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Is there a relationship between odors and motion sickness?

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HIGHLIGHTS

- We evaluate the relationship between olfaction and motion sickness.
- Our study highlighted the lack of influence of odors in motion-induced sickness.
- Our results showed an impact of a nauseogenic test on olfactory perception.

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ABSTRACT

The aim of this study was to evaluate the relationship between olfaction and motion sickness. A sample of 18 participants was recruited and submitted to three sessions of nauseogenic stimulations: off vertical axis rotation (OVAR), performed under conditions of olfactory stimulation with limonene (pleasant odor), petrol (unpleasant odor) or distilled water (as a control). Motion sickness was assessed before, during and after each OVAR session. In addition, participants were asked to evaluate the intensity and hedonic valence of four odors (geraniol, limonene, butanol, petrol) as well as distilled water (as a control) before and after each OVAR session. Our analysis showed that OVAR has consistently increased the induced-motion sickness. However the addition of an odor that is pleasant or unpleasant during the rotation did not affect the occurrence of motion sickness symptoms compared to the control condition. Our results also showed that intensity of odors was significantly increased after OVAR and the intensity was significantly higher for unpleasant odors than for pleasant one. For the hedonicity, OVAR made unpleasant odors more unpleasant ($p < 0.0001$) while it made limonene odor slightly more pleasant ($p < 0.05$). The present study highlighted the lack of influence of odors in motion-induced sickness but an impact of a nauseogenic test on olfactory perception.

Introduction

Technological evolution of modern transports, such as cars or trains, significantly increases motion sickness symptoms occurrence. Motion sickness (MS) is defined by a set of four main symptoms that regularly appear: facial pallor, cold sweats, nausea and vomiting. Other additional signs such as dizziness, headache, fatigue, postural instability, which are more variable in their appearance and duration, can be also observed [9]. One of the most established theories to explain in which circumstances motion sickness arises is the "sensory conflict" theory [21]. This theory postulates that motion sickness originates from a sensory mismatch between actual versus expected invariant patterns of vestibular, visual and somatosensory inputs [21]. It has been accepted that the vestibular system influences individual motion sickness susceptibility (MSS) since patients with bilateral vestibular deficit have greatly reduced susceptibility or do not become motion sick at all [15,25]. This sensory mismatch leads to an activation of vestibuloautonomic pathways, which have been shown to be also involved in producing nausea and vomiting during motion sickness and those that generate illness after ingestion of toxins [25].

Among factors that may contribute to motion sickness, such as alcohol or hunger, the presence of strong smells is very often reported by individuals who are sensitive to motion sickness.

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Similarly, there are a variety of companies claiming that the inhalation of some essential oils can alleviate motion sickness symptoms. Besides, an interesting parallel between motion sickness and the olfactory system may be underlined. On one hand, it is granted that women are more sensitive to motion sickness than men [7,18,19]; in particular, it has been shown that the MSS fluctuates across menstrual cycle [10,11] as a consequence of hormonal variation [2]. On the other hand, women demonstrate better olfactory abilities than men [1]. But, surprisingly, the link between olfaction and MSS has been poorly investigated by the research community. Sharma and Aparna [22] showed that participants with high-MSS were more sensitive to unpleasant odors. Fessler and Arguello [6], who asked participants to report on a 5-point scale how sensitive they were to unpleasant odors, highlighted a positive correlation between sensitivity to unpleasant odors and MSS in women. Similarly, Paillard et al. [18] reported pilot data demonstrating that high-MSS participants perceived the odors of petrol and leather as more unpleasant than participants who were not sensitive to motion sickness.

The aim of the present study is to delve further into these initial findings and to assess the relationship between odors and motion sickness.

We can question the influence of odors on motion-induced sickness (i.e. can pleasant or unpleasant odors have an influence on MS symptoms occurrence?) as well as the influence of motion-induced sickness on the perceived quality of an odor (i.e. can a nauseogenic test influence odors intensity and hedonicity?). The study focuses specifically on these two dimensions because they have long been recognized as the most important features of odors [12,26]. Previous study showed that high-MSS participants are more sensitive to unpleasant odors [22] and also perceived the odors of petrol and leather as more unpleasant than participants who were not sensitive to motion sickness [18]. Moreover, Herz et al. [13] supported the statement that hedonic judgment of familiar odors is deteriorated in an unpleasant context. Besides, it has been shown that the perceived intensity depends, at least in part, on experience-dependent factors [5]. Thus, our hypotheses are that (i) the motion sickness occurrence may be influenced by unpleasant odors such as petrol or leather during a nauseogenic test; (ii) pleasant odors smelt by participants during a nauseogenic test are perceived as less pleasant after the test and unpleasant odors are perceived as more unpleasant and (iii) perceived intensity of odors is increased after a nauseogenic test.

