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Abstract

The present study focused on the relationship between previous experiences of, and rated susceptibility to, motion sickness and its correlation to subjective measurements and actual performance. Performance was measured in terms of shooting precision among 23 participants from the Swedish amphibious corps after transportation in a small amphibious boat, while sealed off with no reference to the outside world. Self-rating questionnaires were collected regarding perceived performance and presence of motion sickness. The physiological status perceived by each participant was related to factors that generally indicate early stages of motion sickness, which also were correlated to deficits in performance. It was further shown that participants who believed that their performance could be affected by motion sickness also performed less well.

Introduction

This is a follow-up study on perceived performance and motion sickness of 22 basic training conscripts with limited experience of riding in a commonly used combat vehicle (Dahlman, Falkmer, & Nählinder, 2006). That study supported the idea that motion sickness and its effect on performance should be studied by using actual performance measurements as a supplement to subjective ratings. However, no actual performance defects were reported in the Dahlman et al., study (2006), and for that reason a more provoking transportation environment was chosen for the present study.

The Swedish amphibious corps operates in shallow waters close to land and includes both marine and land transportation units. For marine transportation, they use the combat boat 90, among others. The combat boat, shown in Figure 1, is a 15-meter-long transportation boat with the capacity of carrying up to 20 passengers. After disembarking the combat boat and other transportation units, the conscripts are required to be fully operational and combat ready. Disembarking the combat boat is normally done from two front hatches and with supportive fire from a boat-mounted gun. Due to their tactical goal as a task force used to operating rapidly in the Swedish archipelago, transportation often occurs regardless of weather or comfort for the transported conscripts. It is likely to assume that conscripts who are frequently or even only sometimes transported in the combat boat, at some time during their active duty may experience motion sickness symptoms to some extent. Previous research has shown that perceived motion sickness in these environments can cause performance decrements (Cowings, Toscano, DeRoshia, & Tauson, 1999; Dahlman et al., 2006).

In order to reduce symptoms and to create a reference to the outside world, the combat boat in the present study was fitted with several small windows in the transportation area. However, to reduce the boat's appearance, these windows were covered with infrared goggles.

Figure 1. Combat boat 90.

The occurrence of motion sickness, as explained by Reason (1975), is created by a conflict between what is perceived, what is not perceived, and what is expected. The physiological sensors involved in this conflict are the vestibular apparatus, the eyes, and proprioception. In the above described case, the conscripts are unable to see the outside world and they only perceive the boat's motions with the vestibular system and proprioceptive receptors, that is, their bodies are moving as a result of the boat's movements, without any visual reference to the outside world. In this case, the origin of motion sickness is thus a result of a vestibular conflict, that is, the eyes provide no information on what movement to expect.

Studying human performance in this type of transportation environment often requires research to be conducted in a natural environment. Because many factors that affect the soldier are difficult to recreate in an experimental laboratory setting, many of the physiological triggers and responses happen only as a result of a genuine stimulus (Hawton & Mack, 1997). Studying motion sickness is especially sensitive to the setting because its appearance, to a large extent, is based on expectations and previous experiences. Furthermore, it may be contagious to some extent in groups of people (Burcham, 2002). Considering these confounding factors that influence the development of physiological status and the importance of providing a representative motion sickness triggering stimulus, the reasons for conducting studies in a natural environment become obvious.

Choosing a representative, valid, and reliable performance variable is important. When studying possible negative effects on performance, an objective measurement of the variable that can be correlated to a subjective rating of perceived performance and physiological status is recommended (Cowings, Suter, Toscano, Kamiya, & Naifeh, 1986). In the present study, shooting was chosen as the performance variable measured in terms of accuracy. However, recent research has illustrated the difficulties of correlating perceived status of an individual to a decline in performance, and furthermore, of establishing a relation between such declines and the actual exposure to motion sickness triggering movements (Dahlman et al., 2006). There are many confounding factors that are difficult to observe and control only by using subjective measurements and at the same time conducting the study in the field. Ultimately, objective ways of identifying motion sickness stages are needed in order to further explain performance deficits and their origins (Stout, Toscano, & Cowings, 1995).

