2009

Simulator Sickness in the Flight School XXI TH-67 Flight Motion Simulators

Catherine Webb M.S.
Julie Bass SSG
David Johnson Ph.D.
Amanda Kelley Ph.D.
Christopher Martin M.D.

See next page for additional authors

Follow this and additional works at: https://corescholar.libraries.wright.edu/isap_2009

Part of the Other Psychiatry and Psychology Commons

Repository Citation

This Article is brought to you for free and open access by the International Symposium on Aviation Psychology at CORE Scholar. It has been accepted for inclusion in International Symposium on Aviation Psychology - 2009 by an authorized administrator of CORE Scholar. For more information, please contact corescholar@www.libraries.wright.edu, library-corescholar@wright.edu.
SIMULATOR SICKNESS IN THE FLIGHT SCHOOL XXI TH-67 FLIGHT MOTION SIMULATORS

Catherine Webb, M.S.1
Julie Bass, SSG1
David Johnson, Ph.D.2
Amanda Kelley, Ph.D.1
Christopher Martin, M.D.3
Robert Wildzunas Ph. D.1

1US Army Aeromedical Research Laboratory, Fort Rucker, AL
2Army Research Institute, Rotary Wing Aviation Research Unit, Fort Rucker, AL
3US Army Aeromedical Center, Fort Rucker, AL

Simulator sickness (SS) is a common problem during flight training and can affect both instructor pilots (IPs) and student pilots (SPs). This study was conducted in response to complaints about a new rotary wing flight simulator. To investigate, Simulator Sickness Questionnaire (SSQ) data were collected from 129 SPs and 73 IPs. Analysis of these data helped direct recommendations based on the scientific literature for reducing SS. One year later, a post-test collected SSQ data from 50 SPs and 25 IPs. To test the effectiveness of the recommendations, a 2 (experience) x 2 (time) between-subjects Multivariate Analysis of Variance was used. There was a main effect of time and experience for the nausea, oculomotor and total scores of the SSQ. While it may never be possible to completely ameliorate SS in the new simulators, the recommendations that were implemented did reduce SS symptoms.

The phenomenon of simulator sickness (SS), a form of motion sickness caused by physical and/or visual motion in a simulator, has been well documented. Compared to motion sickness, the symptoms of SS tend to include more visual disturbances than gastrointestinal manifestations. The most accepted theory of SS is the sensory conflict theory proposed by Reason and Brand (1975), which suggests that sickness results when the vestibular, visual, and proprioceptive senses perceive motion information that conflicts with expectations based on past experience of actual flight (Crowley & Gower, 1988).

The purpose of this study was to assess reports of SS in a new rotary wing flight simulator. Recommendations were provided to reduce, or preferably, eliminate the SS problems, and a post-study was conducted to evaluate the effectiveness of the recommendations. It was hypothesized that IPs would report more SS (in terms of prevalence and severity) than SPs. An additional hypothesis was that adherence to the recommended guidelines would reduce SS.
Methods

Equipment

The TH-67 Flight Motion Simulator is a full motion flight simulator manufactured by FlightSafety International (Broken Arrow, Oklahoma). Each simulator has a three channel panoramic visual system and a six-degree-of-freedom motion system. These simulators are used in Phase 1 of the US Army’s Flight School XXI for instrument and military skills training. The same group of simulators was used over the course of the entire study.

Questionnaire

The Simulator Sickness Questionnaire (SSQ) is a well validated pen-and-paper questionnaire designed to detect the prevalence and severity of 16 possible symptoms generally associated with SS (Kennedy, Lane, Berbaum, & Lilienthal, 1993). Participants rate the severity of symptoms on a scale ranging from 0 (none) to 3 (severe). In addition to a total severity score, the SSQ yields a nausea, oculomotor, and disorientation subscale score.

