

Olfactory facilitation of dual-task performance

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Abstract

We investigated the differential effects of olfactory stimulation on dual-task performance under conditions of varying task difficulty. Participants detected visually presented target digits from amongst a stream of visually presented distractor letters in a rapid serial visual presentation (RSVP) task. At the same time, participants also made speeded discrimination responses to vibrotactile stimuli presented on the front or back of their torso. The response mapping was either compatible or incompatible (i.e., lifting their toes for front vibrations and their heel for back vibrations, or vice versa, respectively). Synthetic peppermint odor or clean air (control) was delivered periodically for 35 s in every 315 s. The results showed a significant performance improvement in the presence of peppermint odor (as compared to air) when the response mapping was incompatible (i.e., in the difficult task) but not in the compatible condition (i.e., in the easy task). Our results provide the first empirical demonstration that olfactory stimulation can facilitate tactile performance, and also highlight the potential modulatory role of task-difficulty in odor-induced task performance facilitation.

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Several researchers have reported that the presentation of certain odors (such as lavender, lemon, muguet, and peppermint) can modulate human performance (e.g., [20]), cognition (e.g., [4,21]), and emotion (e.g., [18,19]). For instance, Millot et al. [20] reported that the presentation of an ambient odor, no matter whether it was the pleasant odor of lavender or the unpleasant odor pyridine, resulted in a 10% decrease in response latencies to simple auditory and visual stimuli relative to a no-odor baseline condition. In another influential early study, Warm et al. [41] reported a marked improvement in cognitive performance in a sustained visual attention task. In their between-participants design, Warm et al. reported an overall performance advantage of about 20% in the number of visual targets detected by different groups of participants periodically exposed to either peppermint or muguet (lily of the valley) odor (30 s bursts every 5 min), as compared to a no-odor (i.e., air) control group of participants.

Several other researchers have, however, failed to obtain any significant effect of odor on performance. For instance,

Gilbert et al. [14] reported no significant effect of the presence of either pleasant or unpleasant odors, when compared to no-odor, on performance when participants had to perform a clerical coding task, or to cross-out target digits from a page of random numbers. Meanwhile, Ilmberger et al. [17] reported no effect of the presentation of ylang-ylang, 1,8-cineole, menthol, peppermint, or jasmine on speeded visual target detection performance. The lack of any significant effect of the presence of odor on task performance in these studies may partly be due to the insensitivity of the specific tasks used to alerting manipulations (cf. [13]), or to a specific failure of olfactory alerting when using these odorants. In addition, the performance differences obtained in all of the above studies may well be caused by the discrepancy between the different groups of participants tested, given the use of between-participants designs and the large individual differences typically found for olfactory perception [9,22]. Another potentially important factor in this area of research may be that performance can be affected either positively or negatively depending on the initial level of arousal or stress of the participants (e.g., [11]; cf. [42]), with alerting and sedative odors acting in an opposing manner to either

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increase or reduce levels of stress. To date, however, no one has examined the differential effects of odors on tasks of varying difficulty. Note also the potentially important distinction here between the use of continuously presented ambient odors (e.g., [19,20]) versus periodically presented bursts of odors (e.g., [41]), as people's sensitivity to odorants typically decreases with prolonged or repeated exposure to the same olfactory stimulus (see [8]).

The present study was designed to further investigate the effect of the presentation of peppermint odor on dual-task performance, given the mixed results reported in previous studies. We chose to use peppermint odor because many other researchers have argued for its alerting properties (e.g., [33,41]). We hypothesized that the smell of peppermint should improve concentration (and/or alertness), and hence lead to better performance in both monotonous simple detection and discrimination tasks. The two tasks used in the present study consisted of a rapid serial visual presentation (RSVP) task in which participants had to detect target digits embedded amongst a stream of distractor letters, and a vibrotactile front/back discrimination task that required either a compatible or incompatible response (see [12]) to vibrotactile stimuli presented to the participants' torso. This manipulation of response compatibility allowed us to vary the difficulty of the task while keeping the stimuli and task constant (see [28] for a recent review of the literature on spatial-compatibility). We chose to use a within-participants design, with all of the participants being tested in both the peppermint odor and air conditions, in order to minimize any possibility that individual differences in olfactory perception would affect performance (e.g., [9,22]).

