

A Case Study of Severe Space Motion Sickness

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- BACKGROUND:** Motion sickness remains a significant and unpredictable problem during spaceflight. One of the major difficulties in understanding the etiology of space motion sickness has been a lack of data at the time the symptoms occur, i.e., immediately after entry into space and during return to Earth; in these phases of the mission is when critical operational tasks are performed.
- CASE REPORT:** We report here the case of a crewmember who experienced severe motion sickness symptoms immediately after launching into space and for several days into the mission. Verbal reports recorded during and immediately after the flight describe in detail the symptoms and their underlying causes. The prominent cause was oscillopsia that was induced by moving the head, wearing prescription eyeglasses, and translating the whole body.
- DISCUSSION:** In this case, space motion sickness was sudden and induced by voluntary or involuntary head or body movements in any plane. These head movements caused a visual disturbance that induced the perception that the environment was oscillating. The exaggerated motion perceptions suggest an increased vestibular sensitivity and/or decreased pursuit-optokinetic mechanisms in orbit and immediately after landing.
- KEYWORDS:** motion sickness, spaceflight, oscillopsia, spatial disorientation.

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Approximately 70% of crewmembers experience space motion sickness during their first space mission. Common symptoms include stomach awareness, vomiting, malaise, loss of appetite, and impaired concentration.⁸ Half of the crewmembers, however, report transient, moderate symptoms that do not impact their activities during the mission. Only a few Russian and U.S. crewmembers have been incapacitated for 1 wk or more.⁵

Space motion sickness symptoms are generally documented after a space mission when the flight surgeon interviews the astronauts. However, the severity and time course of the symptoms and their underlying causes are often not reported in these postmission medical debriefings.¹ We present below the transcript of verbal reports recorded in flight by one crewmember who experienced severe motion sickness symptoms. The crewmember also described the situations that provoked the motion sickness.

The NASA Institutional Review Board approved the protocol and a written informed consent was obtained before the start of the study. The crewmember approved the publication of this manuscript. Reports were recorded on a tape recorder or written notes. Transcriptions of the tapes were performed immediately after flight and the transcripts were discussed during a postflight interview with the crewmember for clarification.

This crewmember was flying in space for the first time. The mission was more than 7 d on board the Space Shuttle (the exact mission duration is not included to protect the anonymity of the subject). The crewmember was trained to score the severity of motion sickness on a scale of 0 to 20, with 20 being frank vomiting and 10 being midway between feeling normal and vomiting.¹⁰ Scores were reported at regular intervals throughout the working day. The median of all reported scores for each flight day is shown in **Fig. 1**.

CASE REPORT

The crewmember had a pilot's license and was a copilot of a subsonic jet trainer aircraft for almost 3 yr before he participated in a space mission. He was not a sailor. When he was a

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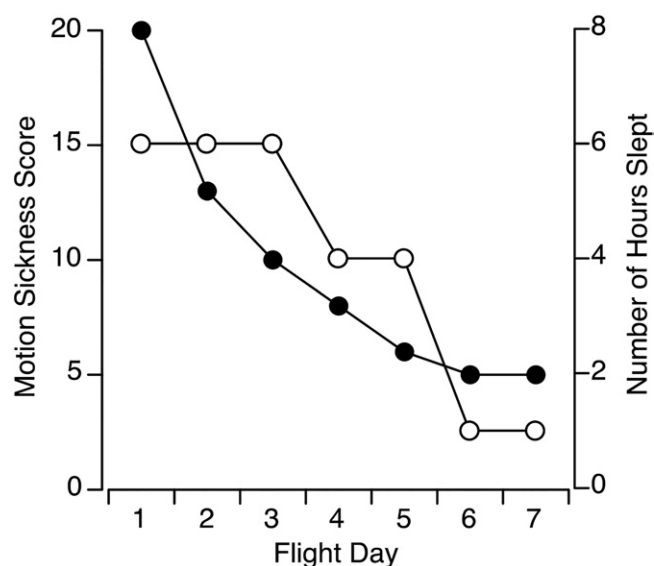


Fig. 1. Median motion sickness scores (black circles) and number of hours slept (white circles) reported by the crewmember during each flight day.

child, he was susceptible to motion sickness during car rides and carnival rides. The crewmember has not been involved in activities that showed superior balance or vestibular capabilities (e.g., figure skating or ballet dancing) or had any events that might have damaged the vestibular system (e.g., multiple ear infections as child or head trauma).

