Olfaction influences affect and cognitive-motoric performance: Evidence for the negative impact of unpleasant odours

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Abstract

Odours have been shown to affect mood as well as cognitive abilities. In this line of work specific odours like lavender, peppermint or ylang ylang have been examined. This paper examines whether the pleasantness of odours has an impact on participants affect and cognitive-motoric performance. Therefore a preliminary study was conducted in which 24 adolescent participants were exposed to either pleasant (e.g. pine tree) or unpleasant odours (e.g. soaked smoked cigarettes). Before and after being exposed to either one of both odours, subjects rated their affective status and completed the lane change task. Results showed that the interindividual experience of pleasantness differs much more for pleasant odours than for unpleasant odours. Furthermore participants felt significantly less positive and showed decreased lane change performance after being exposed to unpleasant odour, while pleasant odours showed no such effects. It can be concluded that unpleasant odours induced negative affect and influenced subjects’ performance in this cognitive-motoric task. A possible application of these results could be the driving context where sensory input is one of the main factors for longitudinal and lateral vehicle control. In addition to visual, acoustic and tactile information, olfactory stimuli could also influence driving. However, subsequent studies should address real drivers in realistic driving scenarios.

Introduction

Most people do not doubt the importance of hearing and vision in their lives, but it is uncommon to think about the sense of smell as influencing ones behaviour and experience (Wrzesniewski, McCauley, & Rozin, 1999). Yet the olfactory system is closely associated with the limbic system (Sugawara et al., 2013) and odours modulate affect, behaviour, autonomic parameters and cerebral activity (Pollatos et al., 2007). In detail the piriform cortex and the amygdala are structures constituting the primary olfactory cortex while the insula and the orbitofrontal cortex belong to the secondary olfactory cortices (Doty et al., 1997; cited in Pollatos et al., 2007). This close physiological relationship between the olfactory system and the limbic system strengthens the hypothesis that odours stimulate positive and negative affect. Thereby odour research needs to consider dispositional preferences that can be acquired on an individual or culturally shared level (cf. Desmet & Heckert, 2007).
For example, gaseous emissions in agriculture can constitute health problems for exposed workers, and odours from livestock affect the wellbeing of nearby residents (Nimmermark, 2004). But odours do not only impact people’s affect. They also manipulate information processing behaviour. Moss, Cook, Wesnes and Duckett (2003) showed that both lavender and rosemary caused a significant impairment of speed of memory. Lavender decreased the quality of working memory while rosemary enhanced its overall quality. Peppermint odour has also been argued to enhance memory (Moss et al., 2008). In terms of behaviour odours cause actions of approach or avoidance, at simplest. In a visual-tactile dual-task scenario, Ho and Spence (2005) showed a positive effect of peppermint odour on performance. Subjects reacted faster in a vibro-tactile task if exposed to peppermint scent.

Summing up, olfactory information influences a wide range of people’s affect and behaviour. Previous studies showed that odours influence their well being, information processing and behaviour. To date few experimental investigations looked at the effect of odours on subjects’ affect and behaviour in cognitive motoric tasks. The present pilot study aims at generating first indications whether it is worth exploring the role of odour in this type of tasks.

**Objectives**

The present investigation has two objectives. First, it examines the influence of pleasant and unpleasant odours on participants’ affect. As the sense of smell is closely related to emotions, positive odours should elicit a positive affect and negative odours should lead to a negative affect (e.g. Pollatos et al., 2007). Second, the study investigates the effect of pleasant and unpleasant odours on a cognitive-motoric task. Regarding this question, positive odours (pine tree, perfume) should relax participants (Berneker, 2008) and therefore should increase their performance in the lane change task. Negative odours (soaked smoked cigarettes or acetone) should, in contrast, distract participants and lead to a reduced performance.

On these accounts, a pre-study was conducted to differentiate between pleasant and unpleasant odours. In the main study, subjects were exposed to either pleasant or unpleasant odours followed by a standardized cognitive-motoric task, the lane change task.

**Method**

*Pre-study*

The pilot study was conducted to distinguish between pleasant and unpleasant odours. For that reason 13 subjects (2 male) with an averaged age of $M = 37.5$ (ranging from 14 – 76 years) rated 10 everyday odours in a randomised order. All odours (jasmine, strawberry, pine tree, perfume, christmas mix, vinegar-based cleaner, chlorine, soaked smoked cigarettes, acetone, petrol) were presented in liquid form (1.2 ml) in opaque bottles. Subjects task was to open the bottle, smell the odour for about 30 s and rate their experience with respect to pleasantness (9-point Likert-type scale) and intensity (7-point Likert-type scale) following a standardized
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procedure (see Sucker, Bischoff, Krämer, Kühner & Winneke, 2003 for more details). Results showed that participants rated the smells of jasmine, pine tree and perfume as most pleasant and cigarette, acetone and petrol as most unpleasant. There was no difference in intensity between odours.