Participants

Two hundred and two helicopter pilots from Fort Rucker, Alabama (73 IPs and 129 SPs) participated in the pre-study. Data from three participants (1 IP and 2 SPs) were excluded from the analysis due to insufficient data. Demographic data is presented in Table 1.

Seventy-five helicopter pilots from Fort Rucker, Alabama (25 IPs and 50 SPs) participated in the post-study. Demographic data is presented in Table 1. Of the 25 IPs in the post-study, 17 also participated in the pre-study; however they were not matched to evaluate individual change because the data was de-identified.

Table 1. Participant Characteristics.

<table>
<thead>
<tr>
<th></th>
<th>Pre-Study</th>
<th>Post-Study</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IPs</td>
<td>SPs</td>
</tr>
<tr>
<td>n</td>
<td>73</td>
<td>129</td>
</tr>
<tr>
<td>Mean Age (SD)</td>
<td>51.1 ± 8.3</td>
<td>24.8 ± 3.2</td>
</tr>
<tr>
<td>Mean Flight Hours (SD)</td>
<td>6541.7 ± 4515.8</td>
<td>48.6 ± 194.9</td>
</tr>
</tbody>
</table>

Procedure

Pre-Study

For the pre-study, data was collected over three, 5-day class cycles. On the first day of data collection, each IP was assigned two SPs. For each simulator session, one student flew the simulator, while the other student observed from the rear area of the simulator cabin. After 2 hours (hr), the students changed roles. The IP remained in the front seat during both sessions. On each day of the class cycle, the students and their IP completed the SSQ immediately after the simulator flight period. The participants did not use the same individual simulator for all 5 days.
of data collection; simulator assignments were based on availability. A total of 950 SSQs were completed in the pre-study.

Recommendations

After analyzing the data from the pre-study, a number of recommendations to reduce SS were provided to the directors of the flight training program. The recommendations that were implemented and incorporated into the training program were: simulator flights were reduced from 4 to 3 hr (1.5 hr per student); pilots were instructed to close their eyes before freeze/reset; and unusual or unnatural maneuvers were limited. The course was reduced from 5 days to 3 days since most of the hover training and ground work were removed from the program of instruction entirely. There was an effort to avoid improperly calibrated simulators (e.g., misalignment, out of focus, luminance mismatch, distortions) until repaired. And finally, emphasis was placed on stressing the importance of proper rest/health discipline, and giving instructors enough time to adapt and maintain adaptation.

Post-Study

Based on results of the pre-study, recommendations were made and implemented during the post-study. Procedures were similar to those in the pre-study however the class cycle was shortened from 5 days to 3 days; thus data was collected over a 3-day class cycle. Additionally, the time each student flew the simulator was reduced from 2 hr each to 1.5 hr. The SSQ was completed at the end of the simulator session on each of the 3 days of the class cycle. Data from 225 SSQs were collected in the post-study.

Results

Pre-Study

In the pre-study, participants completed the SSQ across one 5 day class cycle (i.e., five administrations). The most commonly reported symptoms overall included eyestrain, general discomfort, headache, and difficulty focusing. Regardless of severity, 72% of IPs and 91% of SPs reported at least one symptom over the course of the five sessions. As for the profile of the SSQ subscales, disorientation symptoms predominated, followed by oculomotor symptoms. Over the course of the 5 days, mean total SSQ scores ranged from 10 to 45.

Post-Study

One year following the pre-study, after the recommendations were implemented, the post-study was conducted. Instructor pilots and SPs completed the SSQ across one 3 day class cycle (i.e., three administrations). In the post-study, the most commonly reported symptoms included eyestrain, general discomfort, nausea and burping. With regard to frequency data, 64% of IPs and 90% of SPs reported at least one symptom, regardless of severity, over the course of the 3 days. The profile of the SSQ subscales was the same as that of the pre-study, with disorientation symptoms predominating, followed by oculomotor symptoms. Over the course of the 3 days, mean total SSQ scores ranged from 10 to 17.
Effectiveness of Recommendations

