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MOOD AND SIMULATOR SICKNESS AFTER TRUCK SIMULATOR EXPOSURE

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Abstract
Objectives: Studies involving simulators are increasingly popular. We examined to what extent exposure to a variety of test conditions on the simulator affects the level of mood and severity of simulator sickness. In addition, we were interested in finding out to what degree the changes in mood are associated with the severity of the symptoms of simulator sickness. **Material and Methods:** Twelve men (aged M: 29.8, SD: 4.26) participated in the study, performing two 30-minute tasks in a driving simulator truck (fixed-base and mobile platform). For measuring mood, the UMACL questionnaire was used, and to assess the severity of the symptoms of simulator sickness, the SSQ questionnaire was used. Mood and the severity of simulator sickness symptoms were measured 3 times during the study (pretest, 2 min and 0.5 h after the test). **Results:** Symptoms of nausea and disorientation occurred after the tests on both simulators. In the case of the mobile platform, exacerbation of the symptoms associated with oculomotor disturbances was observed. These symptoms were particularly severe 2 min after completion of the test on the simulator, and they persisted for at least 0.5 h after the end of the test. The correlations between simulator sickness and mood explained from 35% to 65% of the variance of these variables. In particular, a strong association was observed between the oculomotor disturbances and a decrease in energetic arousal. This refers both to the effect level and the duration of these symptoms. **Conclusions:** Simulator sickness is a major problem in the use of simulators in both the research and the training of operators. In the conditions involving the mobile platform, not only was a higher severity of the symptoms of simulator sickness observed, but also a decrease in energetic arousal. Therefore, the implementation of the mobile platform can provide an additional source of conflict at the level of incoming stimuli and changes in mood may increase this effect. Thus, it seems important to consider the tasks performed on the simulator in the context of utility and the purpose for which we use them.

Key words:
Arousal, Motion sickness, Drivers, Mood, Simulator sickness, Simulator test

INTRODUCTION

The growing interest in simulators both in terms of research and training has highlighted the problem of simulator sickness. Currently, it is probably not necessary to convince anyone that simulator sickness is a phenomenon that should be controlled as much as possible. This is particularly evident in scientific research, in which the controlled variables include measures of simulator sickness, such as the Simulator Sickness Questionnaire (SSQ) [1]. On the other hand, attempts are being made to indicate such physiological variables on the basis of which it

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would be possible to perform early detection of simulator sickness [2].

The use of simulators in research is becoming more and more popular [3–5]. It should be remembered that in the course of these studies, the impact of specific test conditions on the level of fatigue or workload is being assessed [6,7]. Simulators are also used to evaluate the influence of certain psychoactive substances on the operator (e.g. a driver or a pilot) [8]. We should also bear in mind that the level of performance of the task executed on the simulator is not only judged by the accuracy of performance indicators, but also by physiological variables (e.g. oculographic indicators, electrodermal response or cardiovascular reactions) [9,10].

On the basis of these studies, general conclusions, or recommendations, are formulated regarding the impact of specific occupational conditions on human activity. However, it should be noted that it is the oculographic indicators, electrodermal response or cardiovascular reactions that are used in the evaluation of the early symptoms of simulator sickness. In addition, the use of psychoactive substances may aggravate the symptoms. All this leads to the conclusion that on the one hand simulators are used to record the functioning of the operator, while on the other, they can cause certain phenomena, such as simulator sickness. Moreover, the phenomenon of simulator sickness can translate into depressed mood, and thus cause adverse reactions in the subjects.

The fact that simulator sickness causes symptoms that persist in the long term also suggests that we need to bear in mind safety when using simulators. Although no association has been confirmed between the increased number of traffic accidents and exposure to the simulator, it should be remembered that researchers recommend avoiding scheduling simulator and aircraft flights on the same day [11].

Research on simulator sickness has investigated a wide range of factors relating to individual characteristics (e.g. gender, age, experience), test time and test conditions on the simulator [12–14]. We were interested in the impact of test conditions on the simulator on simulator sickness symptoms and changes in mood.

The severity of simulator sickness symptoms varies with simulator type. Drexler showed that the highest intensity of disorientation symptoms is observed when using a driving simulator [15]. Oculomotor disturbances (O) produced the greatest discomfort in fixed-wing simulators, followed by rotary-wing ones, and lastly driving simulators. In contrast, levels of nausea (N) were similar in all test conditions. For driving simulators, the most serious complaints related to oculomotor disturbances, followed by disorientation (D), and lastly nausea (D > O > N SSQ profiles).

