15

The Effects of Motion Induced Sickness on Military Performance

ARNON ROLNICK AND CARLOS R. GORDON

Motion Sickness and Human Performance Laboratory, PO Box 8040, Israeli Naval Hyperbaric Institute, Haifa, 31080 Israel

ABSTRACT

This chapter describes the motion sickness syndrome, its etiology and incidence. Laboratory and field studies on the effects of motion sickness on human behavior and performance are reviewed. An explanation of the debilitating effects of motion sickness within the frame of reference of uncontrollability and 'helplessness' is proposed. Current treatments and preventive measures are summarized.

INTRODUCTION

The logistics of modern military operations require rapid transfer of military personnel by land, sea or air to the combat zone. The moment a human being boards a vehicle designed to transport him passively, he incurs the risk of motion sickness. Though the term sickness is somewhat misleading—motion sickness is a transient normal response to unnatural motion stimulation—there is no doubt many people experience it as a devastating condition which makes them highly passive, apathetic and depressed. The debilitating effects of motion sickness, and the subsequently impaired operational performance, constitute a major threat to the success of military operations and sometimes to the soldiers' lives.

In this chapter, we briefly describe the motion sickness syndrome and its etiology. The extent of the problem is described by presenting data on its incidence in the military. We then focus directly on the effects of motion sickness on human performance with a review of the main laboratory and field studies. We propose an explanation of the debilitating effects of motion sickness within the frame of reference of uncontrollability and 'helplessness'. Finally, we present current preventive measures.

Handbook of Military Psychology. Edited by R. Gal and A. D. Mangelsdorff.

1119 GAL.

The Motion Sickness Syndrome

Motion sickness is a transient disorder in healthy subjects exposed to certain motion patterns. It is the normal response to certain abnormal types of motion in a subject with no organic or functional disorder. Travel sickness, car sickness, seasickness, airsickness and space sickness are some of the forms taken by motion sickness or kinetosis. Seasickness is the form most often encountered, and it is for that reason that seasickness will be given special consideration in this chapter.

Motion sickness is easily recognized. It is characterized by the development of pallor (mainly facial), cold sweating, a general feeling of discomfort, nausea, and ultimately by emesis (Tyler & Bard, 1949; De Wit, 1953). One can generally rely on the appearance of these symptoms, and they exhibit a sequential pattern of development. Pallor and cold sweat usually precede the epigastric discomfort and nausea, which intensify to the point of emesis. A few individuals, however, reach the emesis stage so rapidly that nausea and other early signs may not be encountered prior to emesis. Other individuals sometimes reach severe nausea but never vomit; such subjects usually suffer more (Reason & Brand, 1975).

There is another important group of symptoms which accompany seasickness. These include drowsiness, sleepiness, apathy and depression. Although most of the important reviews mention the existence of these symptoms, very few studies deal with these phenomena. We discuss this point in detail later.

Generally, on return to land, seasickness symptomatology rapidly disappears. Some people continue to feel a certain amount of general discomfort for a few hours, while others report a tumbling or swinging sensation similar to that experienced at sea. This latter phenomenon, 'mal de débarquement', is a relatively non-disabling condition regarded as a process of adaptation to the motion of the ship.

Etiology

Motion sickness is a disturbance caused by certain motion patterns. A wide variety of motion conditions can produce motion sickness: the motion of swings, ships, airplanes, automobiles, and even trains. Both the vertical-linear component and the combination of angular accelerations with head movements are very provocative. The common characteristic of all the conditions which cause motion sickness is varying acceleration. That is, for motion to produce motion sickness, the acceleration of the subject must be changing with time (Money, 1970).

The vestibular labyrinth in the inner ear acts as a sensor for acceleration. The otolith organs register linear accelerations, while the semicircular canals react to angular accelerations. It has been shown that motion sickness does not occur in individuals lacking the labyrinth (Graybiel & Johnson, 1963). These facts led some researchers and ear, nose and throat specialists to argue that overstimulation of the vestibular system causes an unnaturally large influx of neural messages into this area of the brainstem, which is responsible for eliciting the characteristic motion sickness reaction (De Wit, 1953; Jongkees, 1967).

However, a closer examination of the conditions which produce motion sickness reveals that the overstimulation theory is an oversimplification of the issue. It has been shown that other sensory systems may be involved in eliciting motion sickness. Witkin (1949) reported that movement of the visual field without movement of the body can produce motion sickness. A wide cinema screen and some static flight simulators (which include a large moving visual display) are also provocative (Miller & Goodson, 1960; Kennedy & Frank, 1984). Similarly, proprioceptive stimulation can also produce a sensation of motion and motion sickness (Bles, 1981).