Much research effort has been placed on identifying the underlying physiological parameters that stimulate or give rise to what is potentially perceived as motion sickness (Cowings et al., 1986; Harm, 2002; Jang et al., 2002; Kennedy, Moroney, Bale, Gregoire, & Smith, 1972; Kennedy, Stanney, Rolland, Ordy, & Mead, 2002; Murray, 1997). Among many, there are some responses to motion sickness that correlate well with each other and which later on also evolve to a perceived status that in many cases begins with either drowsiness, gasping, perceived warmth, or stomach awareness. In some cases, where the response evolves very quickly, no such indications are given prior to nausea. Given this, one realizes that motion sickness, and especially perceived motion sickness, is largely individually experienced with respect to susceptibility expectancies and to its physiological responses (Keinan, Friedland, Yitzhaky, & Moran, 1981). Some of the physiological responses commonly examined are measurements of heart rate, electrodermal activity (EDA), respiration, blood volume pulse (BVP), and body temperature.

However, in the present field trial no objective physiological measurements were used. Instead, only subjective ratings of perceived physiological state and ability were collected and analyzed against shooting accuracy, in order to focus on a possible relation between these parameters.

Aim of the study

The aim of this field trial was to study perceived motion sickness in relation to target performance among rifle unit conscripts in the Swedish amphibious corps after transport in combat boat 90.

Methods

A total of 23 male rifle conscripts from the Swedish amphibious corps were included, with a mean age of 20 years (SD 0.5). The study had a within-subject with repeated measurements design. The conscripts were recruited on a volunteer basis. Their participation was part of their regular training and took place a few weeks prior to termination of their service. In total, the conscripts had performed 10–15 months of training, depending on their individual responsibilities. The conscripts initially filled out a screening questionnaire regarding previous motion sickness experiences and their expectations on how motion sickness would affect their performance. It included questions on conditions causing motion sickness. After that, a kneeling baseline shooting was done from 100 meters distance (320 feet) using their standard AK.5 rifle (5.56 caliber), firing 10 shots within 30 s. After the baseline shooting and completing the before first transportation questionnaire, they were transported to the combat boat and seated in random order. The boat departed and transported the conscripts for 50 minutes on a representative normal route with varying speeds and comfort with regard to wind and wave height. The weather conditions were windy (on average 10–12 m/s, 25–26 mph) and wave height varied between 0.5 and 1.5 meters (1.6–4.8 feet), but otherwise there were sunny skies and a temperature of about 15–17℃ (58–63℉). Inside the boat, the conscripts were told to stay awake and were monitored by one of the boat crew members.

When the boat returned after its first 50-minute run, there were buses waiting ashore to transport the conscripts 600 meters (0.38 miles) to the shooting range as quickly as possible without causing any further changes to their physical and mental status. The buses were covered so the soldiers would not have any visual contact with the outside world. It took on average 3.5 minutes between leaving the boat and firing the first shot.

After performing the after transportation shooting, soldiers were asked to fill out the after first transportation questionnaire based on their perceived physiological status and performance abilities. The completed questionnaires were collected by supervisors at the scene, and results from the shooting were recorded after the conscripts had left the shooting range. The after transportation questionnaire included physiological statements that the conscripts were told to rate from 1 to 7, according to their perceived status (Table 1).

After the first round, a 4-hour break gave conscripts a chance to have lunch and to rest before preparing for their second baseline shooting, questionnaires, and final transportation.

After performing the second baseline shooting and filling in the before second transportation questionnaire, the group left the harbor for their second transportation.

Table 1
Parameters that the conscripts rated in questionnaires, with regard to their perceived status.

Rated factors		
Headache	Frozen	Exhausted
Sleepy	Abdominal pain/uneasiness	Tranquil
Hungry	Problems with maintaining focus	Stressed
Indolent	Visual problems	Worried
Dizziness/vertigo	Safe	Motivated
Low appetite	Impaired balance	Feel bad/nausea
Thoroughly rested	Coordinated	Nauseated
Thirsty	Concentrated	Happy
Warm	Easily irritated	Doubtful of own ability

Table 2
Description of the test procedure.

(1) Screening questionnaire
(2) Baseline shooting I
(3) Before first transportation questionnaire
FIRST TRANSPORTATION
(4) After first transportation shooting
(5) After first transportation questionnaire
BREAK
(6) Baseline shooting II
(7) Before second transportation questionnaire
SECOND TRANSPORTATION
(8) After second transportation shooting
(9) After second transportation questionnaire

This second transportation also lasted for 50 minutes and took place under the same weather conditions as the first run. When this second run was completed, the same shooting procedure was performed as in the first and was followed by an after second transportation questionnaire. Table 2 shows an overview of events included in the study.

