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A Questionnaire for the Assessment of the Multiple Dimensions of Motion Sickness

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Abstract

Background—A limited number of attempts have been made to develop a questionnaire that assesses the experience of motion sickness. Further, many available questionnaires quantify motion sickness as a unidimensional construct

Method—Exploratory and confirmatory factor analyses of motion sickness descriptors were used to derive and verify four dimensions of motion sickness, which were defined as gastrointestinal, central, peripheral, and sopite-related. These dimensions of motion sickness were then used to construct a motion sickness assessment questionnaire (MSAQ) that was administered to individuals who were exposed to a rotating optokinetic drum.

Results—Total scores from the MSAQ correlated strongly with overall scores from the Pensacola Diagnostic index ($r = 0.81$, $p < 0.001$) and the Nausea Profile ($r = 0.92$, $p < 0.001$).

Conclusions—The MSAQ is a valid instrument for the assessment of motion sickness. In addition, the MSAQ may be used to assess motion sickness as a multidimensional rather than unidimensional construct

Keywords

factor analysis; motion sickness; questionnaire

Motion sickness is an aversive behavioral state that affects several psychophysiological response systems. Because multiple response systems may be activated by real or apparent motion, an individual is likely referring to a complex set of symptoms when she or he uses the term “motion sick”. Moreover, there are individual differences in the extent to which particular motion sickness symptoms (e.g., nausea vs. dizziness) are experienced; and different contexts that cause motion sickness (e.g., visual simulators vs. vehicles) may elicit more or less of a particular symptom. In contrast to the many contributions to the development of a questionnaire that predicts overall susceptibility to motion sickness

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(1,4,6,9,10,12,13,16,18), there have been fewer contributions to the development of a questionnaire that assesses the experience of motion sickness across a broad range of contexts. The most widely used questionnaire for the assessment of motion sickness is the Pensacola Diagnostic Index (PDI; 8). Other questionnaires for assessing motion sickness include a peer evaluation questionnaire (5), and the Pensacola Motion Sickness Questionnaire (MSQ; 11). There may be several limitations, however, to each of these questionnaires (13,15).

Although the PDI has long been used by many investigators, one limitation of this index is that it yields a single score that depends on the composite magnitude of the following symptoms: nausea, dizziness, headache, warmth, sweating, and drowsiness. These univariate PDI scores imply that motion sickness is a construct that varies along a single continuum, ranging from a slight to severe experience. Alternatively, motion sickness may be better quantified as a multidimensional construct with several symptom components. Such a multidimensional approach was recently employed by Kennedy et al. (14), who used a factor-analytic procedure to develop a questionnaire that assesses the occulomotor (eyestrain, difficulty focusing, blurred vision, headache), disorientation (dizziness, vertigo), and nausea (nausea, stomach awareness, increased salivation, burping) dimensions of simulator sickness. A similar multidimensional approach was used by Muth et al. (17), who suggested that nausea is not a single symptom, but rather a syndrome comprised of at least three dimensions: gastrointestinal distress (sick, queasy, ill, stomach awareness/discomfort, vomiting), somatic distress (shaky, lightheaded, sweaty, tired/fatigued, weak, warmth), and emotional distress (upset, worried, hopeless, panicked, nervous, scared/afraid). The primary advantage of these multidimensional approaches is that the syndrome under study may be more accurately assessed in terms of its component parts. In contrast, a single score from the PDI or MSQ could be based on a number of different symptom combinations, which might vary between susceptible individuals and evocative contexts. Therefore, motion sickness may be more appropriately quantified as a multidimensional syndrome rather than a univariate symptom, and more appropriately analyzed via a questionnaire that provides a score for each of its dimensions

One possible dimension of motion sickness that may not be accurately assessed by current questionnaires is the sopite syndrome (15). Graybiel and Knepton (7) originally suggested that sopite-related symptoms include drowsiness, yawning, and disengagement from the environment; however, symptoms of negative affect have also been suggested to reflect sopite (7,15). To date, symptoms of negative affect have not been included in motion sickness questionnaires such as the PDI and MSQ. Thus, another limitation of motion sickness questionnaires such as the PDI and MSQ is that they may provide a restricted account of the occurrence of sopite-related symptoms.