Main study

Subjects
Twenty-four adolescents (16 male) with an average age of 13.74 years ($SD=0.41$) were tested in the main study. Almost all of them had prior experience with driving games and 42% of the subjects stated to play frequently.

Material
The independent variable pleasantness of odour was varied between subjects on the levels pleasant and unpleasant odours. For that reason, the two most pleasant (pine tree and perfume) and two most unpleasant (soaked smoked cigarettes and acetone) odours from the pilot study were used in liquid form (1.2 ml each) filled in opaque bottles for manipulating subjects’ affect and performance in the main experiment. A short questionnaire was used to evaluate the subjective experience of pleasantness and intensity. This questionnaire was the same as in the pre-study and consisted of a bipolar item for pleasantness (9 point rating) and a bipolar item for intensity (7 point rating, Sucker et al., 2003, p. 26).

To measure affect a German version of the affect grid was used. The affect grid (Russel, Weiss, & Mendelsohn, 1989) consists of a 9x9 grid with the two-axis valence (extremely negative – extremely positive) and arousal (extremely sleepy – extremely aroused). Its theoretical basis is the circumplex model (Russel, 1980). The lane change task was used as the cognitive-motoric task. It is a standardized driving simulation that was shown in parallel on four desktop PCs with a 19-inch screen each. Subjects could change the speed and steering via the arrow keys on standard keyboards. Maximum speed was set at 60 km/h. Participants heard the simulator sound via earphones.

Procedure
Both conditions (positive and negative odours) were tested in two separate rooms with two subjects in each room at a time. After entering the room, participants were separately placed in front of a PC. Now they received a short introduction into the goals and the course of the experiment, the questionnaires and the lane change task. After that, they completed the first affect grid. Subsequently they had three minutes time to complete the practice trial of the lane change task. They were instructed to hold the speed at its maximum of 60 km/h at all times. Moreover they should change the lane as early as possible. Following the practice trial, subjects had the opportunity to ask questions. Now they performed another 3-minute section of the lane change task. These data were used as baseline. Another affect grid and the odours followed. As for the pilot study, the two positive or the two negative odours were presented in liquid form in opaque bottles to each subject and participants were instructed to hold one bottle at a time directly under their noses and smell it for 30s. Subsequently to each smelling participants rated their subjective experience of the odour and their affective mood. They closed the lids of the bottles and accomplished
the test track of the lane change task. Again, this track consisted of a 3-minute stretch. Before starting this section, the experimenter refreshed participants’ instruction to keep the speed at 60km/h and change the lane as soon and as quickly as possible. Due to the high intensity of the odours and the long smelling interval, the scent of the odours stayed in the room during the ratings and the test drive. After each group of participants the room was thoroughly aired. A short debriefing followed after the final test track. The experiment was part of a larger set of studies.

Results

To insure that the odours were experienced as pleasant and unpleasant, the ratings for pleasantness were evaluated (Table 1). All odour ratings’ means were significantly different from zero, except for the pine tree. To sum up, the manipulation for pleasant odours was only partly effective while the manipulation for unpleasant odours was successful.

Table 1. Means, SD and one sample t-test against zero for pleasantness ratings of the four odours

<table>
<thead>
<tr>
<th>Odour</th>
<th>Mean Pleasantness</th>
<th>SD Pleasantness</th>
<th>One sample t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pine tree</td>
<td>0.2</td>
<td>2.0</td>
<td>t(10) = 0.311 , NS</td>
</tr>
<tr>
<td>Perfume</td>
<td>1.8</td>
<td>1.6</td>
<td>t(11) = 3.783 , p = 0.003</td>
</tr>
<tr>
<td>Soaked smoked cigarettes</td>
<td>-2.1</td>
<td>2.2</td>
<td>t(11) = -3.354 , p = 0.006</td>
</tr>
<tr>
<td>Aceton</td>
<td>-1.3</td>
<td>1.5</td>
<td>t(11) = -3.084 , p = 0.010</td>
</tr>
</tbody>
</table>

Note. NS = non significant.

For analyzing whether odours affected subjects’ affect, difference values for the affect grid scores of the baseline (without odours) and the test condition (with odours) were computed. The same applies for the question if odours affect behaviour. Here performance measures of the test condition (mean and standard deviation of the lateral position in the lane change task) were subtracted from the scores of the baseline condition. Due to a setting error six subjects had a smaller viewing distance in the lane change task. To compensate the difference the computational model of the standard line was adjusted. Both analysed measures were not affected by this, neither the mean deviation of lateral position (t(22)=-0.317, NS) nor the standard deviation of the lateral position (t(22)=-0.539, NS).