Approximately 2 yr before his spaceflight, the crewmember participated as an operator and a test subject in a series of parabolic flights on NASA's KC-135 aircraft. He was nonmedicated during the first flight and got sick on the seventh parabola. On the subsequent flights, he took anti-motion sickness medication (scopolamine and dextroamphetamine) and he did not get sick.

The crewmember also demonstrated average susceptibility to motion sickness during three visual and vestibular tests performed approximately 2 yr before his spaceflight. The first test was an exposure to a virtual environment, during which the crewmember only reported stomach awareness. The second test was a Staircase Velocity Motion Test (SVMT), during which the crewmember was asked to pitch and roll his head during passive yaw body rotation that increased in velocity. During the SVMT, he had severe motion sickness (vomiting) after 275 head movements and the chair velocity had reached 13 rpm. During the third test, the crewmember wore vision reversing prisms while walking around the laboratory and he experienced severe motion sickness after wearing up-down reversing prisms for approximately 4 min, and moderate motion sickness after wearing right-left prisms for approximately 20 min. The crewmember also reported that he had oscillopsia when he wore single vision glasses after he switched to wearing bifocals.

The following section is a daily description from the crewmember of what occurred during the flight.

Flight Day 1

"I was sitting in my chair and as soon as we got MECO [main engine cut-off] I just felt I was in the KC-135 and had that

tremendously full feeling in my head and when I moved my head around at all it felt very unstable. I had oscillopsia—vertical and horizontal gaze. This was associated with a marked stomach awareness, and I escalated on my scale from being at 0 at solid rocket booster separation to rapidly 15 going on 18. The first thing I wanted was some Phenergan. I asked [crewmember] immediately if he had any oral Phenergan on board and he said he would get me some as soon as he finished the DTO [detailed technological objective]."

"And so, I left my helmet on. I felt that with my helmet on, it would help decrease my head movement. I was distracted by trying not to throw up. I could not reach my emesis bag—I had the gloves on, so I was battling to get the gloves off so I could put the camera together. We then proceeded to get the camcorder out. At this point, I really felt that I was going to be in big trouble. I tried to sit very calm in the chair. I didn't even want to even try taking my helmet off. I just felt like sitting quietly in the chair strapped in."

"I was helping people to put things in the bag. I found I had to take my helmet off and as soon as I did, I just grabbed this bag and vomited three times. And then taking off my suit, I vomited again another three times. And I just kept throwing up and feeling just terrible. I was throwing up about every 10 minutes 'till I had counted—I had thrown up at least 30 times. It felt like it was a space of like 1 minute, but I know it was more like 45 minutes."

"I had a full feeling in my head and wanted to get my stethoscope and listen to bowel sounds, but I couldn't even bring myself to do that. I was quite amazed. Although in the KC I've been sick, I was able to work. This was totally incapacitating for me. I'm certain any movement at all—even if I didn't move my head, would start to make me feel terrible."

"Um, things that made it worse in flight? I remember one time I was doing something and ended up standing on the middeck lockers. And I felt like I was standing on the floor where all the mid-deck lockers were. I didn't find that particularly provocative. But when we had to go to the module to do the Spacelab activation, I really became quite sick. I found the tunnel very disorienting (Fig. 2). Although I knew which direction I was going in, I had to stop in the tunnel to throw up and again on entering the lab. Luckily, everyone helped me do my activities."

"I tried taking an oral Phenergan right at the beginning, but promptly threw it up so I had [crewmember] give me an IM [intra muscular] injection—50 mg of Phenergan—in my left hip. This may have helped a little, but not a lot. I just seemed to keep vomiting. And I didn't feel like eating—I wasn't taking any liquids in the first 24 hours and certainly no food. I required another 50 mg IM Phenergan and went to bed as soon as I could. I noticed that even my sleep station was moving. When I moved, the sleep station was moving. It just seemed that the environment was moving and I was moving."