The outline of the present study did not require application to a local ethical committee according to Swedish law concerning ethical approval of research on humans (2003:460; 2003:615).

Statistical analyses were done using a one-way analysis of variance, Wilcoxon Signed-Rank Test, and a three factor Varimax rotated factor analysis. The alpha level was set to 0.05.

Results

In the data analysis the two baseline shootings were combined with the two after transportation shootings. The results showed that those conscripts who thought their shooting abilities could be affected by motion sickness performed significantly worse in terms of shooting precision; on average, 45 mm (1.78 inches) spread prior to transportation and 53 mm (2.09 inches) spread after transportation $F(1,21) = 8.83$ $p < 0.05$.

However, for those who claimed to be unaware of the possible effects of motion sickness on their performance, actual performance was the same for the two after transportation shootings (Figure 2).

Factor analysis divided the rated status into three factors (Table 3), which generally can be described as ranging from psychological to more psycho-physiological and physiological status. The eigenvalues of factors 1–3 were 10.2, 2.2, and 1.7, respectively.

The second factor was most representative of the stated symptoms that the conscripts had perceived during and after the first and second transportation, because it represents many of the well-known physiological measurements used to study autonomic responses associated with motion sickness and other related decrements (Cowings, Naifeh, & Toscano, 1990). The results indicated a positive relation between Factor 2 and the two repeated occasions

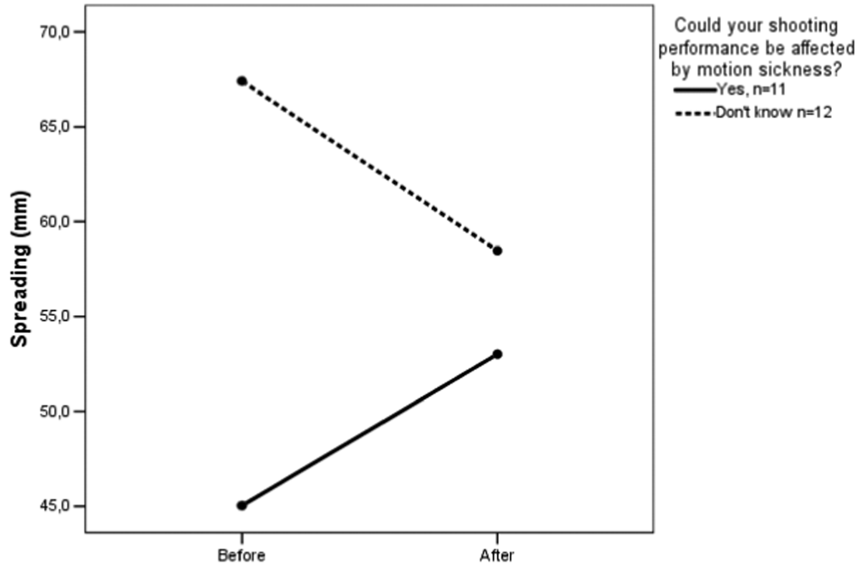

Figure 2. Relation between possible effects of motion sickness on performance due to transportation in combat boat 90.

($F(1,23) = 8.59$ $p < 0.05$), as well as after the first and second transportation ($F(1,23) = 8.06$ $p < 0.05$).

Hence, the conscripts gave the words in Factor 2 higher scores after the second transport, compared to the first, and also after their second baseline shooting, compared to the first (Figure 3).

The average rating of previous motion sickness experiences when transported in a boat, collected in the screening questionnaire, showed that the symptoms were most apparent when conscripts were exposed to windy conditions and when experiencing roll movements. This also happened to be the type of conditions they encountered

Table 3
Results of rotated Varimax factor analysis into three factors.