Another key factor in simulator sickness research, in addition to the mode of presentation of visual stimuli, is the kind of platform used (fixed-base vs. motion-base). On fixed-base simulator platforms, information on traffic comes from visual information. Motion systems have been added to many modern driving simulators in an attempt to make them more realistic and increase the validity of operator responses whilst also reducing simulator sickness [14]. The motion-base platforms used in simulators can provide 2 types of inertial cues: acceleration and tilt [16]. Curry et al. compared the severity of simulator sickness induced by fixed-base and motion-base (6 Degrees of Freedom – 6 DOF) driving simulators [17]. The analysis of the results showed that the symptoms were more intense in case of fixed-base than motion-base simulators, however the SSQ profile in both cases was the same (D > O > N).

Other studies have demonstrated that when movement is perceived only through visual cues, as it is on fixed platforms, the severity of nausea increases [18,19]. Stoner et al. also noted that the use of mobile platforms may alter the severity of simulator sickness compared to fixed platforms or may even worsen the simulator sickness symptoms [14]. It seems therefore that further research on the effects of the type of traffic simulation (fixed-base vs. motion-base platforms) on the symptoms of simulator sickness is needed. The limited movement of the platforms means that they do not simulate the motion cues perfectly, so from a sensory perspective they will almost always increase the mismatch. Platforms are used to increase the realism of the simulation, and not decrease the sensory mismatch.

The most popular theories designed to explain the phenomenon of simulator sickness include the Sensory Mismatch Theory or Perceptual Conflict Theory [20,21], and the Postural Instability Theory [22–26].

The Sensory Mismatch Theory assumes that simulator sickness, and more broadly the motion sickness, occurs when information from all the senses designed to help with the orientation in space and motion perception is in conflict with what has been the subject of the previous experience of a given person [20,21]. Under this approach, it is assumed that when an operator executes a task in a new environment, in this case the simulator, the movement information pattern which this person has had so far is in conflict with what is presented on the simulator. This mismatch between the current sensory information and what the perceptual system was set to causes simulator sickness. According to the advocates of this theory, it is supported by research results, which state that pilots with more completed flights experience a greater severity of the symptoms of simulator sickness than pilots with little experience in aviation [20,21].

Researchers explain this result by saying that with the acquisition of aviation experience, the perceptual system adjusts more to realistic flight conditions and the susceptibility, expressed by the degree of sensory conflict, to the differences between the simulated and the actual conditions is greater in experienced pilots. The Sensory Mismatch Theory is also the source of another conclusion. The human perceptual system is flexible, and depending on the time of exposure to simulated conditions and the individual characteristics of a pilot it adapts to the new conditions. This adaptation allows the operator function in the new environmental conditions, which is appropriate from the point of view of operating in the simulated environment, but can lead to impaired operation after returning to real conditions. This type of situation, although not confirmed by empirical data, may affect the safety of the tasks performed after exposure to simulated conditions.

On the other hand, the advocates of this theory believe that the occurrence of adaptation to the conditions that initially caused the symptoms of simulator sickness is another argument in favor of this theory. Despite the fact that this theory concerns the differences concerning visual, vestibular and proprioceptive stimuli, it is the vestibular receptors that play the key role. This theory assumes that the occurrence of disturbances at the level of vestibular receptors is a prerequisite for the manifestation of the symptoms of simulator sickness.

A critique of the Sensory Mismatch Theory and an alternative model aimed at explaining the phenomenon of simulator sickness were presented by Stoffregen and Riccio [22]. They noted that the lack of similarity between the actual and expected sensory information is impossible to measure because the output level cannot be defined in any way. Thus, the size of the difference between the 2 reference points is concluded based only on the symptoms, assuming that the more severe the symptoms of simulator sickness, the greater the difference. To put it another way, which has been emphasized by Stoffregen and Riccio [22], not knowing the starting point we cannot determine the size of the difference. In addition, the authors found that the sensory conflict is a widespread phenomenon and its role is limited to adaptive changes involving the introduction of modifications to the action control.

Therefore, an alternative theory was proposed, which was based upon the assertion that simulator sickness is the result of long-lasting postural instability. According to this theory, what is responsible for the symptoms of simulator sickness is the fact that a person exposed to the simulation conditions does not implement appropriate strategies aimed at reducing the body movements caused by the "simulator". Stoffregen and Smart [23] conducted a study in which subjects were asked to stand still in a moving environment. It turned out that the level of postural instability just before the presentation of the stimuli correlated positively with the level of motion sickness.

Analogous results were obtained by Owen et al. [24]. The authors argue that, based on the level of postural stability/instability, we can predict whether the symptoms of simulator sickness are going to occur or not. Postural stability is not considered in this approach as only a factor that changes during exposition to simulated conditions, but also as a factor conducive to the occurrence of simulator sickness.