It seems that the *interaction* between vestibular information and the other senses, in particular vision, is highly relevant in explaining motion sickness. It is known that the incidence of seasickness on a ship's bridge is lower than it is below deck. When on the bridge, one can see the outside world, and thus there is agreement between the information coming from the eyes and from the vestibular system. Below deck, the individual's whole visual world is moving with him, thus providing him with

the mistake
relation to t
A similar
children tra
car, who oft
ness becaus
outside the
children a fe
sickness. M
studies conc
summary, h
sickness can
of visual info
On the ba
psychologist
rearrangemen
This states t
producing m
senses: the
vestibular pr
and tendons).
situations wh
acterized by
which the sig
patible with
variance with
basis of past

The Extent o
Motion Sickn

It is rather c
motion sickn
because the o
many differen
lity, the type
as the criterio
person with
cumb to mot
appropriate a
time.

Seasickness

Reports on th
1"; (Tyler, 1

the mistaken impression that he is not moving in relation to the outside world.

A similar phenomenon might be observed in children travelling in the rear passenger seat of a car, who often develop symptoms of motion sickness because they cannot see the environment outside the vehicle. It is sufficient to seat these children a few centimetres higher to prevent motion sickness. Money (1970) reviewed a number of studies conducted on the role of vision. In his summary, he states that the incidence of motion sickness can be reduced by 50-90% by correct use of visual information.

On the basis of such observations, the British psychologist J.T. Reason formulated the sensory rearrangement theory (Reason & Brand, 1975). This states that the sensory systems involved in producing motion sickness are the so-called spatial senses: the vestibular system, vision, and non-vestibular proprioception (in the joints, muscles and tendons). The basic assumption is that all those situations which provoke motion sickness are characterized by a condition of sensory conflict, in which the signals from the spatial senses are incompatible with one another and consequently are at variance with what we have come to expect on the basis of past experience.

The Extent of the Problem: The Incidence of Motion Sickness

It is rather difficult to estimate the incidence of motion sickness among the general population, because the occurrence of sickness is dependent on many different factors: the individual's susceptibility, the type and magnitude of the stimulus, as well as the criterion used to define motion sickness. Any person with normal vestibular function can succumb to motion sickness, if the type of motion is appropriate and continues for a sufficiently long time.

Seasickness

Reports on the incidence of seasickness vary from 11% (Tyler, 1946) to 100% (Chinn & Smith, 1953). Holling, McArdle, Trotter (1944) ranged it between 15% and 70%. To avoid confusion, we quote examples of the seasickness percentages reported while referring to the question of the criteria employed and vessel size.

Chinn (1963), who was responsible for a large post-war research project aboard American military transports making the North Atlantic crossing, summarized his studies as follows: 'During moderate turbulence, about 25% to 30% become sick to the point of vomiting.' While vomiting is the observable ultimate sign of motion sickness, it is clearly not the only one. Some persons might feel severe malaise and pronounced nausea, but never reach the point of vomiting (Reason & Brand, 1975).

In a recent British study, two thousand sailors serving in the Royal Navy were asked to indicate the frequency of episodes of motion sickness (Pethybridge, 1982). The 'episodes of motion sickness' were not limited to vomiting. The results indicated almost 70% of Naval personnel suffer from seasickness episodes, especially when serving on smaller vessels. One of the advantages of this report was that it compared incidence of sickness in 14 different types of vessel. On the basis of a mathematical model developed in that study, it was shown that episodes of seasickness were negatively related to ship size.

Many navies now employ the Fast Attack Missile Craft (FAC), because of their relatively low cost and high effectiveness. However, the small size of these craft and their high speed render them unstable at sea, and therefore very likely to provoke seasickness. For example, 62% of the sailors aboard the Israeli SAAR Missile Boats (300-500 tons) reported episodes of emesis, while 80% experienced nausea on their first cruises (Rolnick, 1984, 1985).

