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IDENTIFICATION OF MOTION SICK INDIVIDUALS: A CLASSIFICATION METHOD ACCOUNTING FOR NON-SPECIFICITY

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The identification of "motion sick" individuals is a challenge because of "misreported" motion sickness, i.e. symptoms developed from reasons unrelated to the nauseogenic stimulus. A behavioral method is proposed to address the confounding effect of the non-specificity associated with motion sickness and sopite syndrome symptoms. The proposed method is based on a within-subject approach with three classification groups; symptoms occurring in static conditions are used as normative to classify whether an individual is motion sick in motion conditions. Participants without any symptoms in both static and motion conditions are classified as "Asymptomatic." If symptom severity in motion conditions is greater than the static, the participant is identified as motion sick (Symptomatic). If symptom severity in motion is less than or equal to the static condition, it is considered that the individual is reporting symptoms not attributable to motion sickness and is excluded from analysis. As part of a broader study, the proposed method was applied in a laboratory experiment and the corresponding results are compared against two alternative methods. The utility and problems of the proposed method are discussed.

INTRODUCTION

With symptoms ranging from headache to emesis (Money, 1970), motion sickness is a stressor with debilitating effects on human performance (Hettinger, Kennedy, & McCauley, 1990). Furthermore, Graybiel and Knepton (1976) defined the "sopite syndrome" to describe a symptom-complex centering on drowsiness and lethargy related to motion sickness. There is a long discussion about how and when an individual should be defined as suffering of motion sickness (e.g., Birren, 1949). Motion sickness severity has been objectively assessed by measuring psychophysiological metrics (Lentz, 1984) and subjectively by observer rating scales or self-reports. The observer, typically a researcher, logs the occurrence and rates the observed symptoms. Alternatively, the subject verbally reports his or her state of well-being and internal experiences. However different, both subjective and objective symptoms and signs of motion sickness are non-specific (for example Lang, Sarna, & Shaker, 1999; Wiker & Pepper, 1978), i.e. they also can be observed in the absence of a nauseogenic stimulus, because of stress, pathology, or other reasons. In general, subjective ratings of well-being are considered "the single most valuable source of information about the subject's condition" to assess motion sickness severity and symptoms (Reason & Brand, 1975, p. 82). Yet, the utility of self-reporting questionnaires is not without issues of concern. First, an individual may not accurately determine the nature and intensity of symptoms. Second, individuals may be biased in reporting their state, reluctant to report their full range of motion sickness severity, or they may overstate it.

The non-specificity of motion sickness symptoms may confound research findings. The investigation of severe motion sickness with healthy individuals in the absence of underlying pathological factors partially alleviated the problem of non-specificity; symptoms like nausea, dizziness, or cold sweating, could be fairly attributable to motion sickness. The problem of non-specificity is more pronounced when we focus on mild motion sickness and sopite syndrome wherein malaise often is experienced as fatigue, drowsiness, feeling annoyed or irritated, etc. The methodological challenge is to classify participants based on their symptom severity scores in such a way to minimize "misreported" motion sickness, hence the development of minor symptoms, either because of reasons other than motion sickness, or in the absence of a nauseogenic stimulus.

There are two basic groups of scales, either a single-value scale of overall motion sickness severity, or a list of symptoms combined with a severity scale for each, such as the Pensacola Motion Sickness Questionnaire - MSQ (e.g., Kennedy, Lane, Berbaum, & Lilienthal, 1993) In general, the minimum level refers to the absence of motion sickness/ symptoms, whereas all levels thereafter denote a severity from minimal to severe (e.g., Bos, MacKinnon, & Patterson, 2005; Donohew & Griffin, 2004). To our surprise, few efforts have systematically approached the issue of the non-specificity associated with motion sickness symptoms. Miller and Graybiel's efforts focused explicitly on the classification problem (Graybiel, Wood, Miller, & Cramer, 1968; Miller & Graybiel, 1974), whereas the second approach was based on a revised version of Motion Sickness Assessment Questionnaire - MSAQ (Muth, 2009).

