

Assessing (dis)comfort: measuring motion sickness progression

Anna J. C. Reuten^{1,2}, Suzanne A. E. Nooij^{2,3}, Jelte E. Bos^{2,1} & Jeroen B. J. Smeets¹

¹Department of Human Movement Sciences, Vrije Universiteit Amsterdam, The Netherlands, ²Human Performance, TNO Soesterberg, The Netherlands, ³Department of Human Perception Cognition and Action, Max Planck Institute for Biological Cybernetics, Tübingen, Germany

ABSTRACT

Motion sickness has a dominant contribution to the broader concept of discomfort when self-motion is at issue, for example when travelling in a self-driving car. Recent studies are devoted to finding ways to mitigate motion sickness even though the relationship between the different types of scales used to measure motion sickness is largely overlooked. For this reason, we here compared two major types of self-report rating scales: those measuring general unpleasantness and those measuring specific symptomatology. For up to 30 minutes of ongoing motion stimulation, we found that 1) symptoms generally manifested in a fixed order, while unpleasantness seemed to increase non-monotonically, and 2) symptoms that manifested later were generally reported as more unpleasant, except for nausea onset. The onset of nausea was systematically rated less unpleasant than the preceding pre-nausea symptoms. This indicates that unpleasantness does not monotonically increase during the progression of motion sickness symptoms. Studies having used the two different types of scales can accordingly not directly be compared, particularly at nausea onset. Our results imply that rating how bad someone feels is not the equivalent of rating how close someone is to the point of vomiting.

KEYWORDS

Symptom progression, well-being, self-report

Introduction

The introduction of self-driving cars provides the prospect of a mode of transport with various societal benefits (Begg, 2014). However, their introduction is accompanied by an expected and observed increase in motion sickness (Diels & Bos, 2016; Iskander et al., 2019; Sivak & Schoettle, 2015). Motion sickness has a dominant contribution to the broader concept of discomfort when self-motion is at issue (Bos et al., 2007). Research on the mitigation of motion sickness is proliferating to ensure a successful embedding of these cars into society. However, to assess these countermeasures, it should be clear how we can measure motion sickness progression unambiguously with the use of self-report rating scales.

Motion sickness concerns a syndrome that is associated with discomfort. It encompasses several classes of symptoms that are suggested to progress in a fixed order over time. Bodily symptoms like flushing, stomach awareness, and dizziness often vary between people, but are typically followed by nausea, retching, and vomiting (Lawson, 2014; Reason & Brand, 1975). In parallel, motion sickness is recognised by its feelings of unpleasantness, that can vary from slight discomfort to absolute dreadfulness. One may observe that both symptomatology and unpleasantness lend itself for the use of a severity grading, typically rated using self-reports with label descriptions expressing

a symptom or feeling in a single number. Despite their common usage, is the relationship between the two different types of scales still unclear.

Although some studies have reported positive correlations between measures of unpleasantness and symptomatology (Bos et al., 2005; D'Amour et al., 2017; Keshavarz & Hecht, 2011; Nooij, Pretto, Oberfeld, et al., 2017; Reason & Graybiel, 1970), exact knowledge on the development of unpleasantness with symptom progression is still missing. Correlational research can hide possible local deviations of a monotonic relationship, as also suggested by anecdotal evidence. To illustrate, vomiting is generally considered the final manifesting symptom, yet also reported to offer relief of misery (Dobie, 2019; Lackner, 2014; Leung & Hon, 2019). Moreover, despite finding an overall positive correlation, one study reported specific and temporary decreases in unpleasantness ratings midway the scale during ongoing motion stimulation (Reason & Graybiel, 1970).

Because we believe there is reason to assume that rating how bad someone feels may not be equivalent to rating how close someone is to the point of vomiting, we investigated whether one feels worse as symptoms progress. To that end, we first examined the temporal development of unpleasantness and symptomatology during ongoing motion stimulation (Part I), and secondly the development of unpleasantness during motion sickness symptom progression (Part II). These results have been reported partly in Reuten et al. (2020) and will be presented fully in a journal publication (Reuten et al., 2021).