List of words	Factor score			Factor 2
	1	2	3	
Headache	−0.0429	0.1310	0.5723	
Sleepy	0.4044	0.1295	0.6101	
Hungry	0.0856	0.0052	0.4651	
Indolent	0.4625	0.3991	0.4399	
Dizziness/vertigo	0.3019	**0.6701**	0.1837	Dizziness/vertigo
Low appetite	0.5445	0.3385	0.4757	
Thoroughly rested	−0.4109	0.0106	−0.1969	
Thirsty	0.0218	**0.6337**	0.0595	Thirsty
Warm	−0.0967	**0.6953**	0.1926	Warm
Happy	−0.7054	−0.0949	−0.3986	
Frozen	−0.0315	0.1519	0.5787	
Abdominal pain/uneasiness	0.4350	0.3983	0.5373	
Problems with maintaining focus	0.8064	0.2803	0.1177	
Visual problems	0.4012	**0.4231**	−0.3500	Visual problems
Safe	−0.7910	−0.1747	−0.0715	
Impaired balance	0.5095	0.4345	0.0856	
Coordinated	−0.6721	−0.1763	0.1715	
Concentrated	−0.7960	−0.1235	−0.0423	
Easily irritated	0.4944	0.3542	0.3333	
Doubtful of own ability	0.5107	0.3491	0.2141	
Exhausted	0.4656	**0.4982**	0.4397	Exhausted
Tranquil	−0.5293	−0.4320	0.1400	
Stressed	0.3040	**0.6863**	0.1352	Stressed
Worried	0.2674	**0.5104**	0.3688	Worried
Motivated	−0.7242	0.0273	−0.3687	
Feel bad/nausea	0.4357	**0.5087**	0.4910	Feel bad/nausea
Nauseated	0.3099	0.5427	0.5482	

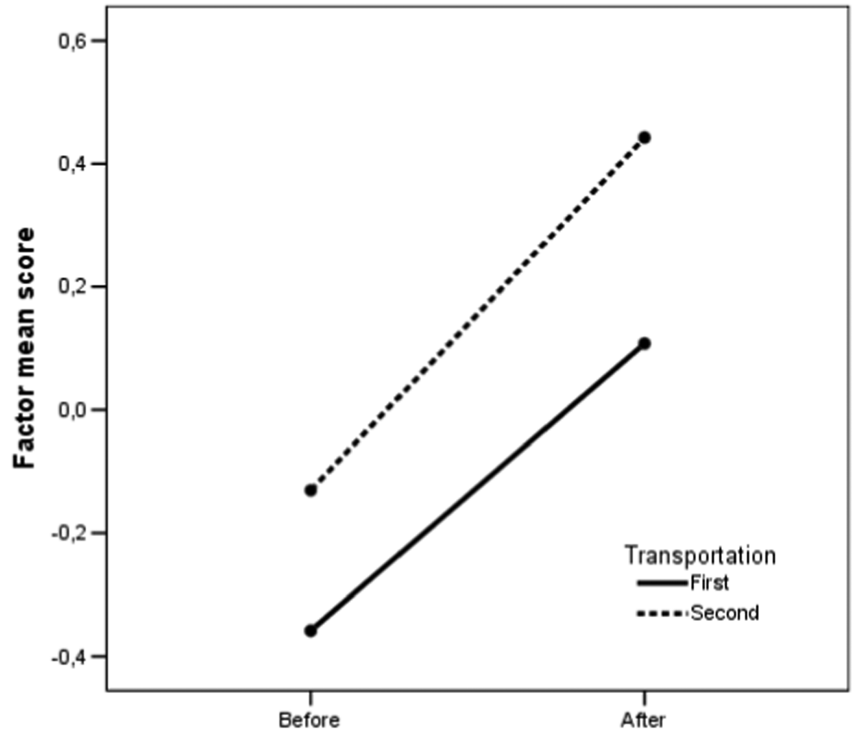

Figure 3. Development of Factor 2 for different occasions.

during transportation. However, more than 60% did not believe that this could affect their shooting performance. The conscripts later on also stated that their perceived motion sickness after the first transportation disappeared before disembarking the boat. After the second transportation, however, their discomfort lasted throughout the entire shooting trials and terminated shortly thereafter.