The most widely used tool in motion sickness research is the Pensacola Diagnostic Rating Scale, in its original or revised forms (Kennedy, Tolhurst, & Graybiel, 1965; Miller & Graybiel, 1970, 1974). The significance of this line of research is that it provided criteria for clinical evaluation of different levels of severity of motion sickness, and "end points" for severity levels far less severe than frank motion sickness. The severity of the symptoms is graded along a continuum scored in points (1 to 50) and broken down into five levels. Slight Malaise (M-I) ranged from 1 to 2 points, moderate malaise B (M-IIB) from 3 to 4 points, moderate malaise A (M-IIA) from 5 to 7 points, severe malaise (M-III) from 8 to 15 points, and frank sickness (FS) above 16 points. The investigation of the reliability of this scale showed the test-retest reliability of all endpoints, with the M-IIA and M-III endpoints demonstrably reliable. Given that the onset of malaise at M-I level was based on a single symptom, the researchers postulated that M-IIA might be the lowest malaise level that is of practical value for assessing susceptibility, and to avoid false indication of both low susceptibility or even insusceptibility (Miller & Graybiel, 1974). Later, the National Aeronautics and Space Administration (NASA) used the M-IIA (< 7 points) criterion to classify motion sickness severity into three levels: a) transient motion sickness with less than M-IIA severity, b) exacerbated or repetitive symptoms of motion sickness that are mission-impacting that exceed the M-IIA level (> 7 points), and c) unresolved/incapacitating motion sickness (NASA, 2007). Muth and colleagues evaluated motion sickness severity using a modified version of MSAQ (Muth, 2009). The severity of motion sickness associated symptoms was identified based on the maximum reported score for each participant. To distinguish between "negligible" and non-negligible motion sickness symptoms, the cut-off point was set at MSAQ being less or equal to 7 (maximum reported score), but no rationale was provided for this criterion. Other studies used the existence of at least one symptom as the criterion between symptomatic and asymptomatic individuals (e.g., Davis, Vanderploeg, Santy, Jennings, & Stewart, 1988).

Lastly, we should note two different approaches based ad-hoc dichotomization in "sick" and "well" participants. In the first, participants were divided post-experiment in those who terminated participation early, and those who completed the study. Given that the two groups were significantly different in motion sickness severity, analysis was based on the comparison of these ad-hoc groups (Dahlman, Sjörs, Lindstörm, Ledin, & Falkmer, 2009). Ad-hoc dichotomization in "sick" and "well" participants, based on self-reports, also has been used in studies investigating postural instability and motion sickness (Stoffregen & Smart, 1998). These approaches either used unambiguous post-treatment self-reports of motion sickness (e.g. "I need to stop, I feel horrible"), or participants were asked whether they were motion sick or not, and answered yes or no.

Although far from being thorough, this review identifies that few efforts have systematically approached, or explicitly focused on, the issue of non-specificity associated with motion sickness symptoms (Graybiel et al., 1968; Kennedy et al., 1993; Miller & Graybiel, 1974; Muth, 2009). However useful, these studies either address only the clinical perspective, or do not provide a rational for the classification criteria. Other studies are conceptually based on a dichotomy approach. The absence of any symptoms identifies an Asymptomatic/ Non-motion Sick individual, whereas even minimal severity of at least one symptom identifies a Symptomatic/ Motion Sick individual (for example, Bos et al., 2005; Donohew & Griffin, 2004). Therefore, these scales implied the logical distinction of the "no symptoms" level as opposed to other levels. Overall, there is no standardized method to classify individuals based on the severity of their symptoms. This review emphasizes what Reason and Brand noted more than 40 years ago, "…there is no single best way of assessing experimentally-induced motion sickness. The scheme adopted by any particular investigator will reflect his inclinations…, and will necessarily be governed by the nature of the investigation" (Reason & Brand, 1975, p. 82).

The objective of this work is to provide the rationale for a method to classify individuals in mild motion sickness conditions, and experimentally evaluate the proposed method. Specifically, a behavioral method is proposed based on a) using the symptoms occurring in static conditions as normative towards identifying the motion sickness groups in motion conditions, and b) a three-group classification scheme.

PROPOSED CLASSIFICATION METHOD

The proposed method is based on a within-subject approach with three classification groups; symptoms occurring in static conditions are used as normative to classify whether an individual is motion sick in motion conditions. Participants without any symptoms in both static and motion conditions are classified to be "Asymptomatic." We then compare each individual's severity of symptoms between motion and static conditions. If symptom severity in motion condition ($MS_{Mot.}$) is greater than the static, the participant is assumed to be motion sick and classified as "Symptomatic." If symptom severity in motion is less than or equal to the static condition, it is assumed that the individual is reporting symptoms that may not be attributable to motion sickness; in this case, the individual is classified as "Neutral." Table 1 is a 2-by-2 depiction of our approach.