Material and methods

Participants

A sample of 18 volunteer participants (mean age 23.8 years old, range 19–40 years old, 11 women and 7 men) was recruited in this experiment. In order to assess the MSS, participants were required to complete the motion sickness susceptibility questionnaire (MSSQ) [8]. According to Paillard et al. [18], who found that high-MSS subjects judged odors related to transports as more unpleasant than low-MSS subjects, our participants were divided in two groups: 10 subjects represent low MSS individuals (MSSQ scores from 0 to 10.75; 6 women and 4 men) and 8 subjects represent high MSS individuals (MSSQ scores from 17.63 to 44; 5 women and 3 men).

All participants were non-smokers and reported normal smell sensitivity. None of them had a history of nasal/sinus disease or extensive exposure to chemical with potential olfactory toxicity. Participants with past or present otologic or neurological disorders were not included in the study. Women were not tested during their menses period. All participants provided informed written consent. This study was conducted in accordance with the Declaration of Helsinki (1964).

Motion sickness induction and symptoms ratings

The off vertical axis rotation (OVAR) test is ideal for our purpose, as it has been established that it is highly effective in evoking MS. On the basis of a previous study performed in the laboratory [4], the stimulation parameters ($70^\circ\,s^{-1}$, 15° tilt, in total darkness) were chosen to make the examination moderately nauseogenic. Subjects were comfortably seated and secured into a rotating chair driven by a torque. They were restrained by means of a seat belt. The center of their head was also positioned and maintained at the center of the rotation by means of a concave headrest and a helmet fixed to the chair.

The degree of motion sickness during OVAR test (i.e. motion sickness rating, MSR) has been used to define the end-point of the OVAR test. MSR was rated every minute; (1): no symptom; (2): initial symptoms but no nausea; (3): mild nausea; (4): moderate nausea. The MSR score is defined as the time (in minutes) to reach MSR-level 3, which was defined as the end-point of each OVAR test. Motion sickness symptoms were also assessed before and after motion with the simulator sickness questionnaire (SSQ) [17] that probes polysymptomatic responses to motion and yields a score between 0 (no symptoms) and 51 (maximum symptoms).

Odorants

For the test of olfactory perception, four specific odorants were used: two pleasant odors (geraniol and limonene, corresponding to rose- and orange-like smells, respectively) and two unpleasant odors (*n*-butanol and petrol). Pleasantness scores of each odor were obtained from preliminary self-report ratings. We also used distilled water as a control condition. The dilutions used in our study have been determined according to a pretest carried out on 10 participants: three dilution series (100%, 50%, 25%) were prepared for each odorant and participants were required to rate from 0 (weak) to 10 (strong) the perceived intensity of odors. The dilutions that reach a similar moderate perceived intensity have been chosen for the tests. Specifically, geraniol and limonene were used without dilution (100% of the stock solution), while petrol and butanol were diluted at 25% in odorless mineral oil. Four milliliters of each odorant solution was placed into glass tubes (6.5 cm high, 1 cm at the opening).

For the OVAR session, 10 μL of pure limonene or 25% petrol or distilled water was placed on a piece of cotton attached to participant facemask. The concentrations for each odorant were determined during pretesting such as they were both of equal perceived intensity. Before and after the nauseogenic test, participants were asked to rate the perceived intensity and hedonic valence of the four odors as well as the control odor on analogic scales ranging from 0 (weak/unpleasant) to 10 (strong/pleasant).

Procedure

The experiment consisted of three OVAR sessions. In order to avoid habituation, there was at least one week between each session. Before each OVAR session the test of olfactory perception of the four odors (geraniol, limonene, butanol and petrol) and the distilled water was carried out in a separate room. Odor presentation order was randomized for each participant. At the beginning of each OVAR session, participants were informed on how to recognize symptoms of motion sickness as they developed and how to report them. Then the first SSQ was administered. The participant seated on the OVAR chair and was equipped with a facemask soaked with limonene, petrol or distilled water. The participants performed these three sessions in a random order (balanced for order design) and the OVAR stimulation always started immediately after