Because motion sickness may be more appropriately viewed as a multidimensional construct, the first objective of the present study was to identify the different components of motion sickness using exploratory and confirmatory factor analyses The second objective was to develop a motion sickness questionnaire that assesses these multiple dimensions. The final objective was to assess the validity of the developed questionnaire.

Phase 1: Generation of Motion Sickness Symptoms

METHOD

Participants—There were 67 students (44 female, 23 male; median age 21) at The Pennsylvania State University who provided informed consent and participated for course credit

Procedure—In the first phase of the present study, participants recalled any context in which they were motion sick and generated 10 adjectives other than “motion sick” that described their experience. Participants were instructed to rank these adjectives from the most to the least descriptive of their experience. The adjectives were then scored such that those descriptors that were ranked 1st received ten points, those ranked 2nd received nine points, those ranked 3rd received eight points, etc., until 10th-ranked adjectives were assigned one point. Points for similar descriptors were then summed across participants.

RESULTS

A list of 87 adjectives was generated. The adjectives were examined independently by three reviewers to determine if any adjectives had similar connotations. Adjectives that all reviewers agreed had a similar meaning were combined. Combining adjectives with similar meanings yielded a final list of 71 items. The 34 top-ranked items were included in a questionnaire that was distributed to participants in the second phase of the study.

Phase 2: Identification of Motion Sickness Dimensions

METHOD

Participants—There were 747 students (448 female, 302 male; median age 19) at The Pennsylvania State University who provided informed consent and participated for course credit.

Procedure—In the 2nd phase of the study, the 34 descriptors from Phase 1 were distributed to participants who rated how accurately each of the 34 items described their experience of motion sickness Participants rated the items by using a 4-point likert-type scale (0 = not at all, 1 =slightly, 2 = moderately, and 3 = very) to determine how well each descriptor completed the following sentence: “When I am motion sick, I feel _____.” Descriptors that: (a) a minimum of 50% of the participants did not rate as at least slightly descriptive of their experience during motion sickness, or (b) were considered ambiguous with regard to their meaning, were dropped from the list prior to factor analysis. Excluded items consisted of the following: butterflies, confused, drunk, disgusted, shaky, gross, need to lie down, claustrophobic, woozy, scared, watering mouth, uncomfortable, weak, headache.

RESULTS

Symptom ratings were submitted to a principal axis factor (PAF) analysis with a Promax rotation to evaluate the potential dimensions of motion sickness. The scree plot suggested an initial three-factor solution; however, four-, five-, and six-factor solutions were also obtained and evaluated. Examination of the different factor loadings for each solution suggested

that the four-factor solution provided the most straightforward interpretation of symptom inclusion for each factor. These four factors were labeled as gastrointestinal, central, peripheral, and sopite-related dimensions of motion sickness. Communality estimates for each motion sickness descriptor are presented in Table I. Table II displays the rotated-factor loading for each descriptor and Table III shows the interfactor correlations. The percentage of total variance of symptom ratings explained by the gastrointestinal, central, peripheral, and sopite-related factors were 38.09%, 9.79%, 4.18%, and 2.83%, respectively.

Phase 3: Confirmation of Motion Sickness Factor Structure

METHOD

Participants—There were 310 students (172 female, 138 male; median age 19) at The Pennsylvania State University who provided informed consent and participated for course credit.

Procedure—In the 3rd phase of the present study, we attempted to replicate the 4-factor structure of motion sickness obtained in Phase 2. To this end, the 20 items retained in Phase 2 were re-distributed to a new group of participants. Although the item “drowsy” was not generated by participants in Phase 1, this item was added to the present list because it is a primary symptom of the PDI. All other symptoms from the PDI were generated by participants in Phase 1. As in Phase 2, participants rated how accurately each of the items described their experience of motion sickness using a 4 point Likert-type scale. These ratings were submitted to a maximum likelihood confirmatory factor analysis using the EQS program (2).