Methods

Study characteristics

We reanalysed sickness ratings from seven previous and partly published experiments on motion sickness. These experiments exposed subjects to a 20- or 30-minute motion sickening stimulus using either virtual motion (Exp 1: Nooij et al., 2017; Exp 2: Nooij, Pretto, & Bülthoff, 2017; Exp 3: Nooij et al., 2021) or real motion (Exp 4: Bos et al., 2005; Exp 5: Bos, 2015; Exp 6-7: unpublished). Each experiment (except for Exp 3) consisted of multiple sessions presented on separate days. All experiments were approved by the ethical review board of the institution where the experiment took place.

Part I. The temporal development of unpleasantness and symptomatology

Our first goal was to obtain more insight in the temporal development of unpleasantness and symptomatology ratings during ongoing motion stimulation. We therefore analysed the transitions between consecutive ratings given on an unpleasantness scale, in this case the Fast Motion sickness Scale (FMS, Keshavarz & Hecht, 2011) in Exp 1-3, and consecutive ratings given on a symptomatology scale, in this case the MIserY SCAle (MISC, Bos et al., 2005) in Exp 4-7. The FMS has endpoints varying from 0 (no sickness) to 20 (frank sickness) without intermediate anchoring. The MISC ranges from 0 (no symptoms) to 10 (vomiting), with each intermediate number referring to a specific class of symptoms (see Table 1).

Ratings were repeatedly obtained within each experimental session at two- to five-minute intervals until the session was completed, a stop-criterion was reached ($FMS \geq 15$ or $MISC \geq 7$, except for Exp 4 that used no stop-criterion), or a subject expressed the wish to stop (see also Table 2). We examined the FMS ratings of 132 sessions and the MISC ratings from 528 sessions with at least two ratings within each session. We analysed the difference in rated FMS or MISC class during consecutive ratings (i.e., transitions). We then first determined the number of observed transitions between two classes, and subsequently calculated the proportion of cases in which the rating after a certain class decreased (contradictive of a monotonic increase).

Table 1: The Motion Illness Symptoms Classification (MISC, Bos et al., 2005).

Class description		MISC
No problems		0
Some discomfort, but no specific symptoms		1
Dizziness, cold/warm, yawning, headache, tiredness, sweating, stomach/throat awareness, burping, blurred vision, salivation, ... but no nausea	vague	2
	little	3
	rather	4
	severe	5
Nausea	little	6
	rather	7
	severe	8
	retching	9
Vomiting		10

Part II. The development of unpleasantness during symptom progression

We collected information on how unpleasantness corresponds with each of the MISC classes to assess the development of unpleasantness during motion sickness symptom progression. To that end, subjects performed a psychophysical rating task before and/or after the last motion sickness session in Exp 6-7 (see Table 2).

We asked subjects in Exp 6 to perform a magnitude estimation (MAG) task, in which we asked them to draw lines which lengths represented the level of unpleasantness they associated with each MISC class description (1 to 10). These drawings were made relative to a 10.5 cm reference line, which represented the unpleasantness for MISC 6 (i.e., MAG₆). To investigate whether the choice of reference was relevant, we let subjects perform these MAG ratings using MISC 4 as a reference in Exp 7 as well (i.e., MAG₄). To investigate whether the choice of task was relevant, we also added a two-alternative forced choice (2AFC) in Exp 7. We then asked subjects to compare 45 pairs of MISC class descriptions (1 to 10) and to choose which of the two symptoms they thought was most unpleasant. For all of these tasks, we only presented the class descriptions, without their corresponding class numbers. Note that these tasks were indirect comparisons of unpleasantness and symptomatology in which subjects needed to imagine how they would feel when experiencing the symptom. Therefore, subjects performed one additional measure directly after completion of each motion sickness session in Exp 6-7. In this task, we asked subjects to indicate their unpleasantness experienced during the session on a 12 cm visual analogue scale (VAS) with endpoints “very unpleasant” to “very pleasant”. We compared this VAS rating to the highest rated MISC class during that session to allow for a more direct comparison of unpleasantness and symptom progression.

