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The contribution of expectations to motion sickness symptoms and gastric activity

Manda J. Williamson*, Matthew J. Thomas, Robert M. Stern

Department of Psychology, 535 Bruce V. Moore Building, Pennsylvania State University, University Park, PA, 16802, USA

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Abstract

Objective: The goal of this investigation was to determine in healthy adults the effect of expectation manipulations on the development of motion sickness, as indicated by abnormal gastric myoelectric activity and subjective reports of symptoms of motion sickness. Method: Eighty participants, moderately susceptible to motion sickness, experienced one of four conditions created from a two-variable (Expectation, Drum), two-factor model (High/Low expectation for sickness; Rotating/Stable Drum). The electrogastrogram (EGG) was recorded 6 min prior to the expectation manipulation; 6 min following the expectation manipulation; 6 min before drum activation; and 16 min during drum activation. Self-report questionnaires indicating expectation for sickness (MSEx) and motion sickness symptoms (Nausea Profile [NP]) were obtained following the expectation manipulation and exposure to the drum, respectively. Results: No significant differences were observed among expectation groups for retrospective reports of motion sickness (NP); however, significant differences in EGG responses to drum rotation were obtained. The unexpected results of a univariate analysis of variance (ANOVA) revealed significantly greater gastric tachyarrhythmia and less normal activity, an indication of motion sickness, in the low expectation for sickness conditions. Conclusion: These results suggest that inducing a high expectation for sickness in healthy individuals about to be exposed to provocative motion results in a protective effect from motion sickness following exposure to the stimulus, while low expectations may induce abnormal gastric activity.

Keywords: EGG; Electrogastrography; Expectation; Motion sickness; Reverse placebo effect

Introduction

Motion sickness is a subjective experience characterized by dizziness, sweating, nausea and headache, sometimes for hours following the inducing event [1,2]. Thus far, research into the predictive factors of motion sickness susceptibility (ethnicity, race, gender and age) has yielded wide variability in terms of explaining the variance in those found to be susceptible [2,3]. Pharmacological agents prescribed to alleviate the nausea of motion sickness have yielded less than satisfactory results, as they either do not sufficiently relive symptoms [4–7] or the side-effects produced by the recommended dosages render the user functionally compromised [8–11]. What is not commonly taken into account when investigating causes of motion sickness and what may account for a portion of the variability seen in those suffering the response are psychological factors such as expectation [12,13].

Expectations are based on previous experiences with a similar situation and serve to protect the individual from a previously encountered threatening situation should it arise again [14,15]. In the same manner that a foul smell might protect an animal from the dangers of toxin ingestion, perhaps expectations for motion sickness perceived in an eliciting situation (e.g., a merry-go-round) might protect the individual from future sickness encounters by causing the individual to avoid the amusement park ride.

The goal of this study was to determine in healthy adults how manipulating expectations for motion sickness might affect subsequent symptom onset in a situation previously found to be provocative [16]. It was hypothesized that high expectations for sickness would induce greater symptoms of motion sickness and greater abnormal gastric activity.

* Corresponding author. Tel.: +1-814-865-6218; fax: +1-814-863-7002.

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Method

Participants

Eighty undergraduate volunteers (40 male) were recruited via the Internet for the experiment. The age of the volunteers ranged from 18 to 26 years; and they reported that they were free of neurological, cardiovascular or GI disorders. Participants were chosen on the basis of a score obtained on the "Motion Sickness Questionnaire" (MSQ) [17]. The MSQ indicates the history of an individual's sickness in a variety of provoking situations (i.e., cars, park rides, ships), such that those who evidence low motion sickness susceptibility (i.e., scoring between 5 and 25 on the MSQ; full range = 0–100) and high motion sickness susceptibility (range: 40–61) were recruited for the experiment. These values were chosen in order to control for possible floor and ceiling effects that may occur in those evidencing extremely low and extremely high susceptibility scores. Participants were counterbalanced across all experimental conditions based on their susceptibility scores and were randomly assigned to one of four experimental conditions (Table 1). Counterbalancing was deemed necessary in this experiment, as baseline motion sickness susceptibility has been found in previous research to affect the severity of the reports of motion sickness following the optokinetic drum stimulus [1].