RESULTS

The goodness-of-flt of symptom ratings to a four-factor model was evaluated using the comparative fit index (CFI; 3) and the average root-mean square-residual (RMSR). CFI values are restricted to a range from zero to one, where values closer to one reflect a greater fit to a given factor structure. RMSRs estimate the average size of the difference between observed correlations among symptom ratings and those correlations predicted by a given factor model. RMSRs near zero reflect a better fit to a hypothesized factor structure. In the present study, the four-factor model of motion sickness accounted for the dimensionality of symptom ratings moderately well, CFI = 0.893; RMSR = 0.107. A three-factor structure was also evaluated. Specifically, the three-factor solution derived from the exploratory analysis in Phase 2 was used as a comparison for the four-factor solution. The 3-factor solution from Phase 2 essentially combined the peripheral and sopite-related factors into a single dimension; however, a confirmatory analysis of this 3-factor structure yielded a CFI = 0.685. Based on these data, a questionnaire was developed for the multidimensional assessment of motion sickness (Motion Sickness Assessment Questionnaire; MSAQ). Prior to the finalization of the questionnaire, an attempt was made to reduce the total number of items by removing those symptoms which were highly correlated with other items and which appeared to connote similar phenomena. For example, “upset stomach,” “stomach ache,” and “sick to stomach” all correlated strongly (rs > 0.70) and likely refer to the same

symptom; thus, only “sick to stomach” was retained for the final questionnaire. The MSAQ along with its scoring criteria are presented in the Appendix.

Phase 4: Validity of the Developed Questionnaire

METHOD

Participants—There were 21 students (13 female, 8 male; median age: 19) at The Pennsylvania State University who provided informed consent and participated for course credit. Participants were screened to exclude those with a history of neurological, cardiovascular, and gastrointestinal disorders. Participants were asked to refrain from consuming caffeine and alcoholic beverages, and abstain from smoking cigarettes, and fast for a minimum of 3 h prior to participating in the experiment.

Procedure—A rotating optokinetic drum was used to elicit motion sickness symptoms. The drum is a large cylinder 91.5 cm in height and 76 cm in diameter. Alternating 3.8 cm (5.7°) black and 6.2 cm (9.3°) white vertical stripes line the interior of the drum. The participants were seated within the drum as it rotated about them at a revolution speed of 10 rotations per minute. Subjective symptoms of motion sickness and nausea were obtained using the PDI, NP, and the questionnaire developed in Phase 3 Scores from the MSAQ were correlated with scores from the PDI and NP to evaluate the validity of the developed questionnaire as an instrument for the assessment of motion sickness.

RESULTS

Overall scores from the developed questionnaire correlated strongly with overall scores from the PDI ($r = 0.81$, $p < 0.001$) and the NP ($r = 0.92$, $p < 0.001$). These data provide evidence that the MASQ is a valid instrument for the assessment of motion sickness. Scores from the subscales of the MSAQ and the NP were also correlated. Specifically, scores from the gastrointestinal subscales of the NP and MSAQ were highly correlated, $r = 0.95$, $p < 0.001$. Scores from the somatic dimension of the NP correlated with the central ($r = 0.80$, $p < 0.001$), peripheral ($r = 0.76$, $p < 0.001$), and sopite-related ($r = 0.83$, $p < 0.001$) dimensions of the MSAQ. These correlations suggest that the generalized nausea syndrome may have an undifferentiated somatic component, whereas motion sickness may have a differentiated somatic component comprised of central-, peripheral-, and sopite-related clusters of symptoms. Indeed, symptoms from the somatic dimension of the NP (e.g., dizzy, hot/warm, tired/fatigued), which are also included in the MSAQ, loaded onto distinct factors in Phases 2 and 3 of the present study, whereas these symptoms loaded onto a single somatic factor in the study by Muth et al. (17).

DISCUSSION

In the present study, exploratory and confirmatory factor analyses were used to differentiate motion sickness symptoms along four dimensions: gastrointestinal, central, peripheral, and sopite-related. A questionnaire was subsequently developed to assess these 4 dimensions of motion sickness. Total scores from the developed questionnaire correlated strongly with scores from the PDI and NP, indicating that it is a valid instrument for the overall assessment of motion sickness. Thus, the MSAQ may be used to assess both the overall experience

of motion sickness (using total scores) and the four distinct dimensions of motion sickness identified (using subscale scores).

The items included in the developed questionnaire overlap considerably with those included in existing motion sickness questionnaires. Because the items included in this instrument were generated independently by non-experts, the present study provides support for the argument that the items included in these existing questionnaires are valid descriptors of motion sickness in a general population. The primary difference between the new questionnaire and earlier instruments relates to the way in which motion sickness is quantified (i.e., uni- vs. multi-dimensional). In addition, the new instrument includes a greater number of sopite-related items. Nonetheless, this questionnaire does not diverge greatly from previous questionnaires, which may allow researchers to make comparisons between results obtained with these different motion-sickness inventories.

