correlated with activation in the amygdala, a subcortical brain area involved in automatic emotion-generation (Goldin et al., 2008; Ochsner et al., 2002, 2004; Urry et al., 2006). Thus, on a neuronal level, the amygdala is among the major targets of voluntary emotion regulation.

Despite the importance of other sensory channels or emotions, emotion regulation research has focused almost exclusively on visual threat stimuli as emotion elicitors. For example, odors are potent elicitors of emotions, but no study to date has investigated whether emotion regulation is also possible towards emotions elicited by odors. The sense of smell is phylogenetically old, has driven the evolution of the mammalian brain (Rowe et al., 2011) and is of vital importance for survival. In humans, for example, chemoperception is strongly involved in the discrimination between food and non-food stimuli and the drive for food intake or rejection (Rolls, 2011; Shepherd, 2006). It furthermore serves as an important early warning system for environmental dangers (Doty, 2001). In line with its importance for nutrition, the predominant negative emotion elicited by odors is disgust (Alaoui-Ismaili et al., 1997; Ehrlichman and Bastone, 1992). Disgust is a basic emotion (Ekman and Friesen, 1971) that has evolved throughout evolution to protect the organism from contamination (Rozin and Fallon, 1987). Disgusting stimuli have been shown to be potent elicitors of emotion, recruiting brain areas involved in emotion processing (Schäfer et al., 2005) and reliably initiating withdrawal behavior (Yartz and Hawk, 2002).

Correspondingly, like visual disgust stimuli, odors trigger a wide variety of emotional responses. Negative emotional odors elicit orienting behavior (Delplanque et al., 2009), and vigilance (Pause et al., 2003), change the blood flow in emotion processing brain areas like the amygdala or the orbitofrontal cortex (Anderson et al., 2003), and strengthen withdrawal related motor behavior (i.e., the startle reflex Miltner et al., 1994; Ehrlichman et al., 1995, 1997) (for an overview on the affect modulated startle reflex Bradley et al., 2001).

Despite these similarities between olfaction and vision, in direct comparisons between olfactory and visual stimuli, emotional odors elicit more intense affective self-report (Hinton and Henley, 1993) and more intense emotional memories (Herz, 1997; Herz and Engen, 1996). Although effects are usually small, such differential access of vision and olfaction to emotion has been found consistently across studies. As compared to visual stimuli, odors are modulating neuronal responses within the amygdala more strongly (Royet et al., 2000). This preferential neuronal processing of odors in emotion generating brain areas can be explained by the strong overlap between olfactory cortex and limbic brain structures. The amygdala, as a part of the primary olfactory cortex (Carmichael et al., 1994), is more closely involved in olfaction than in any other sensory modality. In humans, five of eight amygdaloid areas are located in the corticomedial group (Crosby et al., 1962), which is strongly involved in olfactory functions (Royet et al., 2000), and densely interconnected to central and lateral portions of the amygdala implicated in the generation of emotional responses.

The observation, that odors elicit stronger emotional experience and stronger responses in the amygdala than comparable visual stimuli, has important implications for possible emotion regulation outcome. Given that the amygdala is a major target of voluntary emotion regulation via top-down neuronal control areas it is here expected that voluntary regulation of emotions elicited by odors is less effective than regulation of emotions elicited by visual stimuli. Specifically, stronger emotional responding and less effective attempts to regulate emotions could either manifest in weaker changes of emotional reactions towards odors, or slower changes in emotional responses towards odors accompanying emotion regulation.

2. The present study

The present study aimed to compare the effectiveness and time course of the regulation of emotions elicited by disgusting odors and pictures. Based on the literature we hypothesize that (1) odors elicit stronger emotional reactions than pictures, and that (2) the regulation of emotions elicited by odors is less effective and slower than the regulation of emotions elicited by pictures.

In the present study emotional reactions were assessed with the acoustic startle reflex. Stimuli were presented in a balanced block design (Moser et al., 2006), with blocks representing either enhancement or down-regulation of emotions. Within each trial the evocative stimuli were presented twice. The first stimulus presentation (baseline stimulus) served to evoke an initial emotion. Participants' startle reactions in the context of these initial stimulus presentations were taken to test whether odors elicit stronger emotional responses than pictures (hypothesis 1). Thereafter, participants were instructed to think about a strategy to regulate their emotion and the same stimulus was presented again (target stimulus). Consequently, participant's startle reactions in the context of the target stimuli were taken to test whether the regulation of emotions elicited by odors is less effective than the regulation of emotions elicited by pictures (hypotheses 2). To assess the time course of emotion regulation, the startle reflex was elicited both 2 s (early emotion regulation) and 5 s (late emotion regulation) after the onset of the target stimulus.

Startle responses are expected to be larger during the odor than during the picture baseline stimulus presentations (hypothesis 1). A successful emotion regulation should reveal larger target startle responses as compared to the baseline startle response in the enhance condition, and smaller target startle responses as compared to the baseline startle response in the down regulate condition. A less effective regulation of odor evoked emotions should reveal either no differences in startle responses between baseline and the emotion regulation conditions (both enhance and down-regulate), or the differences between the conditions should emerge later during the regulation process (i.e., during the late emotion regulation interval, rather than during the early regulation interval; hypothesis 2). A $2 \times 2 \times 3$ within subject design with the factors *Stimulus Modality* (pictures, odors) $\times$ *Emotion Regulation* (enhance, down-regulate) $\times$ *Time* (baseline, early emotion regulation, late emotion regulation) was used for statistical hypotheses testing.

3. Methods

3.1. Participants

Participants were 40 non-smoking female students from the University of Düsseldorf who reported having a regular menstrual cycle, no regular medication use (except for oral contraceptives), and no mental and physical diseases. The participants' age ranged from 19 to 40 (M = 23.95, SD = 5.05). All scored low on social desirability, supporting the reliability of the self-report data (<5 on the Lie scale of the Eysenck Personality Inventory, EPI, Eggert and Ratschinski, 1983). Participants scored within the normal range for trait anxiety (M = 39.13, SD = 10.01, State Trait Anxiety inventory, STAI, Laux et al., 1981), depressive feelings (M = 7.08, SD = 4.77, Depression Scale, DS, von Zerssen and Koeller, 1976), disgust sensitivity (M = 2.29, SD = 0.49, Fragebogen zur Erfassung der Ekelempfindlichkeit, FEE, Schienle et al., 2002), and the frequency of everyday-life use of reappraisal (M = 4.99, SD = 0.91, Emotion Regulation Questionnaire, ERQ, Abler and Kessler, 2009). All participants were paid for participation and gave written informed consent to procedures. The study was approved by the Ethics Committee of the German Psychological Society (DGPs).

3.2. Stimuli

Five disgust-related odors (isovaleric acid, ethanethiole, isobutyraldehyde, pyridine, 3-methyl-indole) served as olfactory stimuli. Each odor was diluted in solvent (diethylphtalate or 1.2-propanediol) using three dilution steps following a half-logarithmic serial dilution (see Table 1). The odors were chosen, because they have been successfully used to induce negative affect in previous studies (Masaoka et al.,