Regardless of which theory is used to explain the phenomenon of simulator sickness, it should be noted that it is a multifaceted phenomenon and its presence may interfere with the accuracy of measurements (this applies to both the physiological variables and performance of the task), limit the effectiveness of the training, and increase the number of people who are not able to complete the task [14,27]. Thus, it can be assumed that the occurrence of simulator sickness can also provide an additional source of stress and affect the change in the mood of the subjects, which in turn can translate into the functioning of the subjects.

In our analysis, we were interested in the following issues:

1. Do different simulator test conditions affect the change in the mood of the subjects?
2. Do different simulator test conditions affect the severity of simulator sickness in the tested subjects?
3. Is there a relationship between the severity of simulator sickness and the mood of the subjects?

MATERIAL AND METHODS

Twelve men (aged M: 29.8, SD: 4.26) participated in the study. It should be noted that twelve participants is a relatively small sample even for a within-subjects analysis. This is a potential limitation of the study. All the subjects were professional drivers who had held a driving license authorizing them to drive trucks (driving licence category C) for a minimum of 5 years. The average number of kilometers traveled by the drivers in the study group was about 400 000 km. All subjects had a valid medical certificate entitling them to drive. The subjects had no prior experience in simulators.

The study used a truck simulator manufactured by Environmental Tectonics Corporation ETC-PZL Aerospace Industries. The simulator was built based on a fully-equipped, air-conditioned cabin of a modern Actros truck from Mercedes-Benz. The cabin was mounted on a mobile platform with six degrees of freedom, which allowed changing the position of the cabin along and around the longitudinal, transverse and vertical axes. The simulated road environment images were projected on a cylinder screen with a radius of 4.1 m and a field of view of 180° horizontally and 40° vertically. The frequency of generating the images was 60 Hz and the frequency of displaying the images was also 60 Hz. The images were 4.03 m from the optic point in a straight line.

The simulator allowed for the coverage of the selected route with automatic transmission, and a camera system installed in the cabin made it possible to watch both the road environment and the driver's behavior while driving. The simulator's virtual environment comprised both urban areas (factories, shopping centers, residential zones) and rural areas (meadows, farmlands, single houses). In this study, we used a small area of the available simulator environment, a virtual city, with dense buildings, narrow streets and tight curves and crossings. The simulator environment had a spatial granularity, including registration plate numbers of the cars and the individual leaves on the trees. Different kinds of reflections and shadows were also represented in detail. The study participants were informed of the 50 km/h speed limit which applied.

The simulator test conditions met the standards for this type of studies [14].

Mood was assessed using the UWIST Mood Adjective Checklist (UMACL) [28–30], a 29-item self-report questionnaire which provides state measures of energetic arousal (EA), tense arousal (TA) and hedonic tone (HT). The results in UMACL are expressed on 3 scales:

1. HT – felt on the dimension of feeling a pleasant–unpleasant mood.
2. TA – felt on the dimension nervous–relaxed.
3. EA – felt on the dimension vigorous–tired.

The severity of the symptoms of simulator sickness was assessed with the SSQ questionnaire, which is currently the most widely used measure for the subjective assessment of the symptoms of simulator sickness [31,32]. The Simulator Sickness Questionnaire contains 16 items rated by participants as "none," "slight," "moderate," or "severe". These items form 3 subscales: nausea (N), oculomotor disturbances (O) and disorientation (D); in addition, the total SSQ score (T) is also measured [31]. Each of the subjects performed two 30-minute tasks on the simulator driving along the same route under the same visual conditions. However, the difference between the 2 tests was based on the fact that if one task was carried out on a fixed-base platform, the second was performed on the mobile platform. The measurements of mood and the severity of the symptoms of simulator sickness took place on 3 occasions: before exposure to the simulator, 2 min after exposure to the simulator, 0.5 h after exposure to the simulator.

We controlled for the effects of order by counterbalancing the order in which the subjects experienced the 2 experimental conditions. The break between 2 experimental sessions was 1 week. All the sessions were preceded by training which lasted 5 min. Prior to all simulator sessions, the participants provided SSQ pre-exposure background information and pre-exposure physiological status information. All participants stated that they were in their usual state of fitness and that they had not consumed alcohol or taken any medication during the past 24 h. They also reported that they had slept well the previous night and felt comfortable.

Statistics

Mood (HT, TA and EA) and simulator sickness (N, O, D and T) variations during the experiment were all analyzed by means of 2-way ANOVA with repeated measures (2×3 design). Both simulator conditions (2 levels: fixed-base platform vs. mobile platform) and measurement time point (3 levels: before exposure to the simulator; 2 min after exposure to the simulator; 0.5 h after exposure to the simulator) were treated as a within-the-subjects variable. The effect level for each significant result was calculated using the eta-squared (η2p) measure.