One limitation of the present study is that the participants who generated and rated symptoms may have experienced motion sickness in a relatively narrow range of contexts. Thus, it is probable that the questionnaire developed based on their responses may need to be modified in order to accurately reflect the multiple dimensions of motion sickness across different types of motion environments. It is likely, however, that the motion sickness history of our sample is representative of the general population; therefore, only specialized contexts would be expected to require modification of the questionnaire. Future investigations should examine the extent to which specialized questionnaires, such as the SSQ, overlap with the newly developed MSAQ. Combining items from these differently structured questionnaires could lead to a single instrument which could be used to assess motion sickness regardless of the stimulus.

To summarize, it is our contention that motion sickness should be viewed as a multidimensional construct with gastrointestinal, central, peripheral, and sopite-related components. These distinguishable dimensions may be differentially responsive to various types of real or apparent motion. Furthermore, individuals may experience differing degrees of activation along each of these dimensions in the same type of motion environment. The new questionnaire developed here should allow researchers to quantify individual experiences of the identified symptom dimensions across a broad range of contexts.

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TABLE I

COMMUNALITY ESTIMATES FOR DESCRIPTORS FROM PHASE 2

Descriptor	Communality
May vomit	0.661
Sick to stomach	0.807
Nauseated	0.735
Queasy	0.680
Upset Stomach	0.595
Sick/III	0.640
Stomach ache	0.497
Dizzy	0.720
Spinning	0.548
Faint-like	0.573
Lightheaded	0.495
Blurred Vision	0.372
Head Rush	0.313
Disoriented	0.428
Sweaty	0.752
Clammy/Cold Sweat	0.392
Hot/Warm	0.465
Annoyed/Irritated	0.434
Tired/Fatigued	0.477
Uneasy	0.381

TABLE II

ROTATED FACTOR LOADINGS FROM PHASE 2

Descriptor	Factor 1 (GI)	Factor 2 (C)	Factor 3 (P)	Factor 4 (SR)
Sick to stomach	0.961			
Nauseated	0.882			
Queasy	0.812			
May vomit	0.805			
Upset Stomach	0.756			
Sick/III	0.722			
Stomach ache	0.707			
Dizzy		0.924		
Spinning		0.758		
Faint-like		0.691		
Lightheaded		0.628		
Disoriented		0.592		
Blurred Vision		0.573		
Head Rush		0.566		
Sweaty			0.911	
Clammy/Cold Sweat			0.533	
Hot/Warm			0.522	
Annoyed/Irritated				0.648
Tired/Fatigued				0.536
Uneasy				0.325

Note. GI: Gastrointestinal; C: Central; P: Peripheral; SR: Sopite-related.

TABLE III

INTER-FACTOR CORRELATIONS FROM PHASE 2

	Factor 1	Factor 2	Factor 3	Factor 4
Factor 1 (Gastrointestinal)	—	0.520	0.536	0.455
Factor 2 (Central)	—	—	0.528	0.513
Factor 3 (Peripheral)	—	—	—	0.467
Factor 4 (Sopite-related)	—	—	—	—

APPENDIX A

MOTION SICKNESS ASSESSMENT QUESTIONNAIRE (MSAQ).

Instructions. **Using the scale below, please rate how accurately the following statements describe your experience**

Not at all Severely

1——2——3——4——5——6——7——8——9

1. I felt sick to my stomach (G)	9. I felt disoriented (C)
2. I felt faint-like (C)	10. I felt tired/fatigued (S)
3. I felt annoyed/irritated (S)	11. I felt nauseated (G)
4. I felt sweaty (P)	12. I felt hot/warm (P)
5. I felt queasy (G)	13. I felt dizzy (C)
6. I felt lightheaded (C)	14. I felt like I was spinning (C)
7. I felt drowsy (S)	15. I felt as if I may vomit (G)
8. I felt clammy/cold sweat (P)	16. I felt uneasy (S)

Note. G; Gastrointestinal; C: Central; P: Peripheral; SR; Sopite-related.

The overall motion sickness score is obtained by calculating the percentage of total points scored: (sum of points from all items/144) × 100. Subscale scores are obtained by calculating the percent of points scored within each factor: (sum of gastrointestinal items/36) × 100; (sum of central items/45) × 100; (sum of peripheral items/27) × 100; (sum of sopite-related items/36) × 100.