Yawning as a Behavioral Marker of Mild Motion Sickness and Sopite Syndrome

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Yawning as a Behavioral Marker of Mild Motion Sickness and Sopite Syndrome

Panagiotis Matsangas and Michael E. McCauley

Introduction: Severe motion sickness is easily identifiable with sufferers showing obvious behavioral signs, including emesis (vomiting). Mild motion sickness and sopite syndrome lack such clear and objective behavioral markers. We postulate that yawning may have the potential to be used in operational settings as such a marker. This study assesses the utility of yawning as a behavioral marker for the identification of soporific effects by investigating the association between yawning and mild motion sickness/sopite syndrome in a controlled environment.

Methods: Using a randomized motion-counterbalanced design, we collected yawning and motion sickness data from 39 healthy individuals (34 men and 5 women, ages 27–59 yr) in static and motion conditions. Each individual participated in two 1-h sessions. Each session consisted of six 10-min blocks. Subjects performed a multitasking battery on a head mounted display while seated on the moving platform. The occurrence and severity of symptoms were assessed with the Motion Sickness Assessment Questionnaire (MSAQ). Results: Yawning occurred predominantly in the motion condition. All yawners in motion (N = 5) were symptomatic. Compared to nonyawners (MSAQ indices: Total = 14.0, Sopite = 15.0), subjects who yawned in motion demonstrated increased severity of motion sickness and soporific symptoms (MSAQ indices: Total = 17.2, Sopite = 22.4), and reduced multitasking cognitive performance (Composite score: nonyawners = 1348; yawners = 1145).

Discussion: These results provide evidence that yawning may be a viable behavioral marker to recognize the onset of soporific effects and their concomitant reduction in cognitive performance.

Keywords: yawning, mild motion sickness, sopite syndrome.

Severe motion sickness is easily identifiable. People under significant malaise stop working, vomit or show signs of, such as pallor. The problem is that mild motion sickness and sopite syndrome do not demonstrate such clear and observable behavioral markers. We postulate that yawning may have the potential to be used as such a marker.

Yawning is an involuntary and stereotyped behavior consisting of three phases, a long inspiration phase, the mouth's wide opening, and the final slow expiration (2). Yawning occurrence demonstrates an underlying circadian rhythmicity (1), and has been associated with sleepiness, drowsiness, and boredom (2). Research supports the hypothesis that yawning is associated with transitions in arousal levels (1). It appears that yawning is involved in maintenance of arousal, yet yawning frequency seems to be unrelated to prior sleep amount (1). Johnson and Jongkees (as cited in Baenninger (1)) suggested that yawning may be associated with arousal by regulating cerebral blood flow, and noted that the deafmutes with congenitally incomplete labyrinths are immune to yawning.

It has long been known that yawning is a common symptom associated with motion sickness, and is considered among the typical symptoms of sopite syndrome (8). The term "sopite syndrome" describes a symptom-complex centering on drowsiness and lethargy related to motion sickness (8). Symptoms associated with drowsiness are yawning, disinterest and disinclination to work, lack of participation in group activities, mood changes, sleep disturbances, and signs of mental depression.

The literature on motion sickness does not seem to contain any systematic efforts focusing on yawning per se. In general, earlier research does not extend beyond using yawning as one more symptom toward assessing motion sickness severity [for example, Bos et al. (3)]. Furthermore, existing research is merely based on post-session self-reports of yawning as part of questionnaires reporting motion sickness symptoms [for example, Joseph and Griffin (10)].

Our study is triggered by the operational consequences of soporific effects, which, we hypothesize, can be even greater than the more severe levels of motion sickness. The problem with mild motion sickness and sopite syndrome is that they are not easily distinguishable as problems concerning the person's well-being or their ability to perform assigned tasks. A mild form of motion sickness includes an uneasy feeling with a certain amount of lack of interest in the task being done (14). This phase is not characterized by any visible signs and people may not be aware of their state (11,14). Therefore, a systematic approach to soporific effects must include the investigation of ways to identify this phenomenon. Developing measures can be the first step to countering the effect of sopite syndrome in the operational environment (11,12).