Figure 4 shows the development of all three factors over all four occasions (i.e., baseline I, after first transport, baseline II, and after second transport). The development of Factor 2 is

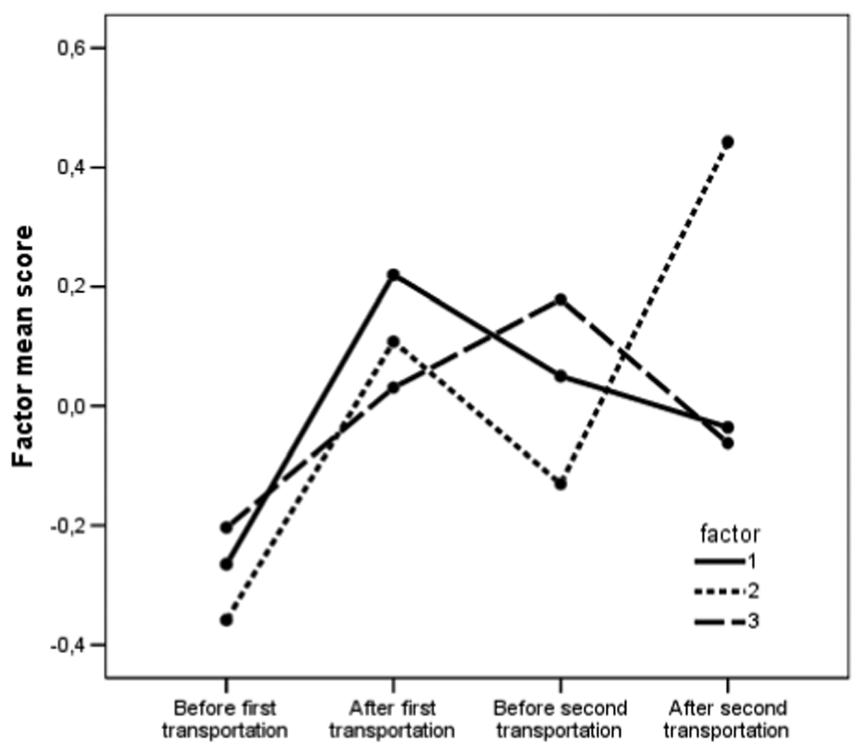

Figure 4. Development of all three factors for all four occasions.

of special interest, because many of the physiological states that are studied objectively with the help of psychophysiological measurements are found within this factor. Ratings for Factor 2 increased between the two baseline measures and between the two transport occasions. No significant factor mean score changes were found between the two baseline shootings or between the two after transportation shootings. However, between the first baseline shooting and the after first transportation shooting, the mean score for Factor 2 showed significant elevation with 0.5 factor value loadings (Wilcoxon Signed-Rank Test, $p < 0.05$). Also, between the second baseline shooting and the after second transportation shooting, the Factor 2 mean score was significantly elevated with 0.6 factor value loadings (Wilcoxon Signed-Rank Test, $p < 0.05$).

The increase in factor value loading between baseline and after transportation, on both occasions, was almost parallel, although it had more than twice the value on the second baseline compared to the first, and three times the value after the second transport compared to after the first. In short, this finding supports the fact that it takes more than the provided 4 hours of rest to recover from the perceived motion sickness status described by Factor 2 when exposed to a moving environment like the one in the present study. It also shows which physiological parameters are further developed and form a basis for potential perceived motion sickness.

Discussion

The purpose of this study was to investigate the effect on target performance after exposure to motion sickness induced by transportation in combat boat 90. Performance in this case was measured as shooting accuracy, and the study was conducted in a natural environment using conscripts from the amphibious corps in Sweden. Performing this type of study in the field created problems with uncontrolled confounding variables regarding boat motion, temperature changes, weather, etc. However, recreating all these affecting parameters in a controlled laboratory setting requires much effort and could, in fact, negatively affect the validity of the results. Hence, conducting the study as a field trial was regarded as the best option. The focus in this study was, however, to see whether previous experiences of perceived motion sickness and self-reported ratings in perceived motion sickness questionnaires were sufficient or if they needed to be complemented with objective measurements for determining the participants' actual physiological state, and thereby their ability to perform their duties.

The results of the present study point to a relation between previous experiences, expectations, and actual shooting performance, as found when conscripts rated whether they believed that their performance could be affected by motion sickness. A majority of the conscripts stated that they, depending on the weather conditions, could be subjected to motion sickness when at sea. However, almost two out of three did not believe that this could affect their targeting performance. The same conscripts later on rated that their perceived motion sickness after first transportation disappeared before disembarking the boat. However, after the second transportation their discomfort lasted throughout the entire shooting trial. This could be one of the factors contributing to the decline in performance.