To determine the effectiveness of the recommendations in reducing SS, a 2 x 2 between-subjects Multivariate Analysis of Variance (MANOVA) was conducted. The two independent variables were experience (IP or SP) and recommendations for SS reduction (pre-study or post-study) and the four dependent variables were the differences in nausea scores, oculomotor scores, disorientation scores, and total scores of the SSQ. Differences in each SSQ subscale score and total score from the first administration to the last administration were calculated for each participant. Of particular interest was the comparison of the difference scores from the pre-study to those of the post-study. The MANOVA showed a significant main effect of experience, $F(4, 270) = 3.055$, $p = .017$, and a significant main effect of the recommendations, $F(4, 270) = 2.628$, $p = .035$. There were no significant interactions. Levene’s test of equality of error variance showed that this assumption was violated. To account for this violation, the data were subsequently analyzed using independent $t$-tests (equal variances not assumed) and a Bonferroni correction was applied to reduce the risk of a Type 1 error ($p = 0.05/6 = 0.0083$).

Independent samples $t$-tests revealed a significant main effect of experience on nausea, oculomotor, and total SSQ difference scores (Table 2), such that IPs had significantly larger (more negative) difference scores, and thus experienced more SS than SPs. There was also a main effect of the recommendations on nausea, oculomotor and total SSQ difference scores (Table 2), indicating that difference scores were more negative in the pre-study. This signifies that those SS symptoms were more severe over the class cycle in the pre-study than in the post-study.

Table 2. Mean Difference Scores (± SE).

<table>
<thead>
<tr>
<th>Experience</th>
<th>IP</th>
<th>SP</th>
<th>$t$</th>
<th>$p$</th>
<th>Pre-Study</th>
<th>Post-Study</th>
<th>$t$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nausea</td>
<td>-13.14 ± 3.18</td>
<td>-2.19 ± 1.46</td>
<td>-3.13</td>
<td>.002</td>
<td>-8.79 ± 1.80</td>
<td>1.27 ± 2.48</td>
<td>-3.28</td>
<td>.001</td>
</tr>
<tr>
<td>Oculomotor</td>
<td>-12.05 ± 2.80</td>
<td>-2.88 ± 1.40</td>
<td>-2.93</td>
<td>.004</td>
<td>-8.32 ± 1.64</td>
<td>-0.20 ± 2.31</td>
<td>-2.87</td>
<td>.005</td>
</tr>
<tr>
<td>Disorientation</td>
<td>-15.09 ± 4.12</td>
<td>-3.81 ± 1.95</td>
<td>-2.48</td>
<td>.014</td>
<td>-10.08 ± 2.29</td>
<td>-1.67 ± 3.66</td>
<td>-1.95</td>
<td>.054</td>
</tr>
<tr>
<td>Total</td>
<td>-15.19 ± 3.55</td>
<td>-3.26 ± 1.58</td>
<td>-3.07</td>
<td>.003</td>
<td>-10.26 ± 1.97</td>
<td>0.00 ± 2.87</td>
<td>-2.95</td>
<td>.004</td>
</tr>
</tbody>
</table>

Note: Negative difference scores indicate SSQ scores increased from the first administration to the last. Positive difference scores indicate SSQ scores decreased from the first administration to the last.