For these reasons, this study has the objective to investigate the utility of yawning as a behavioral marker in the identification of soporific effects.

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YAWNING & MOTION SICKNESS—MATSANGAS & MCCAAULEY

METHODS

This work is part of a broader study regarding the effect of mild motion sickness and sopite syndrome on multitasking cognitive performance (12). The study protocol was approved in advance by the Institutional Review Board of Naval Postgraduate School (NPS). Each subject provided written informed consent before participating.

Subjects

Thirty nine healthy individuals were recruited from the pool of NPS students, faculty, and staff. All subjects (34 men, 5 women; age range 27–59 yr, mean = 35.2 yr, SD = 6.02) were screened before the beginning and during the study for illnesses or other issues that could affect their physiological state. Subjects were randomly assigned to two statistically equivalent groups, A (N = 20, motion in the first session, no motion in the second) or B (N = 19, no motion in the first session, motion in the second).

Equipment

The ASE Model 500-3 motion seat (Aeronautical Systems Engineering, Odessa, FL) produced the nauseogenic stimulus of 0.167 Hz sinusoidal motion with ± 2 inches z-axis displacement. In the x and y axes, the motion was a ±15° roll and pitch, correspondingly. In general, the overall severity of motion sickness was mild. Subjects performed the SYNWIN battery (TM Activity Research, Inc.), the Windows version of SynWork1 (5) simulating a work environment. It includes four component tasks presented simultaneously, a memory search task, an arithmetic problem task (the only self-paced task in the battery), and two monitor and react tasks (visual and auditory). The memory and the arithmetic tasks are cognitive, whereas the visual and auditory monitoring tasks are primarily sensory and perceptual. The single objective of performing SYNWIN is to obtain as many points as possible, and thereby increase the composite score displayed in the middle of the screen. SYNWIN was projected on a head mounted display (eMagin Z800 3DVisor, 40° diagonal field of view, two displays with 4:3 aspect ratio, 800 x 600 pixels resolution per display).

Procedure

Each individual participated in two 1-h data collection sessions with a 7-d intersession interval. Each session consisted of six 10-min blocks. Subjects performed SYNWIN while seated on a moving platform in a dark room without visual input from the external environment. These settings excluded a possible yawning behavior contagion bias between the subjects and the researcher located in the same room (13). We used a randomized design, counterbalanced in the order of motion stimulus. Motion was presented during the last four 10-min blocks. The experimenter was located in the same room with the subjects. Subjects wore headphones where the tone stimuli were presented. The SYNWIN was set to run all four tasks simultaneously. Per subjects, both experimental sessions were conducted at the same time of day to control for circadian rhythmicity.

Initially, subjects completed the Motion Sickness Susceptibility Questionnaire - MSSQ (7) to assess susceptibility to motion sickness. The single MSSQ score ranges from 0, for no problems, to 222 for severe problems in all questions. For a normal population the 50th percentile is reached at approximately MSSQ 40. Morningness-Eveningness Scale (9) was used to assess subjects’ chronotype, an attribute of human beings related to whether they have a preference for waking earlier or later in the day. The scale includes 19 multiple-choice questions. Scores range from 16 to 86, with scores less than 42 corresponding to evening chronotypes and scores higher than 58 indicating morning chronotypes. Occurrence and severity of symptoms were assessed by the Motion Sickness Assessment Questionnaire - MSAQ (6). The MSAQ includes four subscales (Gastrointestinal, Central, Peripheral, and Sopite-related). The subscale scores’ sum is the Overall motion sickness score. All MSAQ scores range from approximately 11.1 (minimum) to 100. MSAQ responses were provided before the test commenced, and at the end of each 10-min block. Yawning data were collected by the researcher by observing the behavior of the subjects and counting occurrences as they happened.