Flight Day 2

"On flight day 2, I had to restrict my activities. I could not perform the [experiment]. I vomited six times, and I had another 25 mg of Phenergan—orally. The curious part was that any type of movement that I made, regardless of whether it was moving my head or my whole body, it made me feel quite sick. Although certainly,

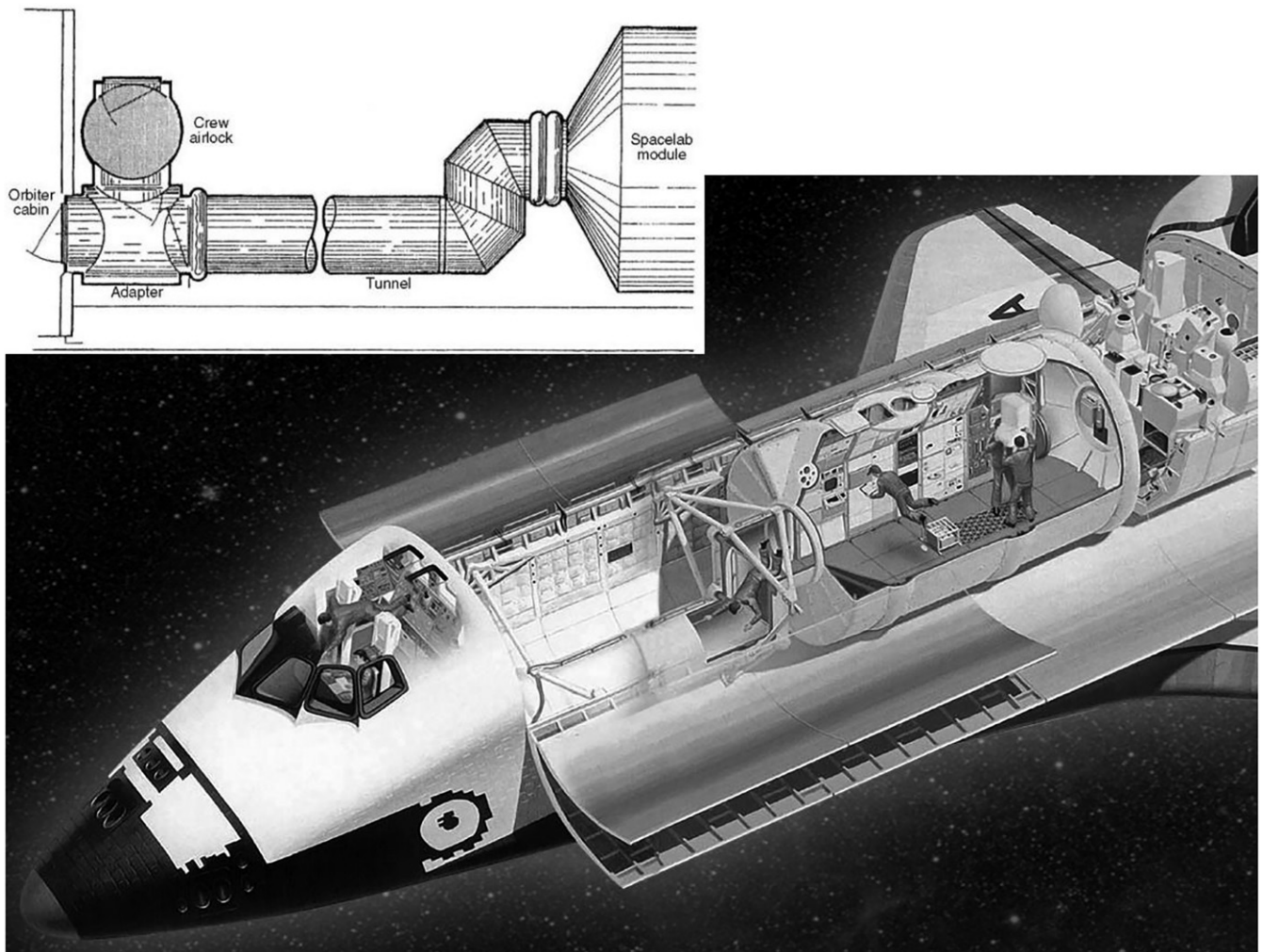


Fig. 2. The transfer tunnel between the Orbiter cabin and the Spacelab module was a cylindrical structure with an internal unobstructed diameter of 1.0 m. The tunnel was 5.8 m long. A joggle section of the tunnel compensated for the 1.1-m vertical offset of the Orbiter middeck to the Spacelab module centerline. Photo and drawing courtesy of NASA.

with the movement of my head, it was much worse than my body alone. I was starting to take in more fluids on FD2.”

