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Joakim Dahlman
Linköping University

Torbjörn Falkmer
Linköping University

Staffan Nählinder
Swedish Defence Research Agency

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Perceived Motion Sickness and Effects on Shooting Performance Following Combat Vehicle Transportation

Joakim Dahlman, Torbjörn Falkmer, Linköping University, and Staffan Nählinder, Swedish Defence Research Agency

This study used a quasi-experimental, repeated measures design to study the relationship between targeting performance and perceived motion sickness following exposure to motion in a land-based transportation setting. The targeting performances of 22 basic training conscript soldiers were examined after repeatedly being transported in the vehicle. Soldiers also rated their perceived motion sickness according to subjective scales before and after the two exposures to transportation. Results showed that perceived motion sickness was correlated to perceived decrease in targeting performance, due to factors labelled as "Combined subjective symptoms". The study supports the idea that motion sickness and its effect on performance should be studied by using actual performance measurements as a supplement to subjective ratings.

In the Swedish armed forces, combat vehicle PBV 401 personnel in rifle units are exposed to motions without the ability to maintain visual contact with the outside environment. Conscripts being transported in this vehicle can sometimes be exposed to motions for several hours and at the same time must prepare or perform tasks inside the moving vehicle. When the team disembarks, they are expected to get organized quickly and may instantly have to open fire at the enemy. Hence, it is important that the team is not experiencing disorientation or is under the influence of motion sickness after disembarking. However, it is possible that motion sickness among the conscripts is perceived, with the potential to negatively affect targeting performance. If early stages of perceived motion sickness could be reported by the conscripts, then this phenomenon could possibly be diminished. The present study explored these issues and assessed the relationship between perceived motion sickness due to motion exposure and targeting performance.

BACKGROUND

For as long as people have been exposed to motion, the occurrence of motion sickness has affected personal well being (Morton, Cipriani, & McEachern, 1947). However, perceiving motion sickness does not require exposure to actual motion. It is possible to acquire a sensation of motion based on signals from the vestibular system, the eyes or the body at levels high enough to induce motion sickness. In other words, motion sickness can result from the mixture of information from the vestibular sensory channels, vision and proprioceptive information if any of these stimuli are contradictory or in conflict (Förstberg, 2000; Reason,

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Address correspondence to Joakim Dahlman, Linköping University, Faculty of Health Sciences, Department of Rehabilitation Medicine, email: joada@lnr.liu.se

1975). Benson (1988) describes this sensory conflict theory as a conflict between or within these sensory systems and the expectations of the participant. This conflict can be expected to be present for personnel riding in armoured vehicles and other environments that are sealed off from the outside world.

Motion sickness may induce both physiological and psychological symptoms. The symptoms vary from perceived disorientation or disturbed vestibulo-ocular or spinal reflexes to physiological symptoms such as pallor, increased salivation, nausea and vomiting. In addition, some may experience the so-called "sopite syndrome," which includes mood changes and sleep that may occur as a single symptom without any signs of nausea (see e.g.: Lawson, Graeber, Mead, & Muth, 2002; Magnusson & Örnham, 1994). These symptoms clearly have the potential to interfere with basic human functions can also negatively affect performance (Cowings, Toscano, DeRoshia, & Tauson, 1999), for example in how well one is able to aim and fire a weapon.

Despite the deleterious symptoms of motion sickness, there are relatively few reports of it being a problem for the performance of soldiers riding armoured vehicles in the Swedish Army. Although some research suggests that motion sickness does frequently occur in this context affecting individuals and the team in different ways, depending on the severity of the symptoms (Magnusson & Örnham, 1994), motion sickness' impact on performance and its relationship remains unclear for armoured vehicle occupants. However, research in similar vehicle environments shows that the appearance of motion sickness symptoms do occur and affect task performance (Cowings et al., 1999). One difficulty in interpreting these contradictory findings is discriminating between the causes of the decreased performance, i.e. if it is due to the motion itself or to the occurrence of motion sickness (Rolnick & Gordon, 1991). A study by Abrams et al. (1971) reports, however, that motions themselves did not seem to affect performance, but the occurrence of motion sickness perceived by participants from the U.S. Navy caused a decrease in performance.

Similarly, in a study by Cowings et al. (1999), performance was observed under various military transportation settings, using ratings and a cognitive task battery along with a physiological monitoring unit. The transportation vehicle in that study was similar to the ones used by the Swedish armed forces, in the sense that it keeps the soldiers out of visual contact

with the outside environment. The results indicated that crew performance was significantly impaired during the moving conditions, as well as compared to the baseline measurements performed before and after motion exposure.