Statistical Analysis

Subjects were identified as “yawners” (Y) and “non-yawners” (NY). Then, we verified statistical equivalence differences between Y and NY groups in age, consumption...
YAWNING & MOTION SICKNESS—MATSANGAS & MCCAULEY

of caffeinated beverages, self-reported sleep before the data collection, and in the time of data collection. After a descriptive analysis of occurred yawns, we performed a nonparametric comparison of M-E, MSAQ, and SYNWIN scores between Y and NY groups. MSAQ indices and SYNWIN scores were averaged per subjects and session. The first two (practice) blocks of each session were excluded.

RESULTS

On average, the severity of motion sickness was mild. While in motion, the average MSAQ Total per subjects was 14.4 (SD = 6.35, MD = 12.2), with average MSAQ Total scores ranging from minimum to 43. No yawning was observed during the time the subjects were in the lab before the data collection began (approximately 30 min). During the data collection sessions, five subjects yawned during the motion condition, one woman and four men. One man also yawned during the static condition. Descriptive analysis based on the 10-min blocks showed that yawning occurred in 15 blocks (3.21% of the 468 blocks), 13 during motion conditions (8.33% of the 156 motion blocks), and only 2 in static conditions (0.64% of static blocks).

Based on whether they yawned, subjects were classified as yawners (Y, N = 5), and non-yawners (NY, N = 34). A nonparametric comparison between Y and NY groups failed to identify any differences in age, consumption of caffeinated beverages, self-reported sleep before the data collection (Y: MD = 7.75 h, NY: MD = 7.38 h), or in the time of data collection (Wilcoxon rank sum test, \( P > 0.20 \)). Furthermore, individuals in the Y group demonstrated lower M-E scores than those in the NY group [Y: M-E score = 43.8, NY: M-E = 55.4; Wilcoxon Rank Sum test, \( \chi^2(1) = 6.92, P = 0.009 \)]. Two individuals in the Y group were identified as moderately evening types and three neither type. The time of data collection was approximately 09:30 for two subjects and 15:30 for three subjects. As shown in Fig. 1, subjects’ M-E score ranged from 31 to 70. However, yawners’ scores were less than 50. Yawners are depicted with black dots.

Next, we assessed differences in motion sickness severity in the motion condition between the Y and NY groups. All MSAQ indices are averaged per experimental session in motion conditions. The Y group included only symptomatic individuals, i.e., individuals who reported at least one of the 16 symptoms included in the MSAQ. In the NY group, 16 subjects were asymptomatic and 18 symptomatic. Consequently, analysis showed that symptomatic individuals are more prone to yawning in motion conditions compared to asymptomatic ones (Fisher’s exact test, \( P = 0.058 \)). Further analysis showed that, compared to the NY group, the Y group reported increased overall motion sickness severity (MSAQ Total) as well as increased severity of central (MSAQ C), peripheral (MSAQ C), and soporific syndrome related symptoms (MSAQ S). As shown in Table I, the maximum difference was observed in the soporific index, approximately a 50% increase. No significant difference was identified in gastrointestinal symptoms.

The final step in this analysis was to investigate the association between yawning occurrence and cognitive multitasking performance assessed by SYNWIN. Analysis showed that performance of subjects in the Y group was decreased compared to the NY group. As shown in Table II, these differences were evident in the composite as well in the arithmetic task scores. Results are based on average values per subject in the session where motion stimulus was presented.

The aforementioned are diagrammatically depicted in the following figures: Fig. 2 shows the differences in MSAQ indices (Total, G, C, P and S) between yawners and non-yawners; Fig. 3 shows the differences in SYNWIN scores (the composite, as well the four task scores, memory, arithmetic, visual, and auditory).