Optokinetic vs. optostable stimuli

In order to manipulate the likelihood of experiencing motion sickness, two types of rotating drums were employed. The first drum, the "rotating optokinetic drum," consisted of a metal drum (height = 91.5 cm; diameter = 76 cm) covered internally with alternating vertical bands of black (width = 3.8 cm, 7° visual angle) and white (width = 6.2 cm, 11° visual angle) stripes that surrounded the upper one-half of the participant. A light source consisting of a fluorescent bulb illuminated the interior of the drum. The participant sat in the drum as it rotated at a rate of 10 rpm in a clockwise direction. This rotation rate has been previously found to induce motion sickness in roughly 50% of individuals placed in this environment [2]. The second drum, the "optostable drum," was the same optokinetic drum that remained stationary throughout the experiment, while the sound of the motor was presented to the participant via a tape recorder. The participant was told that the drum "imperceptibly" vibrated, thus inducing the desired treatment (i.e., motion sickness or relaxation). Pilot studies indicated that this drum (without specific expectation manipulation) induced motion sickness in less than 1% of participants.

Table 1
Number or participants placed into each condition

Drum condition	Expectation for sickness: High	Low
Rotating	20	20
Optostable	20	20

For each condition, participants were counterbalanced according to susceptibility to motion sickness such that ten exhibited moderately high susceptibility and ten exhibited moderately low susceptibility [17].

Procedure

Upon indicating voluntary consent to participate in the study, participants in each condition were escorted to a laboratory and five Ag–AgCl electrodes were attached to the following areas: Three electrodes were placed on the skin surface over the stomach and one electrode was placed on each arm to divert attention from the stomach area. Following electrode attachment, a 6-min baseline measurement (the "true baseline") of electrogastrogram (EGG) activity was obtained to determine pre-drum exposure, and pre-expectation treatment EGG activity. Following the true baseline recording, participants were given the expectation manipulation. The manipulation consisted of reading a set of detailed instructions concerning the probability of experiencing either adverse or positive side effects as a result of being placed into the drum environment. These instructions appear for both the optostable and optokinetic drum conditions in Appendix A. A second EGG measurement was then obtained to determine the effect of the expectation manipulation on EGG activity. Following the EGG recordings, the participant was then introduced to, but not placed inside the drum, and was given verbal instructions describing the operation of the drum. Following the description of the drum, the participant completed the MSEx indicating his/her perceived likelihood of becoming sick as a result of being placed into the drum. After questionnaire completion, the participant was placed inside the drum. Before the drum session began, participants were told that the experimenter would be monitoring their symptoms and that they were to immediately report any discomfort experienced while in the drum. The drum session included a 6-min baseline task, in which the drum was not activated; it was followed by a 16-min drum activation task, in which the participant received either the optokinetic or the optostable treatment. If the participant experienced a high degree of discomfort while in the drum, the drum rotation period was immediately terminated. EGG was recorded throughout the baseline and rotation periods. After exiting the drum, the participant completed the Nausea Profile (NP) detailing the magnitude of his/her emotional, somatic and GI distress.

Physiological measures and quantification

The EGG signal was recorded by placing cutaneous electrodes (ConMed, Haverhill, MA) on the surface of the abdomen. One of the active Ag/AgCl electrodes was placed approximately 3 cm cephalad from the umbilicus along the midline; and the second active electrode was placed approximately 5 cm cephalad from the umbilicus and 2 cm left of midline. The reference electrode was positioned on the right side of the abdomen, even and 10 cm to the right of the umbilicus. Movement artifacts were minimized by attaching the two active electrodes to Fetrodes (UFI, Morro Bay, CA). The Fetrodes were connected to an EGG preamplifier (UFI Fetrode Bioamplifier, Model 2121FT, Morro Bay, CA) and then to a Gould recorder (Model RS 3800, Gould, Cleveland, OH) with a modified universal coupler. The Gould recorder provided a written record of the EGG signal at a speed of 1 mm/s. From the Gould recorder, the EGG signals were passed through a MetraByte Dash-16 analog-to-digital converter and then to an IBM compatible computer. LabTech Notebook (version 6.3) acquired and stored the signals digitally. Filters were set to receive signals in a bandwidth of frequencies between 0.008 and 0.3 Hz; EGG was sampled at a rate of 4.267 Hz.