Table 1 Classification based on the occurrence of symptoms

Motion condition	Static condition: No Symptoms	Static condition: Symptoms
No Symptoms	Asymptomatic	Asymptomatic
Symptoms	Symptomatic	Symptomatic if $MS_{Mot.} > MS_{Static}$ Neutral if $MS_{Mot.} \leq MS_{Static}$

METHODS

The proposed method was applied in a laboratory experiment as part of a broader study regarding the effect of mild motion sickness on multitasking cognitive performance (Matsangas & McCauley, 2013; Matsangas, McCauley, & Becker, 2014). The study protocol was approved in advance by the Institutional Review Board of the Naval Postgraduate School (NPS). Recruited from the pool of NPS students, faculty, and staff, volunteers provided written informed consent. All participants (45 males, 6 females; age M=35.4 yrs, SD=5.74 yrs) were screened for illnesses or other issues that could affect their state. During the experiment, participants performed the SYNWIN battery (Elsmore, 1994) projected on a head mounted display (eMagin Z800 3DVisor) without view of the environment. The ASE Model 500-3 motion seat (Aeronautical Systems Engineering, Odessa, Florida) produced the mild nauseogenic stimulus of 0.167 Hz sinusoidal motion with ±2 inches z-axis displacement. In the y and x axes, the motion was a ±15 degrees roll and pitch correspondingly. The selection of the motion frequency was based on the Human Factors Research, Inc. (HFR) experiments, which showed that the maximum motion sickness incidence occurs at a frequency of 0.167 Hz (McCauley, Royal, Wylie, O'Hanlon, & Mackie, 1976; O'Hanlon & McCauley, 1974). Occurrence and severity of symptoms were assessed by the MSAQ (Gianaros, Muth, Mordkoff, Levine, & Stern, 2001). The MSAQ includes 16 symptoms in four groups (Gastrointestinal, Central, Peripheral, and Sopite-related). The group scores' sum is the Overall motion sickness score.

Participants were assigned to one of three groups: “A” for the sequence “motion – no motion,” “B” for the sequence “no motion – motion,” whereas participants in “C” did not experience motion in either session. The classification method is used for participants who experienced motion, groups A and B. Group C served as a control group. Each individual participated in two 1-hour experimental sessions (ES) with an 7-day inter-session interval. Each ES consisted of six 10-minute SYNWIN blocks. Without prior experience with SYNWIN, participants performed SYNWIN wearing a head mounted display, while seated on a moving platform in a dark room. The motion stimulus was presented during the last four 10-minute blocks. MSAQ responses were provided before the test commenced, and at the end of each 10-minute block.

RESULTS

Analysis is based on 408 10-minute blocks of data from 51 participants; 252 blocks in static conditions, and 156 blocks in motion conditions. As expected, severity of symptoms in motion was significantly increased compared to static conditions (static MSAQ Total M=11.4, SD=0.809, MD=11.1; motion MSAQ Total M=14.4, SD=6.35, MD=12.2; paired t-test, t(38)=-3.08, p=0.004). No significant differences in the severity of reported symptoms was identified between the two static experimental sessions in group C (paired t-test, t(11)=-0.899, p=0.388). MSAQ scores by motion condition are shown in Figure 1. Vertical bars denoted the standard error of the mean.

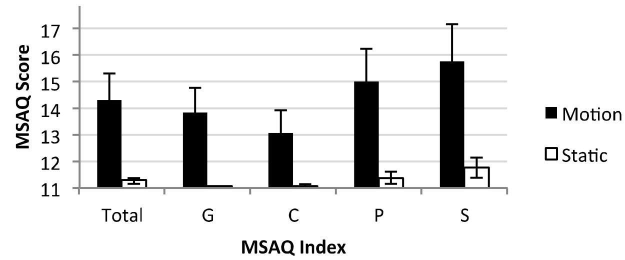

Figure 1 MSAQ scores by motion condition

Fifteen participants (29%) reported at least one symptom in static condition, whereas 16 participants (41%) reported at least one symptom in motion conditions. The occurrence of symptoms in static and motion conditions is shown in Table 2. The first number refers to the number of participants reporting the corresponding symptoms. The percentage in brackets refers to the number of 10-minute blocks that the symptom was reported from the corresponding participants. The absolute number in parentheses refers to the maximum reported severity. Therefore, “Dizzy 10 (50% - 3)” means that 10 participants felt dizzy in 50% of their 10-minute blocks; the maximum reported severity of feeling dizzy was 3.