Discussion

According to Stanney, Kennedy, and Drexler (1997), simulators producing mean total SSQ scores greater than 15 are a concern, and scores greater than 20 indicate a “problem simulator.” Consequently, the simulators used in flight training program could be classified as problem simulators for the pre-study, but not so for the post-study. In addition, the profile of the three subscales indicated that disorientation symptoms predominated in both the pre- and post-study, which is atypical of SS, in which oculomotor symptoms are most frequently observed. High disorientation scores are correlated to postural instability following simulator sessions (Kennedy, Berbaum, & Lilienthal, 1997), which raises concerns regarding ground safety (e.g., exiting the simulator, driving home from the simulator session, and even flying aircraft).
Rotary wing aircraft are known to cause higher rates of simulator sickness compared to fixed wing aircraft (Johnson, 2005). Reviews of rotary wing flight simulators found the occurrence of SS ranged from 13 to 70% (Wright, 1995). The occurrence of SS for both the pre- and post-studies (64 to 91%) are high compared to other frequency rates published in the literature for military flight simulators. There are several possible explanations or factors that may have contributed to the high frequency rate. For example, the logistics of the flight training program require an SP to be in the back of the FMS while another SP is in control. Degree of control is an important factor influencing SS, as sickness decreases as the amount of control increases (Johnson). Also, this study included several IPs with many thousands of hours of flight experience, another factor well known to increase susceptibly to SS (Johnson). Lastly, data was not collected regarding the prior histories of motion/simulator sickness in the participants.

Consistent with previous SS literature, in both the pre- and post-studies, IPs reported significantly higher SSQ scores than the SPs for all four SSQ subscale scores. While this finding was expected on the first day of simulator flight, the IPs showed an increase in SS symptoms over the 5-day course in the pre-study and the 3-day course in the post-study which was unexpected. Despite the role flight experience plays in SS, IPs would be expected to adapt to a simulator over time. There are a number of factors which may have contributed to this unexpected finding such as lack of control over previous day activities (simulator versus actual flight) and variability in instructor schedules. This is, of course, speculation and additional research will need to further identify the root cause of the absence of adaptation in the IPs.

According to Johnson (2005), the best current solution to SS is adaptation (i.e., developing a tolerance to the stimuli that produce sickness). This study revealed evidence of adaptation in the nausea SSQ score in the post-study. Perhaps, for the post-study, the 3-day class cycle was not long enough to adapt significantly to the other symptoms of SS. However, it is important to note that the implemented recommendations were in fact improving adaptation for both IPs and SPs as evidenced by the significant changes in difference scores.

**Limitations**

Although every effort was made to ensure the recommendations provided were implemented, factors such as costs and practicality limited the implementation of some recommendations. Additionally, some behaviors continued that were not recommended, such as positioning the SP in the back seat when not flying. In addition, data was unavailable as to which TH-67 FMS each individual participant used each day. This lack of consistency in simulator use introduces a potential confound to the study thus limiting the precision of conclusions. Future studies should track simulator use/assignment to determine if SS is more prevalent and/or severe in a particular FMS. Finally, in the pre-study, data was collected over three class cycles whereas data was only collected over one class cycle in the post study. Thus, the violation of the homogeneity of variance assumption was potentially due to the unequal sample sizes of the pre- and post-studies. Future studies should aim to ensure equal sample sizes when comparing group differences.
Conclusion

Flight simulators are a safe and cost effective alternative to actual flight and are an invaluable tool for training SPs. However, as the Army relies on simulator technology, it cannot afford to ignore the lessons of the past. These studies provide evidence that adherence to well documented simulator practices within the task, simulator, and individual domains can reduce the prevalence and/or severity of SS in emerging flight simulation systems. Although the optimal solution to the SS problem lies in addressing and evaluating SS during a simulator’s design and development stages, these recommendations can be used as interim solutions to reduce SS.

Acknowledgments

The authors wish to thank the staff and instructors at Warrior Hall for their cooperation during this study and SFC Daniel R. Fuller for his role in data collection. Also, we wish to thank Dr. Loraine St. Onge for her extensive and constructive feedback on early drafts of this paper. The view, opinions, and/or findings contained in this paper are those of the authors and should not be construed as an official Department of the Army position, policy, or decision. Note: SSG Bass is currently stationed at Fort Hood, TX. LTC Wildzunas is currently at the US Army School of Aviation Medicine. LTC Martin is currently at Walter Reed Army Medical Center.

References