Moreover, to estimate the relationship between mood and simulator sickness dimensions, the Pearson's correlation coefficient was calculated. Huynh-Feldt epsilons were used in case of sphericity assumption violation (ε). Post hoc comparisons were performed with the Bonferroni test. Pearson's correlation coefficient was calculated. We used partial η^2 as an index of the effect size. A partial $\eta^2 \leq 0.01$ indicates a small effect; a partial η^2 between 0.01 and 0.06 indicates a medium effect and partial $\eta^2 \geq 0.14$, considerable effect. Differences were considered significant at $p < 0.05$. Post-hoc comparisons were performed using the least significant difference (LSD) test. The PASW 19 statistical package (former SPSS) was used for all analyses.

RESULTS

The descriptive statistics for all measures are reported in the tables below. For the mood variables (UMACL), see Table 1 and for simulator sickness variables (SSQ), see Table 2.

First, we analyzed the impact of exposure to simulator conditions on the level of perceived mood.

In the case of the analysis taking into account the level of Tense Arousal, it turned out that the main effect of the platform type was not statistically significant, $F(1,11) = 1.481$, $p = 0.249$, and this was also the case

Table 1. Descriptive statistics for each variable of UWIST Mood Adjective Checklist (UMACL) depending on the test conditions in the simulator

Type of simulator platform	Mood variables (UMACL)	M	SE	Min.	Max
Fixed-base	before exposure to the simulator				
	TA	14.67	0.924	9	18
	EA	31.00	0.879	26	38
	HT	32.50	0.723	29	37
	2 min after exposure to the simulator				
	TA	14.50	1.151	9	20
	EA	30.50	1.151	23	37
	HT	33.25	1.256	28	40
	0.5 h after exposure to the simulator				
	TA	14.58	1.131	9	19
	EA	30.67	1.075	25	40
	HT	33.58	1.171	30	40
Motion-base	before exposure to the simulator				
	TA	15.50	1.282	9	26
	EA	30.75	1.404	20	38
	HT	32.00	1.015	25	36
	2 min after exposure to the simulator				
	TA	16.42	1.438	10	28
	EA	26.75	1.638	18	38
	HT	30.83	1.821	15	40
	0.5 h after exposure to the simulator				
	TA	15.75	0.799	11	19
	EA	27.58	1.454	18	36
	HT	31.42	1.221	24	39

M – mean; SE – standard error.
Min. – minimal value; Max – maximal value.
TA – Tense Arousal; EA – Energetic Arousal; HT – Hedonic Tone.

for the main effect of the measurement time point $F(1,22) = 0.214$, $p = 0.809$, and the interaction between the type of the platform and the measurement time point $F(2,22) = 0.362$, $p = 0.700$.

However, when the change in the Energetic Arousal level was evaluated, we found that the level was different depending on the type of the platform, $F(1,11) = 3.678$, $p = 0.081$, $\eta^2 = 0.251$ (marginality of significance), and the measurement time point $F(1,22) = 3.428$, $p < 0.05$, $\eta^2 = 0.238$, and an interaction was found between the platform type and the measurement time point $F(2,22) = 3.546$, $p < 0.05$, $\eta^2 = 0.244$, $\varepsilon = 0.577$.

In order to better understand the nature of this interaction, simple effects were analyzed. First, it was checked whether the level of Energetic Arousal varied significantly within each set of simulator test conditions depending

Table 2. Descriptive statistics for each variable of the Simulator Sickness Questionnaire (SSQ) depending on the test conditions in the simulator

Type of simulator platform	Simulator sickness (SSQ)	M	SE	Min.	Max
Fixed base	before exposure to the simulator				
	N	18.29	8.34	0	105.00
	O	22.74	6.19	0	76.00
	D	13.92	9.07	0	111.00
	T	22.13	8.39	0	108.00
	2 min after exposure to the simulator				
	N	31.01	13.19	0	143.00
	O	27.16	9.67	0	91.00
	D	40.60	19.72	0	167.00
	T	36.46	14.96	0	146.00
	0.5 h after exposure to the simulator				
	N	13.52	5.44	0	57.00
	O	17.69	5.39	0	45.00
	D	23.20	9.89	0	111.00
	T	20.26	6.91	0	75.00
Motion base	before exposure to the simulator				
	N	20.67	7.03	0	85.86
	O	27.16	8.37	0	75.80
	D	22.04	12.05	0	139.00
	T	27.43	9.49	0	108.46
	2 min after exposure to the simulator				
	N	48.49	11.53	0	124.02
	O	53.69	10.11	0	98.54
	D	71.92	18.36	0	180.96
	T	64.83	13.80	3.74	142.12
	0.5 h after exposure to the simulator				
	N	28.62	6.32	0	76.30
	O	41.06	8.67	0	90.96
	D	44.08	15.02	0	139.20
	T	43.32	10.35	0	112.20