Previous studies regarding effects from transportation on performance, in general, show that the cause of impaired performance can be difficult to identify (Beck & Pierce, 1998) and therefore needs to be detected by using psycho-physiological measurements (Cowings, Suter, Toscano, Kamiya, & Naifeh, 1986) combined with subjective ratings. Because participants exposed to motion vary in susceptibility to motion sickness, it is important to gain in-depth knowledge regarding the initial physiological processes that cause motion sickness. However, combining psycho-physiological measurements with subjective ratings usually means dealing with expectancy and anticipation of symptoms (Cowings, Toscano, DeRoshia, & Tauso, 2001), which creates problems and adds further importance to the selection and categorization process of the susceptibility of motion sickness symptoms in the participants. Because the occurrence of motion sickness is very individual and stimulus-dependent, effects on one participant can trigger symptoms in participants not previously affected (Cowings, Naifeh, & Toscano, 1990; Williamson, Thomas, & Stern, 2004).

Considering that motion sickness symptoms derives from a mismatch between what we perceive with, for example, our eyes and what we sense with our vestibular system, in addition to our expectancies, one realises that there are many factors affecting the body. Furthermore, in order to study performance under the influence of motion, it should be studied under naturalistic situations, i.e., in its real context. It should also be noted that another major contributor to perceived motion sickness is anticipation, due to its transmittable ability to affect others. Recreating all these influencing factors outside the real world environment, for example in simulators or in an experimental setting, is difficult, particularly because many factors affect motion sickness subconsciously (Hawton & Mack, 1997; Rolnick & Gordon, 1991).

Nevertheless, researchers have used both naturalistic and simulated settings to study motion sickness with some degree of success. For example, research in the transport community (e.g., Colwell, 2000; De Graaf, Bles, & Bos, 1998; Förstberg, 2000; Losa & Ristori, 2002; Morrisson, Dobie, Willems, & Endler, 1991; Previc, 2001; Ritmiller, 1998) provides a more

naturalistic perspective. A considerable amount of research has also been carried out using a variety of simulated environments (Crowley, 1987; Stoffregen, Hettinger, Haas, Roe, & Smart, 2002). However, with the increased use of virtual environments in training and education in recent years, problems with virtual reality (VR) related motion sickness have evolved, creating problems known as vection or the illusion of self motion, which can occur when performing stationary work in a moving environment (Howarth & Griffin, 2003).

Given the aforementioned findings, we first concluded that in order to accurately study how motion sickness influences targeting performance for dismounted conscript soldiers following transportation in land-based combat vehicles, we needed to conduct the study in a real world environmental context. Secondly, considering findings on the effect of motion sickness on performance, we hypothesized that perceived motion sickness would lead to impaired targeting performance. More specifically, the aim of the present study was to evaluate targeting performance, both actual and rated, after transportation in a closed vehicle under the possible influence of motion sickness, in relation to self reported perceived target performance and motion sickness.

METHOD

Participants

The participants were 22 male conscript soldiers from the Swedish armed forces being educated to become rifle unit soldiers who were all completing their military service. The mean age was 19.2 years ($SD = 0.43$). Their regular means of transportation was the combat vehicle PBV 401, which was used in the present study. Their education and training were, in total, 10 months. This study was performed after they had completed 3 months of basic military training and they all had limited experience of riding in armoured vehicles in general. None of the participants had taken any precautionary antihistamines or other performance-affecting substances prior to the experiment.

Materials

Two questionnaires were used, one “before transportation” and one “after transportation” questionnaire. Furthermore, a “background” questionnaire regarding age, target shooting experience, experience of previous motion sickness, and use of medication was

used. The “before and after transportation” questionnaire consisted of a list of words describing different aspects of discomfort and uneasiness that could be associated with motion sickness. The words, translated in English, are shown in Table 1.

Table 1: Words on the “Before and After Transportation” Questionnaire

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

The “after transportation” questionnaire differed from the “before transportation” questionnaire in that it also asked the participants to rate, from 1-7, their targeting performance, if they felt disoriented, and if they felt fit for fighting when disembarking the vehicle.

Apparatus

The PBV 401 (MT-LB modified for Swedish conditions) combat vehicle was used in the present study. This vehicle is solely used for transportation of rifle units and carries between 8-11 soldiers depending on storage availability (see Figure 1). The vehicle normally runs through the terrain with speeds varying between 5-70 km/h (~3-45 mph) and is completely armoured, therefore the transportation room provides no visual or auditory contact to the outside world. Partici-

Figure 1. The PBV 401 (MT-LB modified for Swedish conditions).

pants wore the standard equipment for Swedish army soldiers, which included a standard uniform with a vest fitted onto the outside of the uniform containing weapon belongings and survival equipment. Fully functional, the soldiers' equipment weighted about 30 kilos (approximately 66 Lb) and an extra 5 kilos (approximately 11 Lb) for the rifle. The rifle that was used for target shooting was the AK5, which is the standard Swedish 5.56. calibre army rifle.

