



# Mitigating Simulator Adaptation Syndrome by means of tactile stimulation



Germán Gálvez-García<sup>a, b, \*</sup>, Javier Albayay<sup>a</sup>, Lucio Rehbein<sup>a</sup>, Francisco Tornay<sup>c</sup>

<sup>a</sup> Departamento de Psicología, Universidad de La Frontera, Temuco, Chile

<sup>b</sup> Département de Psychologie Cognitive & Neuropsychologie, Institut de Psychologie, Laboratoire d'Étude des Mécanismes Cognitifs, Université Lyon 2, Lyon, France

<sup>c</sup> Departamento de Psicología Experimental, Universidad de Granada, Granada, Spain

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## ABSTRACT

Some drivers experience Simulator Adaptation Syndrome (SAS), a condition in which nausea, disorientation, dizziness, headache, and difficulty focusing, are exhibited when driving in a simulator. To reduce this syndrome, we investigated the efficacy of tactile stimulation (TS) on mitigating Simulator Adaptation Syndrome (SAS) in a driving simulation. Fifteen drivers (eight women; mean age = 24.07 years) participated in this experiment. We compared the total scores of the Simulator Sickness Questionnaire (SSQ) across two stimulation conditions (TS condition and no stimulation condition as a baseline measure). The experimental outcomes revealed that TS seemed to decrease SAS due to attentional distraction from the symptoms and not because of an improvement in balance ability.

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## 1. Introduction

Simulator Adaptation Syndrome (SAS) is a condition that occurs due to a mismatch between sensory inputs regarding position and what is expected in driving simulators. This syndrome can range from mild discomfort to severe dry mouth, drowsiness, disorientation, vertigo, nausea, dizziness, and vomiting (Ebenholtz, 1992; Cobb et al., 1999). The aetiology of SAS is not completely understood (see Mollenhauer, 2004; for an extensive review of SAS). As Cox et al. (2011) show, the causes of this syndrome can be assembled attending to individual factors (e.g., age), characteristics of the driving simulator (e.g., size of the display screen), and the individual's interaction with the simulator (e.g., exposure time).

To counterbalance this syndrome, some studies focus on mitigating SAS using drugs. The use of drugs (for a review, see Sherman, 2002) is not an efficient countermeasure to mitigate SAS due to side effects that may affect training efficiency (Murdin et al., 2011). First,

studies with scopolamine may cause sedation, dry mouth, blurring of vision, and light-headedness (Crowley, 1987). Secondly, oral medication for SAS reduces gastric motility (Wood et al., 1987). Finally, it should be noted that medications do not reach their efficacy until several hours after administration. Considering these problems, alternative techniques have emerged to mitigate SAS using different sources of stimulation, like galvanic cutaneous stimulation (GCS), galvanic vestibular stimulation (GVS) and, more recently, auditory stimulation (AS). GCS restores normal balance in the context of vestibular sensory deprivation, as in fixed-simulators. For example, Reed-Jones et al. (2008), and Gálvez-García (2015) show that the application of GCS improves balance in subjects performing a simulator task. The improvement in balancing ability is correlated with the mitigation of SAS (Gálvez-García (2015)). In addition, three studies show the positive impact of GCS on SAS (Chu et al., 2013; Gálvez-García, 2015; Gálvez-García et al., 2015). GVS is a similar technique to GCS. This involves providing vestibular motion stimuli to reduce SAS. It is shown that GVS improves the body's balance (e.g., Inglis et al., 1995) and, more importantly, reduces SAS (Reed-Jones et al., 2007). AS (more concretely, white noise) has been recently shown to be an efficient technique to mitigate SAS. Gálvez-García (2015) shows that white noise improves balance in subjects performing a simulator task. Moreover, the improvement in balancing ability correlates with the mitigation of SAS. This finding supports the idea that white noise

**Abbreviations:** SAS, Simulator Adaptation Syndrome; GCS, galvanic cutaneous stimulation; GVS, galvanic vestibular stimulation; AS, auditory stimulation; TS, tactile stimulation.

\* Corresponding author. Departamento de Psicología, Universidad de La Frontera, Temuco, Chile.

E-mail addresses: [german.galvez@ufrontera.cl](mailto:german.galvez@ufrontera.cl) (G. Gálvez-García), [j.albayay91@gmail.com](mailto:j.albayay91@gmail.com) (J. Albayay), [lucio.rehbein@ufrontera.cl](mailto:lucio.rehbein@ufrontera.cl) (L. Rehbein), [ftornay@ugr.es](mailto:ftornay@ugr.es) (F. Tornay).

improves body stability in patients with vestibular problems (Mangione, 2012). More importantly there is evidence that supports that white noise functions as a countermeasure to decrease SAS (Gálvez-García, 2015).