Sixteen participants (eight males and eight females; mean age of 25 years, range 18–35 years) participated in this experiment. All of the participants had normal, or corrected-to-normal, vision, normal tactile sensitivity, and normal olfaction by self-report. The experiment lasted for approximately 45 min. The experiment was conducted in accordance with the guidelines laid down by the Department of Experimental Psychology, University of Oxford. Ten of the participants received a £5 UK sterling gift voucher in return for their participation, the rest received course credit.

The participants rested their chin on a chinrest mounted on the edge of a desk. Synthetic peppermint odor (408571, diluted at a concentration of 10% in diethyl phthalate, 526305, Quest International, Ashford, England) was used as the olfactory stimulus. A custom-built computer-controlled olfactometer was used to deliver the odorants. The flow of medical air through the olfactometer was controlled by a flow regulator (CONCOA 03-054, Utrecht, The Netherlands) connected to a gas cylinder at a rate of 7.5 L/min. The tubes delivering the olfactory stimuli were attached to the chinrest, with the tubes directed toward the participants' nose from below (at a distance of about 4 cm). A LCD monitor (screen refresh rate of 60 Hz) positioned 70 cm directly in front of the chinrest was used to display the visual stimuli for the RSVP task. The RSVP stimuli consisted of 17 distractor letters and six target

digits (cf. [34]). The RSVP characters were 8 mm × 8 mm in size. The participants responded to targets in the RSVP stream via a response box held in their left hand. The two tactors (2.54 cm × 1.85 cm × 1.07 cm, VBW32, Audiological Engineering Corp., Somerville, MA) used to present the vibrotactile signals were attached to a Velcro belt fastened around the participant's waist. One of the tactors was placed in the middle of the participant's stomach, the other in the middle of their back. The belt and the tactors were fastened directly over the top of any clothing that the participant happened to be wearing. The tactors were driven by a 200 Hz signal at an intensity sufficient to deliver clearly perceptible vibrotactile stimuli through clothing. Two footpedals were placed on the floor at a comfortable distance from the participants, one below the toes and the other below the heel of their right foot. White noise was delivered through cordless headphones (SBC-HC075, Philips, USA) at about 60 dB(A) to mask any background noise.

The experimental session consisted of four 10½-min blocks of experimental trials. The RSVP task consisted of a continuous stream of distractor letters with target digits embedded periodically within it. Each item in the RSVP stream was presented for 50 ms, with a blank gap of 100 ms before the onset of the next stimulus (see Fig. 1). Ninety-six targets were presented in each block of trials, with a temporal gap of 2550–7650 ms between successive target digits in the RSVP stream. For the vibrotactile discrimination task, 32 randomized vibrotactile stimuli were presented for 300 ms in each block (half to the participants' front, half to their back), with a gap of 3300–12,300 ms between successive vibrotactile stimuli. The timing of targets in the two tasks was independent.

The peppermint odor or clean air was presented for 35 s at the start of each experimental block, after which no olfactory stimulus was presented for the next 4 min and 40 s. The air or peppermint odor, whichever had not been presented at the start of the experimental session, was then presented for 35 s, with no olfactory stimulus being presented for the remainder of the block. We used an intermittent presentation procedure for the olfactory stimuli to allow time for recovery from any olfactory adaptation (see [8]). Note that participants might have perceived the presentation of the peppermint odor to be shorter or longer than the 35 s duration of actual stimulus delivery. The order of presentation of the peppermint odor and air conditions was counterbalanced across participants.

The participants were given two 2-min practice blocks in which to familiarize themselves with the tasks. In the first block, the participants only performed the RSVP task, which was initially presented at a slower rate that gradually increased to the experimental rate of stimulus presentation. In the second block, the participants performed both the RSVP and vibrotactile discrimination tasks as in the subsequent experimental blocks. Air was delivered through the olfactometer throughout the second practice block.

The participants responded to targets in the RSVP task by pressing a response button with their left thumb. The par-

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