N – nausea; O – oculomotor; D – disorientation; T – total. Other abbreviations as in Table 1.

on the measurement time point. In the case of the test on the mobile platform simulator, the level of Energetic Arousal 2 min after exposure to the simulator (M: 26.75) and 0.5 h after exposure to the simulator (M: 27.58) was significantly reduced compared to the level before the test (M: 30.75), $p < 0.05$.

Comparisons of the level of Energetic Arousal between the simulator test conditions at various measurement time points showed that under the test conditions involving the mobile platform, the subjects experienced lower Energetic Arousal 2 min after exposure to the simulator (M: 26.75) compared to the test conditions involving the fixed-base platform (M: 30.50), $p < 0.05$.

Similarly, the level of Energetic Arousal was significantly higher 0.5 h after exposure to the simulator in the test with the fixed-base platform (M: 30.67) compared to the test conditions with the mobile platform (M: 27.58), $p < 0.05$. These dependencies are illustrated in Figure 1.

Hedonic Tone was the last dimension of mood assessed in our study. We found that the level of Hedonic Tone did not vary depending on the type of the platform on which the task was performed, $F(1,22) = 1.119$, $p = 0.313$, just as the main effect of the measurement time point was not statistically significant, $F(1,22) = 0.305$, $p = 0.740$. No significant interaction between the platform type and the measurement time point was noted, either – $F(2,22) = 1.236$, $p = 0.310$.

As stated above, the object of the study was also, apart from the mood, the assessment of the severity of the symptoms of simulator sickness determined using the SSQ questionnaire.

The level of nausea (N) was found not to vary significantly depending on the type of the platform on which the task was done, $F(1,11) = 1.825$, $p = 0.204$, but it varied depending on the measurement time point, $F(1,22) = 4.425$, $p < 0.05$, $\eta^2 = 0.287$, $\varepsilon = 0.575$. The analysis of main effects revealed that the level of nausea was significantly higher in the second minute after completing the task on the simulator (M: 39.75), compared to the level recorded 0.5 h after the end of the task (M: 21.07), $p < 0.05$. The interaction between the platform type and the measurement time point proved to be statistically insignificant, indicating that the changes in the level of this variable overtime did not take place in a different way depending on the platform on which the task was performed $F(2,22) = 1.014$, $p = 0.379$, $\varepsilon = 0.675$.

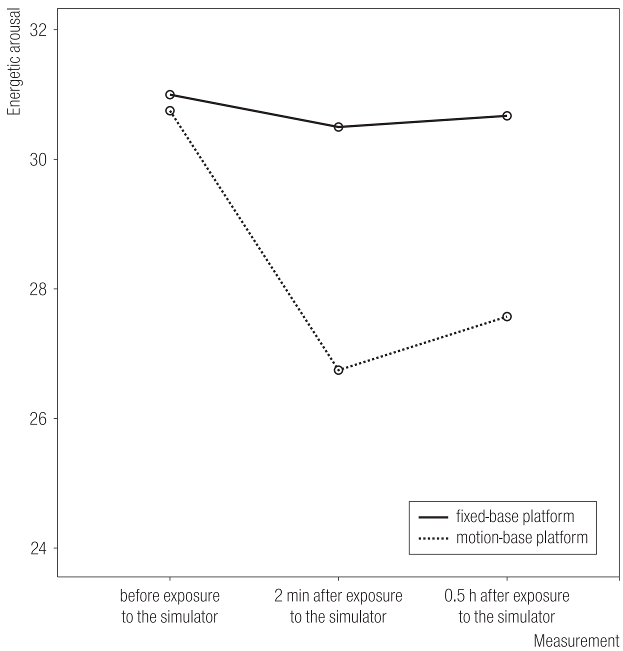

Fig. 1. Influence of the simulator test conditions on Energetic Arousal

In contrast to nausea, the level of oculomotor disturbances varied depending on the type of the platform, $F(1,11) = 4.319$, $p = 0.062$, $\eta^2 = 0.282$ (marginality of significance). This level also varied significantly depending on the measurement time point, $F(1,22) = 4.057$, $p < 0.05$, $\eta^2 = 0.269$, $\varepsilon = 0.592$. In addition, there was a significant interaction noted between the type of the platform on which the task was done and the measurement time point, $F(2,22) = 5.148$, $p < 0.05$, $\eta^2 = 0.319$. In order to better understand the nature of this interaction, simple effects were analyzed. We examined whether the intensity of oculomotor disturbances varies for the various test conditions on the simulator depending on the measurement time point. As was predicted, there was no difference recorded in the level of oculomotor disturbances before the simulator testing.

