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Fast Track Report

Habituation effects of pleasant and unpleasant odors

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ABSTRACT

Objective: The hedonic value of odors is reflected in chemosensory evoked potentials with more salient unpleasant odors being processed differently from pleasant odors. However, it is not known if this effect is stable over time. It was examined if chemosensory evoked potentials towards pleasant and unpleasant odors change with repeated presentation.
Methods: 42 participants received two pleasant (Peach and PEA) and one unpleasant (H_2S) intensity matched odors in a block design. Intensity and pleasantness were rated after each presentation. Subjective ratings, as well as N1 and P2 of the first stimulus of each block were compared with the two following stimuli of each block.
Results: Early and late components of the chemosensory evoked potentials had shorter latencies in response to the unpleasant H_2S compared to PEA and Peach. Pleasantness ratings for H_2S increased with repeated presentation but were far below neutral even for the third stimulus in a row. In line with this, for H_2S only, the P2 amplitude diminished with repeated presentation.
Conclusion: We assume that unpleasant stimuli catch more attention first hand. However, repeated presentation leads to reduced emotional salience of unpleasant stimuli only, which is mirrored in a decrease of neuronal activation.

1. Introduction

Attention is modulated by characteristics of the environmental stimuli, whereby those with enhanced intensity and enhanced emotional value evoke enhanced processing (Pourtois et al., 2012). This is also valid for olfaction: intensity and pleasantness of an odor determinate olfactory processing. Unpleasant odors are detected faster than pleasant ones (Bensafi et al., 2002b) and lead to enhanced heart rate acceleration (Alaoui-Ismaili et al., 1997; Bensafi et al., 2002a, 2002b) and odors are detected faster at high than low concentrations (Wang et al., 2002).

Another approach of studying olfactory processing is using chemosensory event related potentials (CSEP). Event related potentials are electrical changes recorded from the brain. This technique visualizes correlates of neuronal activation with very high temporal resolution and allows examination of the sequential processing of information (Picton et al., 1995). Event related potentials consist of early and late components. The early components are suspected to reflect the physical characteristics of the stimulus to a relatively higher degree than later components; late components reflect endogenous processes like subjective emotional evaluation of the stimulus to a relatively higher degree (Kobal et al., 1992). The late P2 compound is modulated by attention: if people attend to an odor, the P2 amplitude is increased (Andersson et al., 2011). It was shown that the unpleasant odor of hydrogen sulfide evokes enhanced P2 amplitudes compared to the pleasant rated vanillin odor (Kobal et al., 1992). Interestingly, this coherence of the P2 amplitude on odor valence could also be found for the very same odor, which was perceived with different pleasantness by the participants. In a study 22 participants rated the olfactory stimulus androstenone using verbal descriptors. Those who used descriptors of human body odor exhibited enhanced amplitudes in the late positive component of event related potentials compared to those participants who used non-body-odor descriptors (Lundstrom et al., 2006). For odor intensity several studies revealed that amplitudes of early and late components of CSEP increase with increased odor concentration (Tateyama et al., 1998) and latencies decrease (Pause et al., 1997; Tateyama et al., 1998). Even at the very first level of olfactory processing, the olfactory epithelium, a difference of neuronal activation due to stimulus intensity and valence has been observed. Increased odor concentration enhances odor processing at the level of the olfactory epithelium and unpleasant odorants evoked larger amplitudes in comparison to their paired pleasant odorants (Lapid et al., 2009).

We aim to see, how neuronal processing of pleasant and unpleasant odors changes with repeated presentation. CSEPs are typically erased using a block design. Hereby 4 to 20 of the same olfactory stimuli are presented in a row, followed by a block of another stimulus in order to prevent habituation by presenting the same odors for

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a long time. This design is repeated several times and at the end potentials are averaged above all stimuli of the same kind. This method is very efficient and proven to be valid for research and clinical purpose (Hummel et al., 2000).

However, it has been shown, that CSEPs are attention dependent (Pause et al., 1997; Croy et al., 2010b) and attention can be directed to the hedonic characteristics of odors (Djordjevic et al., 2012). Furthermore, perception of the hedonic characteristic of stimuli changes with mere exposure (Cain and Johnson, 1978). Therefore potential shifts of attention in the typical block design could influence the CSEPs. We want to know, if there are already habituation effects in the first few olfactory stimuli. A study conducted with visual material revealed, that early components of event related potentials decreased for pleasant and unpleasant pictures with repeated presentation. Late components also showed a small decrease in amplitude with repeated presentation, but even after 90 repetitions pleasant and unpleasant pictures elicited strong late positive potentials, suggesting that the effect of emotional significance is a very robust one (Codispoti et al., 2007). For olfactory stimuli it is not known how neuronal activation develops with repeated presentation. We examine event related potentials in repeated presentation of one unpleasant and two pleasant odors.

2. Materials and methods

2.1. Participants

A total of 42 healthy participants (11 men, 31 women, aged 20 to 38 years mean = 24.5 years, standard deviation = 2.5 years) volunteered for this study. Most of them were graduate students or members of the Technical University of Dresden Medical School. Completion of a detailed medical history form by each participant enabled confirmation of their good physical health. Normal olfactory function was ascertained by the elaborate olfactory Sniffin'Sticks Test (Hummel et al., 2007); scores of all subjects ranged between 31 and 41.75 (mean = 36, standard deviation = 2.5).