Effect of odours on affect

With respect to the effect of odours on subjects’ affect, no effect was found for unpleasant and pleasant odours on arousal, all t < 0.37, all p > 0.71. In contrast, unpleasant odours significantly decreased subjects valence scores, t(11) = 4.7, p <
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Participants of this group felt less positive after being exposed to unpleasant smells. For pleasant odours, no effect on subjects valence ratings was obtained, $t(11) = 0$, NS. Figure 1 visualizes the results.

Figure 1. The effect of odours on subjects a) arousal and b) valence. Error bars represent +/- 1SD; baseline = before odour exposure, test = after odour exposure.

Effect of odours on the performance in the cognitive-motoric task

With respect to the effect of odours on cognitive-motoric performance, effects of odours on the mean lateral position and the standard deviation of the lateral position were found. Subjects that were exposed to pleasant odours showed a tendency with respect to a decreased lateral deviation compared to their baseline, $t(10)=1.49^1$, $p = 0.08$. In contrast, unpleasant odours resulted into a tendency for an increased lateral deviation, $t(11) = -1.63$, $p = 0.06$. Moreover, pleasant odours did not affect the standard deviation of the lateral position, $t(11) = -0.13$, $p = 0.55$. Again unpleasant odours increased the standard deviation of the lateral position, $t(11) = -1.88$, $p = 0.04$. Figure 2 visualizes the effects of odours on a) the mean deviation from the lateral position and b) the standard deviation of the lateral position.

1 One subject was excluded from the group of pleasant odours because of being a large outlier.
Figure 2. Effect of odours on a) the mean deviation from the lateral position and b) the standard deviation of the lateral position. Error bars represent +/- 1SD; baseline = before odour exposure, test = after odour exposure.

Discussion

The present study had two objectives. First, it examined whether everyday odours affect subjects’ affect. Regarding this objective, only one significant difference was obtained for participants’ valence ratings after they had been exposed to negative odours. This result somewhat deviates from literature findings that used standardized odour samples like the sniffing sticks (e.g. Pollatos et al., 2007). One explanation for this result lies in the fact that participants experienced only one of the two positive odours as pleasant while both negative samples were experienced as unpleasant. Thus the manipulation for pleasant odours was not successful. Kaye (2004) points out several issues when designing pleasant and unpleasant odours of which probably the main problem is interindividual variance in odour perception and judgement. Even though the odour samples were choosen based on a pre-study, two different samples with a different range of age participated in the pre-study and the main study. The difference in sample characteristics might explain these findings partially. Future experiments should try to individually determine pleasant and unpleasant odours or use within-subjects designs with the same subjects in the pre- and the main study. Using personalized stimuli or a different experimental design, a replication of effects from literature with everyday odours might be more likely.

Second, the present study investigated whether pleasant and unpleasant odours affect performance in the lane change task, a simple cognitive-motoric task. When operating this simulation participants have to continuously adjust their lateral position based on visual input. Results indicate that subjects showed a tendency towards better steering performance in this cognitive-motoric task when being
exposed to pleasant odours. Moreover a tendency for worse steering performance was shown for the negative odour group. However, these hypothesis confirming result were just tendencies and only applied to the mean deviation of the simulated vehicles lateral position. In contrast the significant effect of negative odours on the variability of the cognitive-motoric performance seems to be trustworthy. Performance decreased when participants were previously exposed to unpleasant odours. This was shown in the marginal increase of the mean and the significant increase of the standard deviation of the lateral position. Subjects might have been distracted by the unpleasant smell. For example Wrzesniewski et al. (1999) argue that subjects feel the urge to avoid or seek out unpleasant smells. This behavioural tendency even increases with increasing unpleasantness of odours. Therefore participants might have concentrated on their breathing or other strategies of avoiding unpleasant smells instead of concentrating on the cognitive-motoric task. Pleasant odours, in contrast, foster the subject to increase their experience of them (Wrzesniewski et al., 1999). Thus, subjects that were exposed to positive odours were not distracted and could concentrate on the cognitive-motoric task. This explanation seems reasonable since the smell of the odours stayed in the room even after the active smelling and was only removed after the test track.

Summing up, the present study showed that affective states and keeping lateral control in a simple driving simulation was affected by everyday odours. Thus we conclude that the dimension pleasantness of odour indeed has an impact on affect and cognitive-motoric performance of adolescents. Nevertheless the conclusion is limited to the specific sample and to only one pole of pleasantness since the manipulation for pleasant odours was only partial successful. A practical application of this study could be the context of car driving. Here, having longitudinal and lateral control over the vehicle, both cognitive-motoric tasks, is extremely safety relevant. While studies in this field mainly focused on visual, acoustic, tactile modalities and higher cognitive factors, olfactory stimuli could also influence driving performance. This study is a small but relevant step towards more applied research on the olfactory influences on subjects’ affect and behaviour in human-machine interaction situations.

Acknowledgement

We would like to offer our special thanks to Ron Reckin and Thorsten Fischer for spending their valuable time on the project during data collection and to Dick de Waard for his helpful comments.

References