This result indicates that the subjects did not differ in this function at baseline. In the conditions involving the mobile platform, the subjects experienced greater intensity in oculomotor disturbances in the second minute after exposure to the simulator (M: 53.69) compared to the baseline level (M: 27.16), $p < 0.05$. It was also found that the intensity of oculomotor disturbances on the mobile platform was greater in the second minute after exposure to the simulator (M: 53.69), compared to the measurement taken 0.5 h after exposure to the simulator (M: 41.06), $p < 0.05$. For a full understanding of the nature of this interaction, we also compared how the level of oculomotor disturbances changed between the simulator test conditions at different measurement time points.

The severity of oculomotor disturbances 2 min after exposure to the simulator was significantly higher when tasks were performed on the mobile platform (M: 53.69), compared to those done on the fixed-base platform (M: 27.16), $p < 0.05$. Similarly, the increase in oculomotor disturbances 0.5 h after exposure to the simulator was significantly higher under the conditions of the mobile platform (M: 41.06), compared to those with the fixed-base platform (M: 17.69), $p < 0.05$. These correlations are illustrated in Figure 2.

The level of disorientation (D) was found not to vary significantly depending on the type of the platform on which the task was executed, $F(1,11) = 2.941$, $p = 0.114$. It was noted, however, that the level of disorientation changed depending on the measurement time point, $F(2,22) = 6.195$, $p < 0.01$, $\eta^2 = 0.360$, $\varepsilon = 0.575$. The analysis of main effects showed that the level of disorientation was significantly higher 2 min after exposure to the simulator (M: 56.26), compared to the baseline level (M: 17.98) and compared to the level recorded 0.5 h after the end of the task on the simulator (M: 33.64), $p < 0.05$. The interaction between the platform type and the measurement time point proved to be statistically insignificant, indicating that the changes in the level of this variable in time did not take place in a different way depending on the platform on which the task was performed on the simulator, $F(2,22) = 1.155$, $p = 0.333$, $\varepsilon = 0.682$.

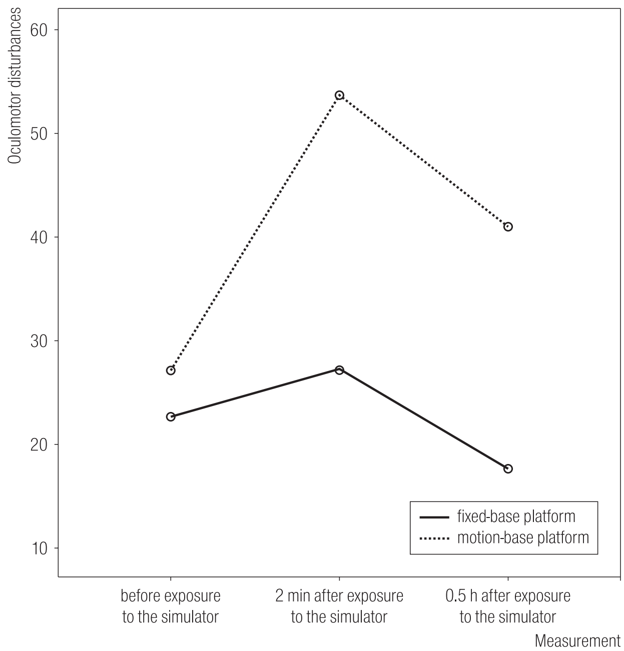

Fig. 2. Influence of the simulator test conditions on the severity of oculomotor disturbances

Although the results obtained for the individual aspects of simulator sickness expressed in the SSQ subscales allow for precise evaluation of the disturbances associated with exposure to test conditions on the simulator, it is worth taking a look at the results of the analysis of the Total SSQ. The severity of the symptoms of simulator sickness determined by the Total SSQ changed depending on the test conditions on the simulator, $F(1,11) = 3.262$, $p = 0.090$, $\eta^2 = 0.229$. It should be noted that this effect is only marginally significant.