The shooting range was located at the training area and fully automatic, meaning that hits were registered automatically and displayed by a monitor next to the soldier. All shootings were performed from a kneeling position, since that is most common and gives good body support and flexibility. The targets were positioned on a 200 m (approximately 640 feet) distance and consisted of regular scoring numbers in a circular order (see Figure 2).

The number of hits and spreading of the hits were automatically recorded and displayed on the monitor, which also showed the coordinates of each hit, time between the first hit and every following hit. While the soldiers were shooting, the monitors were covered so that they could not see their individual results, in order to avoid compensatory behaviour and biases from watching fellow conscripts.

Design

We used a within-participants repeated measurements design with perceived motion sickness based on subjective ratings as our independent variable and number of hits and spreading as our dependent variables. Targeting performance was considered to be an ecologically valid measurement with high face validity. Target shooting is a regular activity for the conscripts and performed daily during their basic training. Being transported in the combat vehicle to a conflict area would also be one of the activities that the rifle soldiers could be exposed to. Targeting performance, measured as the number of hits inside the target figure and their spreading, measured by observing the distance between the two outermost hits on the target figure, in mm.

Procedure

Participants were informed about the study and its aim in advance by an oral briefing and were required to provide consent to participate. Participants were also told not to take any preventive medications or precautionary actions such as ingesting antihistamines or anticholinergics and were asked to get a good night sleep and a normal breakfast the same morning, prior to the testing.

After arriving at the testing area the morning of

Figure 2. The fully-automatic shooting range.

the study, participants were divided into three groups of equal size and each group was assigned to a vehicle. All groups were informed of safety and military regulations relevant to the tasks and then the first group performed a baseline target shooting round, which involved firing 10 shots within 30 s. During this round, all participants began shooting following orders from an officer but then could fire at will. After 30 s, participants were ordered to stop firing and all completed the *background and before transportation questionnaires*.

Participants next entered their vehicles and were transported through varying terrain for 30 min at approximately 25 km/h (15 mph) average speed. Each vehicle left the shooting range approximately 20 min apart in order not to get stalled when coming in for the test shooting. As soon as the vehicles had left the shooting area, participants' targeting results were recorded from the monitor by one of the test leaders.

As soon as the first vehicle had left, the team awaited the second group and immediately started their target shooting. The same procedure as for the

first group was repeated and when their vehicle left, the procedure was repeated again for the third group of soldiers. During the transportation, the participants were given a task to perform inside the vehicle that consisted of a reading a designated text aloud. Each participant had to focus on the text and was therefore not given the time to prevent himself from getting affected by motion sickness. The reading task was not added to provoke or create a conflict per se, but chosen in order to create a situation that would be representative to normal conditions.

When the first vehicle returned to the shooting range, participants disembarked and ran a distance of about 75 metres (240 feet) to the same location used during the baseline targeting round. As soon as everyone had assumed kneeling position and indicated that they were ready, the officer gave the order "Fire!" and the soldiers fired 10 shots within 30 s. after which they were given the order to stop shooting. Next, they answered the first "after transportation" questionnaire and were then asked to wait outside of the shooting area. At this point, an experimenter recorded partici-

pants' targeting results. The same procedure was repeated for the second and third vehicle and group. After approximately 3 h of rest and lunch a second round of transportation was performed after the conscripts had shot the second baseline shooting. The procedure from the first round was repeated with one deviation from the earlier sequence in that the transportation time was prolonged to last for 45 min instead of 30 min. The reason for this extension was to better adjust the average speed to the chosen route and also to see whether this extension had any effect on the participants' perceived status.

RESULTS

A varimax-rotated factor analysis was used to identify three factors and the individual item's factor loadings (Table 2). Performance data and data regarding perceived shooting precision and perceived motion sickness were analyzed with a one-way ANOVA. Spearman's rank correlation was used to address correlation between factor 2 and targeting performance. For all tests the alpha level was set at .05.