Spectral analysis of the EGG data was performed using Spec9 (3CPM, Crystal Bay, NV) to determine, for each condition, the change in power from baseline to the expectation manipulation, and from drum baseline to drum activation period for normal 2.75–3.75 cpm gastric activity and abnormal, i.e., tachygastria (i.e., 3.76–9.00 cpm) activity. The first 4 min of each recording period comprised the first epoch to be analyzed. The last 75% (Minutes 2, 3 and 4) of the first epoch were combined with the first new minute (Minute 5) to comprise the second epoch, and so on. Therefore, three epochs were analyzed (Minutes 1–4, 2–5 and 3–6) and then averaged for each period. These epochs were analyzed via fast-Fourier transform (FFT) to obtain spectral estimates for each 240-s epoch. The change in EGG power from the baseline periods to the manipulation periods (Expectation, Drum, respectively) was calculated for normal EGG power and for tachygastria EGG power. This provided an estimate of the change in normal stomach activity and the change in abnormal stomach activity that is associated with subjective reports of nausea.

Questionnaire data

Motion Sickness Questionnaire

In order to recruit participants with high and low susceptibility to motion sickness, the MSQ [17] was e-mailed to participants approximately 48 h prior to the experiment. Individual susceptibility to motion sickness is measured by obtaining a brief history of an individual's experiences with motion sickness-inducing stimuli (such as airplanes and amusement park rides) as well as the number of times an individual has actually gotten sick from those stimuli. A point value is assigned to each response and those scoring above 40 on the MSQ are considered to be at high risk for rotating drum-induced motion sickness [18].

The Motion Sickness Expectation Questionnaire

Immediately preceding exposure to the rotating drum but after having seen the drum, the participant completed an expectation questionnaire (the MSEx) that was designed by this lab to determine participant expectations concerning their predicted somatic, gastrointestinal and affective responses to the drum environment. This 11-item questionnaire assess the severity of expected symptoms on a scale from 0 = no expectation of symptom occurrence through 9 = certain expectation of symptom for each item (e.g., expectation of dizziness, nausea, nervousness). The MSEx was scored in a manner similar to that described by Muth et al. [1] for the NP. The maximum number of points overall is 99 (corresponding to the total possible points available for indicating amount of sickness). The total MSEx score was calculated as the number of total points obtained divided by 99 and multiplied by 100%.

This questionnaire served as a manipulation check on the Expectation for sickness variable (high or low) employed in the experiment. Results of the manipulation check indicated a significant relationship between the expectation manipulation and experienced expectancy for sickness, $t(70.53) = 4.71$, $P < .0001$, such that those placed in the Low Expectation group expected significantly less sickness than those in the High Expectation group ($M_{low} = 31.21$, $S.D._{low} = 18.46$; $M_{high} = 48.11$, $S.D._{high} = 13.17$).

The Nausea Profile

Participants completed the NP immediately following exposure to the drum [1]. The NP is a 17-item questionnaire designed to quantify the dimensions of nausea derived from a factor analysis and consists of identifying one's subjective level of emotional distress, somatic distress and gastrointestinal distress. For example, the participant is asked to judge the severity of a host of motion sickness symptoms (e.g., dizziness, anxiety, stomach discomfort) by rating the severity of each on a scale from 0 = none through 9 = severe. The NP was scored according to Muth et al. [1]. Specifically, the total score was obtained by dividing the total points obtained by the total points available (153) and multiplying by 100%.

Inferential analyses

To determine the effects of each manipulation on subjective and objective reports of motion sickness, a series of univariate analysis of variance (ANOVA) were employed with NP scores, a 6-min EGG after the expectation manipulation and a 16-min (maximum) EGG during the drum manipulation as each dependent measure, respectively, and Drum and Expectation as the independent manipulations for each analysis. To control for motion sickness history, MSQ was included in the subjective symptom analysis as a covariate. To control for baseline stomach activity for the EGG measurements following each manipulation, the true baseline measurement and the drum baseline measurement, respectively, were used as covariates in each of the two EGG analyses. The first analysis tested for EEG changes following the Expectation Manipulation, while the second tested for EEG changes following Drum exposure.

Results

Subjective reports of motion sickness

A balanced univariate ANOVA using Minitab revealed an effect for Drum on subjective reports of motion sickness, $F(1,75) = 42.94$, $P < .0001$. Specifically, those in the rotating drum condition evidenced significantly greater retroactive reports of motion sickness symptoms than those in the stable drum condition. Although subjective reports were in the same direction as the physiological reports for motion sickness, no significant effect for expectation was found (Table 2).

Objective reports of motion sickness: normal 3 cpm EGG power

To test the changes in normal 3 cpm gastric power following the expectation manipulation (before the participant was exposed to the operating drum), a univariate ANOVA was conducted and included the first EGG measurement (the "true baseline") as a covariate to control for possible baseline differences in EGG 3 cpm activity between groups. Results of the ANOVA yielded no significant differences in 3 cpm power across groups following the Expectation manipulation.