The analysis of main effects showed that in the case of the test on the mobile platform, the overall level of simulator sickness was higher (M: 45.19) than in the case of testing the subjects on the fixed-base platform (M: 26.28), $p = 0.090$. As it has been noted, however, the significance of these relationships was maintained at a level of statistical tendency. It was also revealed that the level of simulator sickness varied depending on the measurement time point, $F(2,22) = 5.131$, $p < 0.01$, $\eta^2 = 0.318$, $\varepsilon = 0.567$. The analysis of main effects showed that the level of simulator sickness was significantly higher 2 min after exposure to the simulator (M: 50.64), compared to the baseline level (M: 24.78) and compared to the level recorded 0.5 h after the end of a driving simulation (M: 31.79), $p < 0.05$. The interaction between the platform type and the measurement time point proved to be statistically insignificant, $F(2,22) = 2.372$, $p = 0.117$.

The final stage of the analysis was to determine whether there is a correlation between different dimensions of mood and the level of experienced simulator sickness symptoms. Pearson's correlation coefficient was calculated.

In the second minute after the end of the test on the simulator, in conditions involving the fixed-base platform, an important correlation was recorded between the Energetic Arousal and all aspects of simulator sickness. The results indicate that the higher the level of simulator sickness, concerning nausea, oculomotor disturbances and disorientation, the lower the Energetic Arousal. In the case of fixed-base platforms, 0.5 h after the test on the simulator there were no significant correlations between the mood and the symptoms of simulator sickness. In the case of the mobile platform, the correlations between the mood and the severity of the symptoms of simulator sickness proved to be stronger than in the case of the fixed-base platform.

It turned out that in the second minute after completion of the test on the simulator with the mobile platform, a higher severity of the general symptoms of simulator sickness (in particular nausea and oculomotor disturbances) meant a higher level of Tense Arousal, and lower levels of Hedonic Tone and Energetic Arousal (in the case of Energetic Arousal, a similar relationship was discovered with the level of disorientation). However, 0.5 h after the test on the simulator with the mobile platform, a significant correlation was also noted between the oculomotor disturbances and Energetic Arousal. The higher was the level of the oculomotor disturbances, the lower was the level of Energetic Arousal.

DISCUSSION

Simulator sickness is an important factor that must be taken into account in studies involving simulators. It may be observed that mobile platforms are used for scientific purposes increasingly more often. Their use is to ensure experiencing motion as realistically as possible. Moreover, introducing mobile platforms is also in part aimed at minimizing the conflict that can occur while performing tasks on the simulator [14].

Using the platforms was intended to reduce the mismatch between sensory cues by introducing proprioceptive cues and it is predicted that this would reduce symptoms of simulator sickness [17]. Previous studies have produced mixed results, both positive effects from the use of 6 DOF motion systems and a lack of significant differences have been reported [33]. The results of our study indicate that enriching the simulator experience by including proprioceptive cues leads to symptoms of simulator sickness and changes in mood. The SSQ profiles obtained in our study of static and mobile platforms are the same as those reported by Curry et al. [17] However in our study the SSQ profile for the mobile platform was much higher than that for the static platform.

Our results indicate that in the case of the mobile platform, there was a significantly higher severity of the symptoms of simulator sickness associated with oculomotor disturbances. These symptoms, in the case of mobile platforms, were particularly high 2 min after completion of the test on the simulator, but they also persisted for at least 0.5 h after the end of the test. In the case of oculomotor disturbances, the type of the simulator accounted for 28.2% of the variance of this variable and the time elapsed since the task on the simulator accounted for 26.9% of the variance. In addition, the simulator test conditions affected differently the severity of oculomotor disturbances depending on the time that has elapsed since the task on the simulator. The effect of the interaction between these variables explained 31.9% of the variance of oculomotor disturbances.

Table 3. Relationship between mood and simulator sickness symptoms

Type of simulator platform	Fixed-base platform								Motion-base platform (6DOF)							
	2 min after exposure to the simulator				0.5 h after exposure to the simulator				2 min after exposure to the simulator				0.5 h after exposure to the simulator			
	N	O	D	T	N	O	D	T	N	O	D	T	N	O	D	T
Fixed-base platform																
TA	0.526	0.508	0.541	0.535												
EA	–0.650*	–0.657*	–0.699*	–0.682*												
HT	–0.431	–0.430	–0.430	–0.440												
TA					0.295	0.355	0.418	0.388								
EA					–0.140	–0.463	–0.390	–0.371								
HT					–0.283	–0.304	–0.361	–0.343								
Motion-base platform (6 DOF)																
TA									0.617*	0.607*	0.564	0.623*				
EA									–0.638*	–0.810**	–0.784**	–0.782**				
HT									–0.677*	–0.642*	–0.557	–0.653*				
TA													0.386	0.516	0.417	0.469
EA													–0.338	–0.587*	–0.522	–0.527
HT													–0.281	–0.358	–0.126	–0.264