Flight Day 3

“Here we are flight day 3 and I haven’t even looked out the window. Today I didn’t have any medication and I have not thrown up, although I’ve had a lot of reflux. I’d say I was having reflux maybe every hour. My head still isn’t perfect at all. In fact, I’ve been going all day long with a level of about 10.”

“I’ll go through the symptoms checklist for the day. I’ve had, I’m sure, pallor—white as a ghost. I’ve had subject warmth and flushing. I’ve been feeling very, very cold although I felt, I’ve felt sweaty. It’s been a cold sweat. I’ve been very dry and I have not had that much strength. I have had yawning, and I’ve had some back pain, but I’ve not had any distorted smell or taste. And I’ve had some lethargy. Earlier on today, I had a moderate persistent headache. It was not as incapacitating. I had some disorientation, especially when I was helping [crewmember] with the [experiment]. I was disoriented a number of times in terms of what was up and what was down.”

“I had a lot of drowsiness. In fact, when I was doing the [experiment] today, I could not keep my eyes open, which was totally unusual for me. I had marked concentration impairment and was making mistakes that I only found out about today. For example, I had one [experiment] container that I did not fix the lid on correctly. When I tried taking it out today, it was stuck. I did manage to get it out, but it gave me a good indication that I was impaired yesterday working.”

“I also found wearing my glasses was exceptionally provocative and I have not worn them since MECO. I’ve known this before, when I put a new pair with my astigmatic prescription—that’s very provocative to me. And so, I’ve taken my glasses off. I tried putting them on today, and it was starting to make me feel worse. In fact, my vision seemed to be worse with them. I felt that I was much less myopic with my astigmatic correction than back on Earth. The only problem I had was that I had to deal with two containers that had written 1 and 7. And it wasn’t a European 7 and I did not distinguish the 1 and the 7 and I mixed the two containers up. But it was only brief—I don’t think it impacted the experiment but it made me realize that, indeed, I did have some impaired concentration.”

"I had total appetite loss and I had severe epigastric discomfort and I had slight diarrhea. I was nauseated, even today. I hope by tomorrow I feel better."

Flight Day 4

No verbal report for that day. The crewmember recorded the motion sickness scores on paper.

Flight Day 5

"My sickness scale all day has been around 5 to 8. For no reason, it would zip right up to 20. I've had about eight bouts of vomiting, frank vomiting, but it has been certainly regurgitation of stomach contents. Where I have been doing absolutely nothing and suddenly it would come up. I haven't had any motion sickness medication for a couple of days, when I had it on the day we arrived and on the 2 subsequent days."

Flight Day 6

"My score today is probably around 5. I still persist having a very heavy feeling in my head and heaviness when I move my eyes. I could make myself quite nauseated if I persisted with head movements. I haven't had too much to eat today, but that's just because I'm tired of the food around here. Positive symptoms—this headache is moderate and persisting. I have not taken any medication for it. I haven't taken any anti-motion sickness medication in 3 days. I have had reflux of stomach contents several times today, and I'm too busy to actually write it down."

Landing Day

"For the first 3 or 4 days in flight I had the most incredible sensation that the whole environment was moving. Like when I'd go to bed at night in the sleep station. You kind of float up into and bang up against the restraints. Well, the whole cabin was moving and undulating all the time. It was like coming back here, the same thing happened. When I first started moving my head, even now I'm having it a bit. When I came back and landed, and [crewmember] said, 'OK you guys, if you want to see something fun, just tilt your head down!' So, I put my head down and of course everything started going like this, and that's when I started getting nauseated."

"I can't do testing today. I can't walk out of the door. I'm gonna probably not be able to shower right now. Like right now I can at least sit here. When I first got in there, the whole wall was moving."

1 Day After Landing

"After the landing, I had the after effects if I moved my head and closed my eyes. With my eyes closed and I could feel myself moving. In fact, when I went into the infirmary and I was on this stretcher, I remember leaning back and I closed my eyes and it just felt like things were just moving. They were still moving. And I'd open my eyes and I said to someone, 'I'd like to be able to bolt my head in place,' because it's just, like it's everything I do, the smallest little movement produced the exaggerated sensations."