A univariate ANOVA, including Drum baseline EGG activity as a covariate (i.e., the drum was not operating while the participant sat inside of the drum), yielded a significant main effect for Expectation after individuals were exposed to an activated drum, $F(1,75) = 4.03$, $P = .048$. Specifically, Tukey post hoc tests revealed that those in the High Expectation for Sickness group evidenced a significantly greater percentage of normal (3 cpm) gastric activity compared to those in the Low Expectation for Sickness group, $t(78) = 2.22$, $P = .003$. A main effect for Drum was also found, $F(1,75) = 4.92$, $P = .03$, such that those in the stable drum evidenced significantly greater normal activity than those in the rotating drum condition, $t(78) = 2.01$, $P = .048$. See Table 3 for mean scores and standard errors.

Table 3
Mean percent 3 cpm power following drum exposure as a function of drum and expectation condition

	Type of expectation		
Type of drum	High	Low	Total
Rotating			
M	67.89	59.37	63.63*
S.E.M.	4.13	4.13	2.92
Optostable			
M	76.67	68.69	72.78*
S.E.M.	4.13	4.13	2.92
Total			
M	72.38*	64.03*	
S.E.M.	2.93	2.93	

* Significant at the .05 level.

Tachyarrhythmic power

A univariate ANOVA that included the true baseline EGG measurement as a covariate was conducted to determine the effects of the Expectation manipulation on tachyarrhythmia measured immediately after the administration of the expectation for sickness instructions and before exposure to the operating drum. Results yielded no significant differences in percent tachyarrhythmic power

Table 2
Subjective symptoms of motion sickness following drum exposure as a function of drum and expectation condition

	Type of expectation		
Type of drum	High	Low	Total
Rotating			
M	38.87	37.03	37.95*
S.D.	4.02	4.02	2.84
Optostable			
M	10.95	11.95	11.45*
S.D.	4.02	4.12	2.88
Total			
M	24.91	24.49	
S.D.	2.84	2.88	

* Significant at the .05 level.

Table 4
Mean percent tachygastric power following drum exposure as a function of drum and expectation condition

	Type of expectation		
Type of drum	High	Low	Total
Rotating			
M	56.93	66.67	61.80*
S.D.	3.79	3.80	2.67
Optostable			
M	43.01	50.75	46.88*
S.D.	3.77	3.77	2.67
Total			
M	49.97*	58.71*	
S.D.	2.67	2.67	

* Significant at the .05 level.

across groups following the administration of the Expectation instructions.

A univariate ANOVA (including Drum baseline as a covariate) yielded a significant main effect for Expectation and Drum following exposure to the drum, $F(1,75) = 15.67$, $P < .0001$ and $F(1,75) = 5.29$, $P = .03$, respectively (see Table 4). A Tukey post hoc test revealed that individuals in the rotating drum evidenced significantly greater tachyarrhythmia than those in the stable drum, $t(38) = 3.96$, $P = .0002$. A Tukey post hoc test on the Expectation variable revealed that those in the High Expectation for Sickness Condition evidenced significantly less tachyarrhythmia than those in the Low Expectation for Sickness Condition, $t(38) = 2.30$, $P = .02$.

Discussion

This research investigated how expectation for motion sickness affects the experience of sickness in otherwise healthy individuals placed in a provocative laboratory setting. The results suggest the following two conclusions: (1) Pretreatment expectations play an integral role in subsequent physiological responses when placed in a provocative situation. (2) Tachyarrhythmia and normal gastric activity changes that occurred from baseline to drum exposure revealed a reverse placebo effect.

The role of expectations in predicting gastric changes

The hypothesized direction of the relationship proposed between level of expectation and gastric changes was not supported in this experiment. In fact, having a low expectation for sickness actually produced greater abnormal gastric activity than having a high expectation for sickness when participants were exposed to the Drum.

To test the validity of the counterbalancing of baseline motion sickness susceptibility (MSQ) for the expectation manipulation, and thus eliminate the possibility that low expectation participants may have had higher susceptibility to motion sickness at baseline, a follow-up t test assessed expectation group differences in the MSQ. Results suggested that there was not a statistically significant difference in motion sickness susceptibility, as evidenced in the MSQ, according to expectation assignment, $t(78) = 0.20$, $P = .84$. Specifically, mean MSQ for the low expectation group was 27.18, while mean MSQ for the high expectation group was 28.15.