The investigations were performed according to the Declaration of Helsinki on Biomedical Research Involving Human Subjects. The protocol was approved by the local Medical Faculty Ethics Review Board (protocol number EK 155052010). After complete explanation of the study to the participants in written form and also during an interview, written informed consent was obtained.

2.2. Chemosensory event related potentials

CSERP were recorded in participants naive to these experiments. They were instructed to keep their eyes open. Monomodal chemosensory nasal stimulation was performed using a stimulator (Olfactometer OM2S, Burghart Instruments, Wedel, Germany) which allows administration of chemical stimuli without causing concomitant mechanical or thermal sensations. This was achieved by embedding chemical stimuli of 200 ms duration in a constantly flowing air stream (8 l/min) applied to the nasal cavity through a canula with an inner diameter of 2 mm inserted approximately 1 cm into the nostril beyond the nasal valve area. Temperature and humidity of the air stream was kept constant (36.5 °C, 80% relative humidity). Rise time of the stimulus concentration was less than 20 ms.

PEA (40% v/v), Peach (40% v/v) and H_2S (4 ppm) were used for olfactory stimulation. Those odors are considered to be specific stimuli of the olfactory system inducing little or no trigeminal activation. Peach and PEA, which smells like roses, are odors which are known to be perceived as pleasant. H_2S smells like rotten eggs and is perceived unpleasant (Hummel et al., 2000; Croy et al., 2010a). PEA and H_2S are odors consisting of only one molecule, while Peach is a mixture. Concentration of the odors remained constant during the experiment, however the participants were not aware of this. As intended, the odors did not differ significantly in intensity ($p = 0.07$) but in pleasantness ($p < 0.001$, compare Table 1). Each participant received 188 olfactory stimuli in total, divided in two sessions. In each session 9 blocks of H_2S stimuli, 8 blocks of PEA stimuli and 9 blocks of Peach stimuli were included. Each block of the unpleasant H_2S consisted of 4 consecutive stimuli. In order to minimize effects of expectation, blocks of the pleasant PEA and Peach odors varied between 2 and 5 stimuli. Six of the nine H_2S blocks of each session were followed by PEA stimuli, three by PEA. In order to prevent memory effects, both sessions were not identical in the sequence of blocks. In total, there were 18 stimuli, where H_2S was presented first time in a block. There were also 18 stimuli where H_2S was presented the second time, 18 on the third and 18 on the fourth. For PEA there were 16 stimuli of first presentation and 16 of second presentation, 14 of third, 9 of fourth and 2 of fifth. For Peach there were 18 stimuli of first presentation, 18 of second, 13 of third, 7 of fourth and 3 of fifth. The odors were presented in an attend task and after each stimulus the participants rated stimulus intensity and pleasantness on a scale from 0 to 100. For better visualization, pleasantness ratings were afterwards transformed to −50 to 50 scales. The procedure lasted approximately 1 h per session. Participants were seated in an air-conditioned room that was darkened and acoustically shielded to minimize other concomitant sensory stimuli.

EEG was recorded during stimuli presentation from two positions of the international 10/20 system (CZ and PZ) referenced to linked earlobes (A1, A2). Blink artifacts were monitored from an additional recording site (Fp2). Stimulus-linked EEG-segments of 2048 s were digitally recorded at a frequency of 250 Hz (low-pass filter 15 Hz). CSERP were obtained by off-line averaging of at least 8 digitized EEG-segments. Records contaminated by eyeblinks (>50 μV in Fp2 lead) or other disturbances (e.g., high-frequency motor artifacts) were discarded during off-line analysis via visual inspection of single trials by a trained observer.

2.3. Data analysis

N1 and P2 amplitude and latency of the first three repetitions of PEA, Peach and H_2S were detected by a trained observer as the highest or lowest value, respectively, in a specified time window (Hummel et al., 2000). Due to unforeseen technical problems, good quality data of each of the nine stimuli (three odors * three presentations) was received only at channel CZ for at least 80% of the participants. Therefore analysis concentrated on this channel.

Data were analyzed using SPSS vs. 19 (SPSS Inc., IL, USA). Ratings of pleasantness and intensity as well as N1 and P2 amplitude and latency were analyzed using analyses of variance (ANOVA) for repeated measurements with the 2 factors odor (3) and repetition (3). Post-hoc tests were interpreted following Bonferroni-adjustment of the p-value.

Table 1
Intensity and pleasantness ratings.

	PEA	Peach	H_2S	Significance
Pleasantness overall	17.4 (12.2)	23.2 (14.0)	−30.5 (8.8)	PEA < Peach $p = 0.001$ H_2S < Peach $p < 0.001$ H_2S < PEA $p < 0.001$
1th stimulus	16.8 (12.1)	23.7 (14.7)	−32.7 (9.1)	Significant decrease
2nd stimulus	18.4 (13.0)	23.3 (14.0)	−30.8 (9.1)	in H_2S $p < 0.001$
3th stimulus	17.3 (12.8)	22.5 (14.0)	28.0 (10.5)	
Intensity overall	40.6 (15.5)	43.0 (17.5)	43.6 (15.6)	n.s.
1th stimulus	42.7 (15.6)	49.2 (18.7)	49.2 (17.0)	Significant decrease
2nd stimulus	42.1 (16.8)	42.9 (17.3)	44.1 (15.5)	in Peach and H_2S
3th stimulus	40.0 (16.5)	40.9 (17.7)	41.0 (16.3)	$p < 0.001$