**DISCUSSION**

In this experiment, yawning was associated with the existence of the nauseogenic motion stimulus. Compared to non-yawners, individuals who yawned in motion were more likely to suffer from mild motion sickness and soporific symptoms and they demonstrated reduced multitasking cognitive performance. What makes

![Fig. 3. SYNWIN scores in the motion condition. Vertical bars represent 1 SD. *\( P < 0.05 \).](image)

**TABLE I. DIFFERENCES IN MOTION SICKNESS SEVERITY BETWEEN NON-YAWNER (NY) AND YAWNER (Y) GROUPS.**

<table>
<thead>
<tr>
<th>Metric</th>
<th>NY M (SD)</th>
<th>Y M (SD)</th>
<th>Significance Wilcoxon Rank Sum test</th>
<th>Hedge’s g</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSAQ Total</td>
<td>14.0 (6.44)</td>
<td>17.2 (5.49)</td>
<td>( \chi^2(1) = 5.85, P = 0.016^{*} )</td>
<td>0.494</td>
</tr>
<tr>
<td>MSAQ G</td>
<td>13.9 (5.80)</td>
<td>14.4 (4.97)</td>
<td>( \chi^2(1) = 0.083, P = 0.774 )</td>
<td>0.085</td>
</tr>
<tr>
<td>MSAQ C</td>
<td>12.9 (5.77)</td>
<td>15.0 (5.13)</td>
<td>( \chi^2(1) = 7.20, P = 0.007^{*} )</td>
<td>0.360</td>
</tr>
<tr>
<td>MSAQ P</td>
<td>14.8 (7.93)</td>
<td>17.4 (5.83)</td>
<td>( \chi^2(1) = 3.59, P = 0.058^{**} )</td>
<td>0.329</td>
</tr>
<tr>
<td>MSAQ S</td>
<td>15.0 (7.81)</td>
<td>22.4 (9.76)</td>
<td>( \chi^2(1) = 3.96, P = 0.047^{*} )</td>
<td>0.901</td>
</tr>
</tbody>
</table>

\* \( P < 0.05 \); ** \( P < 0.10 \).
these results more interesting is the limited severity of the nauseogenic motion. Consequently, the average severity of motion sickness in our study was mild.

However, the experimental methodology did not provide the opportunity to evaluate the temporal distribution of yawning versus soporific symptoms, i.e., to assess whether yawning may be considered as a prodromal response to sopite syndrome or performance deterioration. The time development of symptoms seemed to coincide with performance deterioration because our method was not focused on this assessment.

This study has a number of constraints that limit its external validity. These caveats should be considered when interpreting the generalizability of the results. First, the number of yawning individuals was small (N = 5). The second point of concern is the method we used to identify yawns, which was based on the researcher observing and recording the yawns. Although this approach is better than subject’s self-reports obtained after the data collection session, it is an evaluation subject to the researcher’s bias and error in observations. Future efforts should probably incorporate a 2-researcher approach (4).

A comment should also be focused on the association between yawning and chronotype. Our results suggest the confounding effect of chronotype on yawning occurrence in nauseogenic motion conditions. This finding is in congruence with existing research showing that yawning frequency is affected by differences in sleep-wake or sleepiness rhythms between extreme chronotypes, with evening types yawning more frequently during morning (15). Based on their findings, the researchers concluded that the temporal distribution of yawning frequency differs between chronotypes, supporting the hypothesis that differences in sleep-wake rhythm affect yawning. However, the small number of yawning subjects in our study does not constitute a solid base for our chronotype-related results. Future efforts should investigate further the interaction of motion sickness and chronotype on the development of yawning.

The difference in occurrence of yawns between individuals with soporific and mild motion sickness symptoms compared to asymptomatic individuals under the same motion conditions provides evidence that yawning may be a viable behavioral marker of sopite syndrome. The operational problem with mild motion sickness and sopite syndrome is that both are not easily distinguishable as problems because they are not characterized by any visible signs, with people not being aware of their actual state. From an operational perspective, it would be useful if yawning could serve as a behavioral marker to recognize the onset of soporific effects and their concomitant reduction in cognitive performance.

This work is preliminary, based on a small sample size, and leaves many questions unanswered. A systematic investigation regarding these issues is needed to further elucidate the operational utility of yawning as a behavioral marker for sopite syndrome.

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