In essence, these results suggest a reverse placebo effect. The phenomenon is rarely quoted in the literature; and when it has been, the studies that have produced this same outcome for the participants share a common aspect of the protocol that was also included in this investigation [12]. This similarity concerns the timing of the intervention and the state of the person's symptoms when he/she was administered the placebo. Specifically, when a person is suffering from a disorder that does not involve chronic discomfort (such as motion sickness), it may not be beneficial to "treat" them with a preventative agent. This can be seen in a study by Storms and Nisbett [19] who attempted to treat insomniacs with a placebo intervention. Because the timing of the placebo treatment occurred during the day, when the participants were expected not to be sleeping, they were considered to be "symptom free," just as the participants were in this study during the expectation manipulation. Results of that study demonstrated the same finding as that found in this investigation; that is, that those participants who were given a pill that they were told would help them to sleep experienced insomnia, and those who were given a pill that they were told would make them even more alert actually fell asleep more readily and were relieved from their symptoms. These effects, as well as the effects seen in this study, are attributable to the fact that participants were symptom-free and not suffering during the administration of the placebo. Hence, they had no need for immediate relief; and when the provocative situation finally did occur, participants may have been hyperalert to the effects of the placebo such that any perceived response in a negative direction (any indications that motion sickness-like symptoms may be occurring) was attributed to the fact that, despite, the intervention, their case was so severe that not even a pill (or an expectation manipulation, in this case) could relieve their symptoms.

The dissociation between subjective and objective reports of motion sickness

As noted earlier, there existed a dissociation between the subjective and physiological indexes of motion sickness obtained in this study for the expectation condition. After reviewing motion sickness research in which the NP was used as one of the dependent measures, it may be that the subjective report questionnaire (the NP) was not sensitive enough to capture the differences found in the EGG data measures that indicate an effect of expectation on the development of motion sickness. It should be noted that previous studies using the NP evidenced similar null results that conflicted with EGG reports [12,20].

This study has indicated an unexpected phenomenon concerning the complex role of expectations in affecting the efficacy of treatment interventions vs. prevention interventions. Specifically, the former is commonly employed in patient populations seeking relief from a currently experienced discomfort of some form (e.g., back pain), while the latter is seen in those seeking aid for a potential, but not presently experienced malady (e.g., motion sickness). This study suggests that expectations in those not specifically experiencing the malady during the time that the intervention is administered work in a direction opposite to those given a treatment agent for evidenced symptoms. These data suggest that if an asymptomatic individual is given a pill to prevent a malady he/she is not currently experiencing, but may in the near future, and the individual expects the pill to work, once the individual is placed in the eliciting situation and any symptoms are perceived, the reaction is exacerbated compared to the individual with less than positive expectations concerning the drug's efficacy. While the placebo effect is commonly seen in those seeking treatment, it may be that the reverse placebo effect found in this study is more common in those given preventative agents. Although a unified and comprehensive explanation of how negative response expectancies (nocebos and reverse placebos) come to elicit negative physiological reactions to stimuli remains beyond what is currently known about response expectancies, future investigations might focus on the dynamic relationship between the valence of the expectation for healing by the treatment and the timing that the treatment is administered.

Appendix A. Motion sickness expectation manipulation

A.1. DIRECTIONS (High Expectation)

In a few moments, you will be shown a (Rotating/Vibrating) Drum. It is used to bring about feelings and symptoms of nausea or motion sickness. Specifically, once the Drum is activated, people most often report experiencing symptoms such as dizziness, nervousness and sweating and, in some cases, people vomit. Most of what is known about this (Rotating/Vibrating) Drum, in terms of the symptoms that the Drum induces, is based on research conducted here in this lab. Because the previous research largely involved students like yourself, you may well experience these same symptoms of dizziness, nervousness, sweating and the act of vomiting.

A.2. DIRECTIONS (Low Expectation)

In a few moments, you will be shown a (Rotating/Vibrating) Drum. It is used to treat feelings and symptoms of nausea or motion sickness. Specifically, once the Drum is activated, people most often report experiencing symptoms such as excitement and euphoria, which eventually fades to a sense of relaxation. Most of what is known about this (Rotating/Vibrating) Drum, in terms of the symptoms that the Drum induces, is based on research conducted here in this lab. Because the previous research largely involved students like yourself, you may well experience these same symptoms of excitement, euphoria and eventual relaxation.

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