"The first night after the flight I woke up at 4 am with a full bladder, but I didn't dare get out of bed. I didn't want to get up because the bed was moving, you know, and I decided to hang onto the dresser. I thought this is ridiculous. Do not get up. This is dumb. You're going to kill yourself. So, I thought, go back to bed with a full bladder. There was an oscillation that would damp down, like it wouldn't be constant in one direction. I can just tell you, it would just sort of move like this and it would damp down and then it was quiet. And I'd get up in the middle of the night and roll over to move, to move the cover. And I'd go over and I'd just feel like this and then, and then it would just dampen down. And that's what it was in flight, only in flight it lasted longer and the oscillations were greater."

"The first night it was marked. The second night it was there a little bit. The floor moved when I first got up in the morning. When I first got up out of bed and put my feet down on the floor and went to move, it was like this. Just for a couple of little beats and then it was gone."

"Mmm, what was the most provocative? I had just gross oscillopsia. It happened in any head movement at all, and it was exceptionally provocative. I tried moving my head like that and it was just moving. But it wouldn't sort of just move and stop. It would stay moving. And it was damp and down. This was the strongest thing I've ever felt. It was like I had streptomycin toxicity. It's what I've read in the literature with this guy who took streptomycin and knocked out his inner ear. And then the only thing he could do is to jam his head in the bed in order not to move his head. That's exactly what it felt like."

"The tunnel was provocative too. I had to stop, throw up and I'd go on to the rest of the way. I found that if I closed my eyes and went floating down the tunnel and opened them, only on the last day, did I not get a feeling like I was gonna be sick, because I didn't know where I was inside the tunnel. I didn't mind things being upside down and backwards if I walked that way myself, or hung onto a handrail, or someone was hanging upside down. What I did mind was going through the tunnel with the motion at the same time. It was the combination of the motion and being sort of at the wrong axis and then having to turn your head and figure out which way you really wanted to go through."

"The passive thermal [control] cooling mode the last day of the flight when we started rotating around the z-axis of the Orbiter—that was very provocative for me. The commander said, 'If anybody feels the onset of Gs here, it's because we're maneuvering the Orbiter.' And I mean you could feel it. You could end up sort of floating over towards the cabin because the G force—that was little but it was moving you around. But certainly in the sleep station I could feel it, and I just wanted to stabilize the whole world again. I just did not like that disturbance. And I was nauseated and I was trying to get the Phenegan. I felt too nauseated to get out of my sleep station to get the Phenegan, and nobody was drifting by to get me, so I stayed..."

DISCUSSION

Space motion sickness occurred in the subject during situations that elicited the illusion that the environment was moving.

These situations included moving the head or the body, wearing prescription eyeglasses, and translating in the tunnel. The symptoms occurred when the head or body moved in any plane, and these movements could be voluntary or involuntary. A very slow rotation of the spacecraft (<0.5 rpm) during the Space Shuttle passive thermal control maneuver (“barbecue mode”) generated a centripetal acceleration ($<0.01 \text{ m} \cdot \text{s}^{-2}$) that was perceived by the crewmember as a translation of the sleep station.

The head and body motions caused a visual disturbance that induced the perception that the environment was oscillating. The likely underlying cause of this oscillopsia was an intrinsic potentiation of the vestibulo-ocular reflex and/or a defect in the pursuit-optokinetic mechanisms that allow clear and stable vision during everyday head movements.³ Indeed, increases in the gains of motion perception,⁹ vestibulo-ocular reflex,⁴ and vestibulo-spinal reflex¹² have been previously observed in microgravity. It has been proposed that the reduced gravitational acceleration in space results in an upregulation of the sensitivity of utricular afferents.^{2,13}

The severity of motion sickness decreased throughout the flight for the individual in this case study. However, by flight day 7, the crewmember was still not able to complete all the activities, especially those involving head movements. The symptoms then reappeared after landing, a condition that has been described as “entry motion sickness.”¹¹ The subject had two intramuscular injections of Phenergan (promethazine) on landing day and none on the following days. However, motion sickness symptoms during body motion in both pitch and roll persisted for 8 d after the flight. A recent study has shown that sleep deprivation increases susceptibility to motion sickness during passive horizontal linear oscillation on a parallel swing on Earth.⁶ Interestingly, our subject reported poor sleep quality during the flight (Fig. 1) and insufficient sleep for 1 wk after the flight.

The physiological mechanisms responsible for the elicitation of motion sickness are complex and still not fully known. Lackner⁷ recently reviewed the potential mechanisms and theories of motion sickness. Although cases of severe space motion sickness, similar to the one reported here, are rare in the astronaut population, such an incapacitating condition is to be expected in passengers on suborbital flights.

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