The conscripts rated their psycho-physiological status on four occasions, prior to and after transportation, towards 27 words with relation to different stages of motion sickness, using a numerical scale. When analyzing these data, using Varimax rotated factor analysis, three factors turned out as shown in Table 3, which represented a progressive development ranging from more psychological features including "happy," "motivated," "calm," and "rested" to purely physiological states like "nausea" and "vomiting." Factor 2 is of special interest, because it represents well-known physiological measurements used to study autonomic responses associated with motion sickness and other related decrements (Cowings et al., 1990). As shown, the development of Factor 2 was raised as a result of both the first and second transportations. Given the fact that the conscripts stated increased discomfort as a result of transportation duration and also performed less well in terms of shooting precision, the results indicate that the words in Factor 2 are representative of the development of perceived motion sickness.

Contrary to a previous study (Dahlman et al., 2006), the words in Factor 2 were quite different. Only two words, stressed and feel bad/nausea, were the same, while the remaining five were different. This could indicate that the two environments give rise to a different set of experiences and, hypothetically, the same subject could very well experience different symptoms in the two environments. It also indicates the fact that humans perceive symptoms differently and that motion sickness can express itself in many different ways, both psychologically and physiologically.

Many research efforts have focused on identifying the essential components of physiological responses to motion sickness (Cowings et al., 1986; Graybiel & Lackner, 1980; Webb & Griffin, 2003). Monitoring and collecting data from heart rate, BVP, body temperature, and respiration, as well as EDA changes in, for example, vertigo, stress, and anxiety can be traced and also further investigated and supported by subjective ratings. The status described in Factor 2 is also interesting from another point of view, namely, regarding the magnitude and level of autonomic responses depending on whether the motion sickness has been perceived or not. If these responses are those identified as physiological components in bodily responses to motion, they can also be detected much earlier, at a subliminal level. This, in turn, would open up for more specific countermeasures, either deliberate (i.e., biofeedback) or more subliminal, autonomic nervous system manipulated aids (sound, improved user interfaces, etc.).

As part of Factor 2, the conscripts also reported increased visual problems with increased perceived illness, which exemplifies an autonomic function that has been given little attention when studying components of motion sickness. Previous studies have investigated the impact on saccadic eye movements (Bos, Bles, & de Graaf, 2002; Flanagan, May, & Dobie, 2004) and peripherally presented visual flows under motion sickness conditions and as a trigger for vection, that is, the illusion of self movement (Webb & Griffin, 2003). However, few studies have focused on eye movements other than saccades, for example, fixations, or rather the lack of eye movements during exposure to motion sickness triggering movements and under the influence of motion sickness (Stern, Hu, Anderson, Leibowitz, & Koch, 1990; Webb & Griffin, 2002). Stern et al. (1990) showed that reduced eye movements contributed to less gastric myoelectric activity, which usually simulates motion sickness symptoms. However, further research is needed to evaluate the relationship between fixation strategies and reduced symptoms of motion sickness.

A drawback of the present study is the number of participants included. In order to further study the impact of motion on performance, more participants should be included and the choice of performance measurements can also include more than just accuracy in hitting a fixed target from a kneeling position. One of the key responses to motion is dizziness and impaired balance, which could be further studied by using moving targets or combining the shooting trials with a more precision-oriented task that would clarify the effect on coordination and psychological abilities.

The purpose of using factor analysis is based on the aim of finding underlying variables in the data set. The result of the factor analysis should contain as few factors as possible in order to increase its strength, and representatives. However, using factor analysis is far from uncontroversial, mostly due to interpretations of the outcome (Keinan et al., 1981; Norman & Streiner, 2003). The results in this study should be analyzed with care, due to the fact that the number of participants in the study is not too far from the number of variables that make up the factor analysis. The eigenvalues of the three factors were 10.2, 2.2, and 1.7, indicating that the sum of the values should explain 53.1% of the total variance. Ideally, this should be closer to 75% or at least 60% (Norman & Streiner, 2003). However, subjective measurements of motion sickness tend to ask for sophisticated analyses of the complexity of the phenomena. In this case, factor analysis offered one such possibility.

Conclusions

The study shows that expectations affect performance, in the sense that if one thinks motion sickness could affect one's ability to perform, one also performed worse. Some of the symptoms associated with the autonomic response to motion and the initial stages of motion sickness were found in Factor 2, which further supports the fact that motion sickness should be studied using both subjective statements and objective physiological measurements.

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