The aforementioned techniques (GCS, GVS and white noise) have a positive impact on balance ability, decreasing SAS. Interestingly, this constitutes direct evidence in support of the postural instability theory (Riccio and Stoffregen, 1991), where it has been postulated that SAS is produced by an inability to learn how to maintain postural stability. Nevertheless, the mitigation of SAS could come from other sources, especially considering that the aetiology of this phenomenon is not entirely clear and could be due to several reasons. As the main aim of this research, we want to test an additional source of stimulation that does not affect balance ability as a possible countermeasure to decrease SAS: distraction from sickness. Thus, a source of stimulation that does not deteriorate driving performance will reduce participants' awareness of SAS symptoms (i.e., stomach discomfort, eyestrain, etc.). This hypothesis is based in previous evidence. For example, Reed-Jones (2011) compares a condition of unilateral and congruent GVS (reflecting what the participants can feel during a curve in naturalistic situations) with the opposite situation (unilateral stimulation that provided the opposite vestibular experience). He shows a similar pattern of results in both conditions, concluding that electrical stimulation can distract from the sickness and cause a decrease in SAS. In addition, this attentional disengagement hypothesis can explain, for example, why different types of stimulation, like acupuncture, decrease SAS (e.g., Wesley and Tengler, 2005). Nevertheless, it is important to remark that this explanation based on distraction would be additive to the aforementioned literature supporting the idea of motion induced by a different form of stimulation (e.g., GCS and AS) as the cause of SAS mitigation. Thus, the attentional disengagement hypothesis can coexist with evidence regarding the increase of postural control to mitigate SAS. We want to remark that testing the attentional disengagement hypothesis is crucial in order to provide evidence of SAS as a multifactorial syndrome, which can be dealt with via several different countermeasures. In order to test the attentional disengagement hypothesis, we study how tactile stimulation (TS) influences SAS, as TS is not shown as bothersome in previous studies on tactile attention (e.g., Gálvez-García et al., 2012a; Gálvez-García et al., 2012b). This is crucial in order to avoid a decline in any driving variable, which could be controversial in terms of future recommendations of the technique. We aim to deliver TS on the quadriceps to avoid stimulating the muscles of the trunk or neck, which may fortuitously provide data to the central nervous system on the position of the trunk and head in space. The TS must only affect attentional processes in order to test the attentional hypothesis. In any case, we aim to measure how TS affects body balance to rule out this issue as an explanatory factor of the pattern of results. For this purpose, we measure head postural stability (head sway) as a measure of balance in line with previous research (Easton et al., 1998; Gálvez-García, 2015; Reed-Jones, 2011). Finally, it should be noted that TS is an inexpensive and simple technique to mitigate SAS (i.e., the application of TS only requires a tactile device synchronised with the simulator to provide a tactile signal during curves), which is fundamental for the recommendation of this technique for future interventions to reduce SAS.

An additional aim of this research is to investigate how TS affects driving performance. Previous research (Gálvez-García, 2015; Gálvez-García et al., 2015; Reed-Jones et al., 2009) had failed to find an effect of external techniques that decrease SAS (i.e., GCS and auditory stimulation) on driving performance.

We hypothesise that TS will improve SAS without a positive impact on balancing ability, attending to the attentional distraction

from sickness.

## 2. Method

### 2.1. Participants

We used a similar method previously described by Gálvez-García (2015). Prior to the experiment, participants completed the Motion Sickness Susceptibility Questionnaire (MSSQ; Golding, 1998) to determinate if they had a predisposition to motion sickness. Participants with MSSQ scores higher than 65 (75th percentile) were not included in the experiment because of their susceptibility to sickness (no participants were excluded; mean MSSQ score for our sample was  $39.35 \pm 19.07$ ). The participants included 7 men and 8 women (mean age =  $24.07 \pm 2.84$  years). To be included in this study, participants should have driven at least 3000 km the previous year, should not have a pacemaker or a hearing aid, should never have experienced vestibular vertigo, and finally, should not be taking medicines that affect driving. All participants reported normal or corrected-to-normal vision and normal tactile perception. Participants were instructed to refrain from the use of medication, alcoholic substances, and caffeinated drinks for 24 h before the experiment. Participants were unaware of the purpose of the experiment, received a six Euro gift voucher in return for their participation, and gave their signed informed consent. All procedures were in accordance with the declaration of Helsinki and the ethical standards of the human research advisory committee.

### 2.2. Apparatus and stimuli

TS was delivered during the curves by a small metallic rod for a duration of 5 ms, and each stimulation followed a protocol similar to Gálvez-García et al. (2012a, 2012b).

The study was carried out in an instrumented fixed-base simulator with sensors on the pedals, wheels and gearbox. A high-speed digital camera (S-MOTION) was used to record head movements. On a 7.5 km flat route through an urban environment, participants negotiated 18 curves (nine lefts and nine rights) – gradual or sharp 90° turns. The gradual turns (GTs) consisted of a 70 m lead-in, a 140 m curve, and a 70 m lead-out (240 m in total). The sharp turns (STs) were modelled on a T-junction and consisted of a 40 m lead-in, and a 40 m curve transitioning immediately to the next road (80 m in total) (see Gálvez-García, 2015 for more details about the scenario).

### 2.3. Procedure

Participants performed a driving session (5 min) to become familiar with the car at the beginning of the experiment. After this familiarisation, participants drove the experimental circuit. All participants were asked to drive in the right lane, not to exceed 90 km/h and to reduce their speed during curves in order to perform this manoeuvre efficiently. Participants drove through the simulation two times, corresponding to the two experimental conditions (counterbalanced between participants to compensate for any learned behaviour). These experimental conditions were the following: 1) no stimulation condition, whereby no stimulation was delivered (baseline condition); 2) TS condition, where TS was delivered from 40 m before a curve to the end of the curve. The tactile tappers were placed in position on every subject at the beginning of the experiment to maintain the same set-up across the different experimental conditions. After each drive, participants exited the vehicle for a rest period of 5 min and completed the SSQ. We measured SAS using the Simulator Sickness Questionnaire

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