To compare the MAG with the 2AFC task, we normalised all ratings as follows. For the MAG task, we first measured all drawn line lengths (L) and subsequently determined the normalised ratings for each subject using their shortest and longest drawn line: $MAG = (L - L_{min}) / (L_{max} - L_{min})$. For the 2AFC task, we first counted the number of times each MISC class was rated the most unpleasant (C) and subsequently determined the normalised ratings for each subject using their minimum and maximum counts: $2AFC = (C - C_{min}) / (C_{max} - C_{min})$. For the VAS task, we first measured the distance up to the mark that each subject had drawn and subsequently determined an individual normalised rating by dividing this distance by the total line length. To promote a comparison between the unpleasantness rated using the FMS and the unpleasantness rated using the psychophysical tasks, we rescaled the FMS (further referred to as FMS') to values between 0 and 1.

Table 2: Overview of the used rating tasks and sample sizes.

Task	Exp	When	<i>n</i>
FMS	1-3	At 2-minute intervals during sessions	58
MISC	4-7	At 2- to 5-minute intervals during sessions	148
MAG ₆	6	Before the first and after the last session	30
MAG ₄	7	Counterbalanced before the first or after the last session	79
2AFC	7	Counterbalanced before the first or after the last session	83
VAS	6-7	After each session	107

Results

Part I. The temporal development of unpleasantness and symptomatology

The percentage and uniformity of decreases within the transitions of consecutive ratings on the FMS' and MISC will tell us whether these measures increase monotonically with the progression of motion sickness over time. Frequent and nonuniform decreases across classes then indicate the presence of a non-monotonic relationship. For unpleasantness, decreases in FMS' ratings were relatively frequent and non-uniformly distributed (Figure 1a) compared to the decreases in MISC ratings for symptomatology (Figure 1b). These results thus suggest that unpleasantness increases non-monotonically with time, whilst symptoms manifest in a fixed order over time.

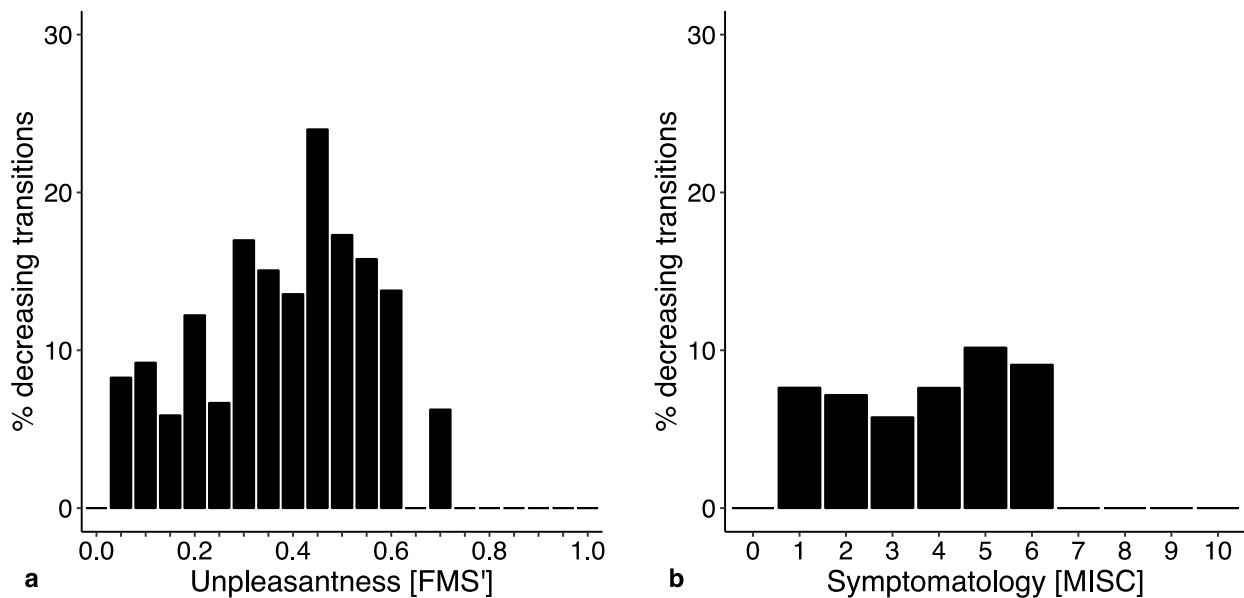


Figure 1: Overview of the percentage of decreasing transitions in consecutive ratings during ongoing motion stimulation using the FMS' (a) and MISC (b). Whereas the decreases for the MISC are uniformly distributed, the more frequent decreases for the FMS' peak in the central area of the scale, suggesting a non-monotonic increase of unpleasantness with time.