Six out of the 16 symptoms included in the MSAQ were reported in static conditions. The most frequent symptom was “feeling tired/ fatigued,” followed by “feeling hot/warm, sweaty,” “annoyed/irritated,” “lightheaded,” and “uneasy.” Gastrointestinal symptoms such as nausea were not reported in static conditions. In contrast, all symptoms were reported in motion conditions.

Table 2 Reported symptoms in static condition

	Static Condition					Motion Condition		
MSAQ symptoms	All (N=51)	B-1 (n=19)	A-2 (n=20)	C-1 (n=12)	C-2 (n=12)	All (N=39)	B-1 (n=19)	A-2 (n=20)
Sick to stomach (G)						8 (41% - 6)	3	5
Queasy (G)						13 (62% - 8)	5	8
Nauseated (G)						10 (63% - 8)	5	5
As if I may vomit (G)						4 (44% - 8)	3	1
Disoriented (C)						8 (59% - 7)	5	3
Dizzy (C)						5 (47% - 8)	5	3
Like spinning (C)						3 (42% - 8)	2	1
Faint-like (C)						3 (58% - 8)	2	1
Drowsy (S)						5 (55% - 8)	3	2
Clammy/ cold sweat (P)						6 (67% - 8)	4	2
Uneasy (S)	1 (25% - 2)			1		15 (61% - 8)	9	6
Lightheaded (C)	1 (100% - 2)		1			6 (71% - 8)	4	2
Annoyed/ irritated (S)	2 (63% - 3)		2			11 (68% - 8)	8	3
Sweaty (P)	5 (75% - 4)		2	2	3	12 (67% - 8)	7	5
Hot/ warm (P)	5 (71% - 4)	1	2	2	1	12 (63% - 8)	7	5
Tired/ fatigued (S)	9 (86% - 4)	4	3	2	2	15 (60% - 7)	9	6

Based on group C (n=12) with the two static sessions, we assessed the idiosyncratic attribute of reporting symptoms, i.e. the personal trend to either report or not report symptoms and how this trend changed between the experimental sessions. Eleven participants in C group consistently reported (n=3) or did not report (n=8) symptoms in both experimental sessions, whereas one participant reported symptoms only in the first session. Although the limited number of individuals in group C does not allow for an analytical approach, these results provide evidence that reporting symptoms in both sessions has a significant individual component.

The implementation of the proposed method led to the Asymptomatic group (n=15), the Neutral group (n=3), and the Symptomatic group (n=21). Participants classified as "Neutral" were excluded from analysis, given that their reported symptoms occurred even in the absence of a nauseogenic stimulus. The outcome of the proposed method was then compared against two alternative methods. The first method, "Alternative 1", is based on a binary logic; participants with at least one reported symptom in motion conditions are classified as "Symptomatic", whereas the rest are "Asymptomatic." The second alternative method, "Alternative 2", is based on an arbitrary criterion of severity; participants whose symptom severity exceeds the 25th percentile in motion conditions are classified as "Symptomatic." Participants with no symptoms are "Asymptomatic", whereas the remaining participants, up to the 25th percentile, are excluded from analysis. The classification results of the three methods are demonstrated in Table 3. In our experiment, the 25th percentile was identified at MSAQ Total=12.9. Alternative method 1 did not have

Table 3 Classification results (number of participants)

Method	Participants groups		
	Asymptomatic	Excluded	Symptomatic
Proposed	15	3	21
Alternative 1	16	0	23
Alternative 2	16	8	15

The excluded participants in the proposed method reported feeling sweaty, hot/warm, and tired/fatigued. However, excluded participants in the second alternative method reported feeling sweaty, hot/warm, and tired/fatigued, as well as sick to stomach, queasy, nauseated, uneasy, dizzy, lightheaded, and annoyed irritated. Results based on analytical comparisons of symptom occurrence cannot be provided because of the small number of participants. However, it is notable that excluded participants in the second alternative report symptoms more clearly associated with motion sickness (e.g. feeling nauseated, or sick to stomach).