The varimax-rotated factor analysis was based on all four questionnaire occasions for all participants. The factor analysis distributed the words into three factors (see Table 2), here denoted as:

- 1 = General psychological states,
- 2 = Combined subjective symptoms
- 3 = Physiological nausea symptoms

The factor loading scores on factor 2, "Combined subjective symptoms" correlated significantly with targeting performance, measured as spreading, $F(1, 68) = 4.70$, $p < .05$ (rho-value .254). This correlation was based on all four shooting occasions and indicated that high ratings on factor 2 were more common among those who also performed less well with regards to spreading. This was further supported by the fact that the two baseline shootings also correlated with factor 2, $F(1, 33) = 4.77$, $p < .05$ (rho-value .355) connecting the perceived physiological states in factor 2 with the time between the two transports (see Figure 3). The eigenvalues of factors 1-3 were 7.8, 3.4 and 2.2, respectively, indicating that the sum of these eigenvalues, should be regarded as explaining 49.5% of the total variance

No differences were found with respect to the number of hits and spreading between the four shooting occasions.

Participants were asked to rate their perceived

Table 2: Factor Analysis Distribution of Words into Three Factors and Loadings

List of Words	Factors			Factor 2
	1	2	3	
Headache	-.042	.816	.045	Headache
Sleepy	-.618	.115	.338	
Hungry	.211	.092	.592	
Indolent	-.544	.412	-.397	
Dizziness/vertigo	-.089	.570	.687	
Low appetite	-.181	.491	-.052	Low appetite
Thoroughly rested	.782	-.090	.045	
Thirsty	-.053	-.100	.725	
Warm	.627	.060	.188	
Happy	.633	-.490	-.037	
Frozen	-.584	.076	-.080	
Abdominal pain/uneasiness	-.166	.391	.380	Abdominal pain/uneasiness
Problems with maintaining focus	-.277	.599	.518	Problems with maintaining focus
Visual problems	.341	.161	.701	
Safe	.569	-.252	-.326	
Impaired balance	-.284	.078	.570	
Coordinated	.437	-.004	-.128	
Concentrated	.592	-.376	-.237	
Easily irritated	-.667	.039	-.055	
Doubtful of own ability	-.033	.610	.315	Doubtful of own ability
Exhausted	-.454	.449	-.078	
Tranquil	.326	-.010	-.516	
Stressed	.075	.509	.156	Stressed
Worried	-.149	.774	-.187	Worried
Motivated	.608	-.056	-.308	
Feel bad/nausea	-.023	.643	.405	Feel bad/nausea
Nauseated	-.290	.378	.487

Figure 3. Spreading and Factor 2 correlation. Left Y-axis in mm, 95% CI represented as error bars.

shooting performance after having performed each shooting. Their perceived performance, (see Figure 4), was rated lower after the second transport, $F(1, 17) = 4.62, p < .05$, than after the first.

This result can also be supported by the fact that they experienced more discomfort (i.e., they were more affected by motion) after the second transport than after the first, $F(1, 18) = 5.16 p < .05$. The uneasiness also lasted for a longer time the second occasion (see Figure 5).

After the transport, participants rated high on the combat readiness scale and reported that they did not feel disoriented as a result of the transport despite the fact that 50% of the conscripts felt some kind of uneasiness during the first transport and 60% during the second transport. It should be added that the terrains used for the transport were the same for both trials and the average speed was slightly lower for the second run than for the first.

DISCUSSION

This study investigated targeting performance under the influence of motion sickness, in relation to self-reported perceived motion sickness. By conducting the study in the soldiers' actual combat vehicle and surroundings, our goal was to collect data with a relatively high degree of realism and external validity. In addition, although participants were required to provide subjective ratings and were measured objectively on performance, their activities during the study were quite similar to their normal training and education activities, presumably increasing the face validity of the study and encouraging participants to behave as normally as possible. The likelihood that we could assign any motion sickness solely to the transportation, i.e., the intervention, increases with the degree of natural behaviour among the participants. To create a similar setting with the aid of simulation or virtual reality would not only have affected the behaviour of the participants, but also have made it hard to single

Figure 4. Perceived shooting performance after first and second transport (19 conscripts).

Figure 5. Perceived motion sickness after first and second transport (19 conscripts).

out the intervention as the primary source of motion sickness, and not the result of confounding variables such as simulator sickness or delay induced motion sickness, which occurs in virtual reality settings.

Despite provoking motion sickness by transporting participants for 30 and 45 min, respectively, in bumpy terrain while reading and having no visual contact with the outside, the soldiers did not report psychological states or physiological nausea symptoms to the extent that we could correlate it to any decreased actual performances. During the second longer trip, the participants reported, however, that they perceived decreased targeting performance. The two baseline measurements also correlated with the factor "Combined subjective symptoms," indicating that performance between the repeated measurements was also affected. These findings advocate that subjective ratings could play a role in early

detection of decreased performances due to motion sickness. It is, however, obvious that subjective ratings are not the sole key for such identification as the correlation was fairly low. It is also clear that objective measurements are needed.