Part II. The development of unpleasantness during symptom progression

Median normalized values of the four psychophysical rating tasks (MAG₆, MAG₄, 2AFC, and VAS) demonstrate the development of unpleasantness with symptom progression in Figure 2. All ratings provided the same pattern of results: there is a positive correlation between unpleasantness and symptom progression, with a clear anomaly at MISC 6. This symptom, "feeling a little nauseated", systematically corresponded to feeling better compared to the preceding pre-nausea symptoms (MISC 5).

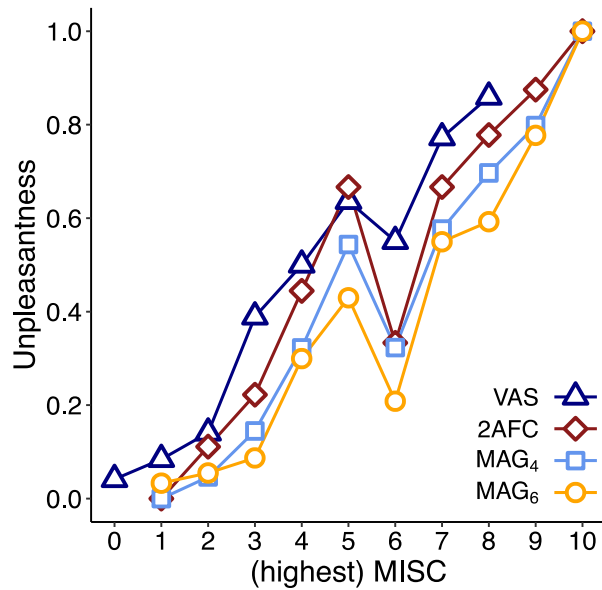


Figure 2: The unpleasantness associated or experienced with the MISC classes rated using magnitude estimations with MISC 6 (MAG₆) or MISC 4 as a reference (MAG₄), a two-alternative forced choice task (2AFC), or a visual analogue scale (VAS).

Discussion

To facilitate research on mitigating motion sickness, we focused on the question of how to unambiguously measure motion sickness progression using numerical self-report rating scales. When investigating the transitions between consecutive ratings given on an unpleasantness or symptomatology scale during ongoing motion stimulation, we observed that decreases in unpleasantness ratings occurred more frequently and peaked in the central area of the scale compared to symptomatology ratings. Based on those results, we suggested in Part I that symptoms manifest in a fixed order over time during ongoing motion stimulation, whilst unpleasantness increases non-monotonically. This interpretation is in accordance with the results of Part II, where we observed that later manifesting symptoms were generally judged as more unpleasant, apart from a clear exception at the onset of nausea. In four comparisons of a psychophysical task, nausea onset corresponded to feeling better compared to any other of the preceding pre-nausea symptoms.

Our results indicate that unpleasantness and symptomatology are positively correlated, but that there is an interval of relief at the onset of nausea. Because of this anomaly at nausea onset, we believe that caution is needed when comparing studies that have used the two different types of scales as ratings on these scales cannot one-to-one be compared in terms of motion sickness progression level. Rating symptomatology may be more relevant when it is important to prevent cleaning up the mess from vomiting, for example in car driving. Rating unpleasantness may be telling more about the (commercial) attractiveness of, for example, playing a game using virtual reality goggles, one game possibly evoking less unpleasantness than another. However, it is important to realize that rating how bad someone feels does not give an answer to the question how close someone is to the point of vomiting. We conclude that unpleasantness and symptomatology are non-equivalent constructs in the quantification of motion sickness progression and cover different aspects within the (dis)comfort spectrum.

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