6 DOF – 6 Degrees of Freedom.
* $p < 0.05$; ** $p < 0.01$.
Other abbreviations as in Table 1 and 2.

However, in the case of both platforms, a significant increase in the level of the symptoms of simulator sickness associated with nausea and disorientation due to the general outcome was observed in the SSQ. These symptoms were particularly high 2 min after completion of the test on the simulator. In the case of nausea, the time elapsed since the completion of the task on the simulator accounted for 28.7% of the variance of this variable. The analysis conducted for the variable of disorientation indicated that the time that has elapsed since the task on the simulator accounted for 36% of the variance of the severity of these symptoms. The analysis of the general result of simulator sickness also indicated a significant effect of time. The time elapsed since the test on the simulator accounted for 22.9% of the Total SSQ Score.

The profiles of simulator sickness for both platforms were similar and were expressed as follows: D > O > N. Only in the case of the fixed-base platform 2 min after completion of the test, the profile of simulator sickness was D > N > O. This may mean that the changes in nausea were more severe, but in oculomotor disturbances they persisted over a longer period of time. Nevertheless, the severity of disorientation symptoms was the highest both in terms of the measurement time point and the type of platform used [17].

Furthermore, the results indicate that in the case of the mobile platform, the mood is depressed in the dimension of Energetic Arousal. In the case of the mobile platform, the mood changes can already be seen in the second minute after completion of the test on the simulator and persist for at least 0.5 h. However, as a result of exposure to the test conditions related to the fixed-base platform, there was no change observed in the Energetic Arousal. The platform type accounted for 25.1% and the measurement time point for 23.8% of the variance in the Energetic Arousal. In addition, the simulator test conditions affected the intensity of Energetic Arousal in different ways, depending on the time elapsed since performing the task on the simulator. The effect of the interaction between these variables accounted for 57.7% of the variance of Energetic Arousal.

Attention should also be paid to the correlation between the severity of the simulator sickness symptoms and the various aspects of mood. In the case of the fixed-base platform, 2 minutes after the test on the simulator, a relationship between Energetic Arousal and all aspects of simulator sickness was observed. It appeared that the intensity of simulator sickness symptoms (nausea, oculomotor disturbances and disorientation) was inversely related to Energetic Arousal i.e. more intense simulator sickness was associated with lower Energetic Arousal. The relationship between simulator sickness and Energetic Arousal accounted for between 43% and 47% of the variance of these variables.

On the other hand, in the case of fixed-base platforms 0.5 h after the end of the test on the simulator, there were no significant correlations between mood and the symptoms of simulator sickness. In the case of the mobile platform, the correlation between mood and the severity of the symptoms of simulator sickness proved to be even stronger. It turned out that in the second minute after the test on the simulator equipped with the mobile platform, the higher was the severity of the general symptoms of simulator sickness (in particular nausea and oculomotor disturbances), the higher was the level of Tense Arousal and the lower were the levels of Hedonic Tone and Energetic Arousal (in the case of Energetic Arousal there was a similar relationship found with the level of disorientation).

Also, 0.5 h after the test on the simulator equipped with the mobile platform, a significant correlation between oculomotor disturbances and Energetic Arousal was noted. The higher was the level of oculomotor disturbances, the lower was the level of Energetic Arousal. The relationships between simulator sickness and mood accounted for between 35% and 65% of the variance of these variables.

In particular, a strong correlation was observed between oculomotor disturbances and Energetic Arousal. This refers both to the effect level and the duration of these symptoms.

In summary, the results of our study confirm that simulator sickness is a significant problem in the use of simulators in both the research and the training of operators [14]. It is believed that the use of the mobile platform can, through a better reflection of natural conditions, reduce the symptoms of simulator sickness and increase the realism of the simulation tasks. The results obtained in the present study indicate that under the conditions of the mobile platform, not only is an increased severity of simulator sickness observed, but it also translates into a change in the mood of the subjects [17,33,34].

Therefore, the introduction of mobile platforms can provide an additional source of conflict at the level of incoming stimuli, and changes in the mood may increase this effect. This outcome is particularly important in the context of a series of studies showing that the level of Energetic Arousal plays an important role in information processing. It is understood that the higher the level of Energetic Arousal, the higher the level of performance, in particular concerning those tasks which require performing complex activities, not necessarily based on automatic processes [35,36].

Thus, summing up, it can be said that the more the conditions on the simulator try to reflect natural circumstances, the greater the risk is of the intensification of the perceptual conflict, and as a consequence, of simulator sickness. It seems important to consider the tasks performed on the simulator in the context of utility and the purpose for which we use them.

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