Most participants reported an increased level of motion sickness after the second transportation compared to the first, advocating that the duration of the transportation is important for the occurrence of motion sickness. In the present study, the transportation duration was increased by 50% in the second trial, which yielded effects on the subjective ratings.

The best method to induce motion sickness is probably based on a combination of the amplitude of perceptual mismatch and exposure time. In this study, the amplitude was kept controlled on a comparatively low level, while the exposure time was changed. We

Figure 6. The Autogenic-Feedback System-2 (AFS-II).

do not know the impact from the amplitude factor from this study. In future studies, both duration and amplitude should be varied so that one of the two factors could be ranked as most important for induction of motions sickness.

We did not find any extreme self reported motion sickness values. With a higher susceptibility to motion sickness within the study population, the psychological, as well as the physiological aspects of self reported motion sickness symptoms could alter the factor analysis. Focusing on the latter, i.e., the physiological aspects, equipment to measure such parameters, such as the AFS II system (Cowings et al., 1999), shown in Figure 6, could be useful in future identifications of symptoms that could be correlated to early subliminal stages of motion sickness.

The finding that it was the factor "Combined sub-

jective symptoms” -related to cognitive aspects of performances - that was most easily affected by the transportation is, in fact, intriguing. Could it be that the cognition initially actually is affected by early stages of motion sickness, prior to more physiologically and psychologically related factors? An answer to this question could be sought with the aid of measurement equipment, such as the one shown in Figure 6, combined with self rating questionnaires in laboratory settings, in which motion sickness is induced.

A drawback of the present study was the use of the varimax factor analysis, generating the underlying factor number 2, which we labeled as “Combined subjective symptoms.” Basically, factor analyses aim to convey the underlying variables in the data set to the investigator, thus trying to reduce the number of them to a minimum, in order to further enhance the analyses. Several authors have addressed the issue of misinterpreting factor analysis results (Chatfield & Collins, 2001; Norman & Streiner, 2003), but no real consensus seems evident in the literature as to the “correct way” of using factor analyses. In this study, the factor analysis was used for reduction and exploration of data. However, the number of variables was high in comparison to the number of participants, which implies that the interpretation of this factor 2 should be done with care. Furthermore, this factor 2, consisting of eight joint underlying variables of 27 possible, displayed factor loadings ranging from .82-.39 (Table 2). In addition to the authors naming it “Combined subjective symptoms”, which in itself could be misleading, the explained variance further points at interpreting the findings with care. Ideally, the factors should explain 75% of the variances, and at least 60% (Norman & Streiner, 2003). However, subjective measurements of motion sickness tend to ask for sophisticated analyses to the complexity of the phenomena. In this case, factor analysis offered one such possibility.

Another drawback of the present study was that the number of participants was low. Future studies should include a larger sample and also use an index of the number of hits, their position on the target boards and the spreading of the shots, i.e., the targeting performance. In a real combat situation, hitting the target at least once is probably more important than having low spread of the shots, if the spread is within the wrong area. As mentioned previously, in this study we could not identify a decrease in performances with respect to number of hits, due to transportation in-

duced motion sickness. Future studies should thus include a range of difficulties to hit the targets so that also minor decreases in hitting performances could be detected from that point of view. With regards to the findings in this study, the notion is that longer missions including increased transportation duration in enclosed environments can affect crew performance negatively. Military transportation is to a larger extent than before conducted in small enclosed rapid vehicles and often in harsh terrain, in order to reduce exposure. Considering the increased degree of illness perceived in the second, longer, transportation, it is also likely that once the perceived illness has started it will further develop, creating discomfort to the participant. In the present study we used subjective statements as the only measurement of motion sickness, but in a military situation where crew performance and combat readiness are crucial, suppression of motion sickness symptoms or understatements in rating them may affect the significance of these subjective statements as they may be too positive.

In situations outside the military domain, it could be of vital importance to be aware of the fact that the perceptual and motor skills can be affected by relatively short exposures to moving environments.

CONCLUSION

The self reported factor “Combined subjective symptoms” correlated with lower subjectively reported shooting accuracy when perceiving a higher rate of motion sickness. This suggests that self-reported motion sickness provides information on performance, but that it is not the sole measurement that should be used. Instead, there is a need to combine it with objective physiological measurements. Our results also support the idea that motion sickness and its effect on performance should be studied by using actual performance measurements as a supplement to subjective ratings.

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