DISCUSSION

This study emphasizes the caution needed when attributing occurring symptoms to motion sickness or soporific effects (Kiniorski et al., 2004; Lawson & Mead, 1998). Classifying individuals based on their motion sickness symptomatology is an inherent problem when addressing mild motion sickness. Symptoms known to be associated with motion sickness and sopite syndrome may be reported even without a nauseogenic stimulus. Therefore, from a research perspective, analysis of a dependent variable (e.g., performance) versus motion sickness scores will not address explicitly the effect of motion sickness, but will be confounded by symptoms emerged from performing the task itself, boredom, etc. Although far from being thorough, our review revealed that there is no standardized method to classify individuals based on the severity of their motion sickness symptoms. This study provides a classification method, which attempts to control for the potential problems of misclassification.

Our results show that the most frequently reported symptom in static conditions was "feeling tired/fatigued," followed by "feeling hot/ warm," "lightheaded," "sweaty," and "annoyed/ irritated." None of the gastrointestinal symptoms was reported. The reported symptoms are to be expected because of stress, boredom, general fatigue, etc. (Kennedy et al., 1993). In this study, the most frequent symptoms in motion conditions were "feeling tired/fatigued," "uneasy" and "queasy." The least frequent were "feeling like spinning" and "faint-like."

The utility of the proposed method is based on the following issues. First, it is built upon the behavioral characteristics reported by each individual. For groups A and B, the fact that each participant experienced both static and motion conditions increased the validity of the classification of whether this participant was motion sick or not. Second, the proposed method goes beyond identifying an arbitrary mathematical criterion. The classification of participants in three groups (Asymptomatic, Neutral, Symptomatic) and the exclusion of the "Neutral" participants from analysis provide a "safe" distance in severity scores between the Asymptomatic and Symptomatic participants. Third, the method is not focused on the absolute difference of motion sickness severity between the static and motion conditions, but merely on the sign of this difference. This approach overcomes the poor reliability of difference scores (Kennedy et al., 1993). In general, the survey tools that have been historically used for the assessment of motion sickness severity are ordinal, hence the actual value of the numbers in the scale and the distance between the numbers hold no intrinsic meaning (McDowell, 2006). In these cases, the psychometric literature notes that severity levels cannot be subtracted to derive a difference score (Merbitz, Morris, & Grip, 1989).

However, the behavioral basis for the proposed method is not without issues of concern. One problem is the situation where severity responses in both static and motion conditions are approximately the same, and the severity under motion is marginally larger. In this case, the individual will be classified as Symptomatic even though the difference could be attributed to chance. Therefore, the method may be sensitive to minor severity increases from static to motion condition. Further research could fill in this gap by identifying a "safety" difference between scores. Second, the need for two experimental sessions poses a challenge for the researcher. The individual should be in the same physiological state at the beginning of both sessions. Illnesses, different psychological state, sleepiness or fatigue, are some of the factors that may affect the responses provided by the participant (Kennedy et al., 1993).

The proposed method addresses to some extent the initial values problem, i.e. individuals may report some symptoms even before the commencement of the experiment. Some researchers exclude from participation individuals not being in their usual state of fitness in the beginning of the data collection (Kennedy et al., 1993). Although we used this screening process, the implementation of such an approach does not ensure that symptoms will not be reported before the beginning of the experiment. An initial report of symptoms may be associated with transient phenomena (for example, stress because of the participation in the test). All other factors being equal, such responses may change over time to more "normal" values, a regression-towards-the-mean trend (Barnett, van der Pols, & Dobson, 2005). One possible way of addressing this issue is to use a repeated measures approach and omit from analysis a number of initial measurements.

Overall, when combined with a pre-study health screening and exclusion of initial motion sickness measurements, the proposed method provides a useful and reliable approach to overcome some of the methodological problems associated with motion sickness research. We believe that the proposed method can be useful in laboratory studies when mild motion sickness and sopite syndrome effects are investigated. However, in experiments with time constraints, its application may be challenging because of the time needed to participate in the data collection.

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