It is generally agreed that some kind of adaptation to seasickness takes place as experience is acquired at sea. However, data from Israel (Rolnick, 1985) and from Britain (Pethybridge, 1982) indicate that although some reduction does occur in the incidence of seasickness, more than 50% of the sailors continue to suffer from episodes of seasickness after one year's service at sea. This by no means implies such a high incidence occurs on every cruise. If the sea is very calm, fewer sailors might suffer. However, the data from the Israeli studies reveal that even a very low sea (1–3 in the Beaufort scale) can provoke a high incidence of seasickness (Rolnick, 1985; Gal, 1974; Keinan *et al.*, 1981; Rosenbaum & Rolnick, 1983).

Airsickness

Airsickness incidence is very high in the first stages of aircrew training. Data from the British Royal Air Force indicate 76% of flying cadets suffer bouts of airsickness, and that 18% of this group suffer to such an extent as to warrant abortion of at least one training flight (Reason, 1968). A recent longitudinal research project conducted at the US Naval Aerospace Medical Research Laboratory (NAMRL, Pensacola) documented the incidence and severity of airsickness in naval flight officers during basic and advanced training, and in fleet readiness squadrons. Seventy-four per cent of the cadets reported being airsick, and 39% vomited on at least one flight during basic training. This high incidence continued during advanced training, but was significantly lower in the fleet readiness squadrons (Hixon, *et al.*, 1979, 1980, 1983). A survey conducted in Israel, using the self-reports of Israeli Air Force flight cadets, revealed that 46% of the subjects experienced nausea at least once during the first five flights (Fox & Arnon, 1988). It should be borne in mind, however, that during training the self-report method may be underestimated, due to the candidate's desire to conceal his problems (Dobie, 1974).

Other members of the crew have more pronounced episodes of airsickness. A recent study conducted by the US Air Force reported the frequency of airsickness in aerial gunners as 76%, and in electronic warfare officers, 57% (Geeze & Pierson, 1986). These crew members do not have any control over the motion stimulation they experience. This may be one of the main reasons for the higher incidence in these groups as compared to pilots. (The influence of controllability will be discussed later.) The problem is most acute in air transported troops, since these personnel are not flight trained, and some of the operations involve low level flight through turbulence, without an adequate external frame of reference.

Other forms of motion sickness

A recent report from Israel (Lerman, 1987) is probably the only one to deal with motion sickness in tanks. In this report, it was found that 20% of the investigated subjects experienced nausea, while 40% complained of lethargy.

Simulator sickness is a relatively new phenomenon, occurring in flying simulators which use wide field visual displays. This is one of the cases in which it is the absence of motion which produces sickness. In the first report on simulator sickness over thirty years ago, Harvon & Butler (1957) found that 77% of the users reported some motion sickness symptoms. Other investigators report an incidence ranging from 27% to 88% (Kennedy & Frank, 1984; Crowley, 1987; Gower *et al.*, 1987).

Space motion sickness was observed early in the Soviet manned orbital flight program, and has been consistently reported since then (Matsnev *et al.*, 1983). No symptoms were reported by American astronauts in the Mercury and Gemini spacecraft. However, the disorder was reported by Apollo crews (Homick & Miller, 1975), and by half of the crew members on the space shuttles (Homick, Reschke, & Vanderploeg, 1984).

THE EFFECTS OF MOTION SICKNESS ON HUMAN PERFORMANCE

The motion sickness literature is characterized by a number of inconsistent findings concerning human performance under motion sickness conditions. While the results of some carefully controlled laboratory studies are inconclusive (though obviously, the act of vomiting itself momentarily precludes the performance of most tasks), other studies and recent field studies indicate that performance is indeed impaired as a result of motion sickness. We try to account for these inconsistent results using a psychological frame of reference.

It is sometimes difficult to differentiate between direct motion effects and motion sickness effects on human performance. Let us therefore briefly discuss these direct effects of motion—specifically ship motion—on performance.

Direct Effects of Motion

Ship motion can be categorized under three headings according to its effects on humans: (a) the effects of impact and high accelerations, (b) vibration effects, and (c) the effect of tilting. In reality, this categorization is not always as distinct, as ship motions are very complex.

Impact effect. These are high accelerations which are produced as the ship meets the waves, usually appearing in the vertical axis (footward-headward, + Gz). Vessels producing these accelerations are usually small and fast, ranging from speedboats to ships weighing several hundred tons. Such impulses, which sometimes reach several G, are highly exhausting, since they require constant awareness and muscle tension. They usually cause performance deficit, and can sometimes produce physical injury (Arwas & Rolnick, 1984).

Vibration effects. The vibration is a low amplitude, high frequency movement resulting from the flexibility of the ship's body and the work of the engines. Though there are individual differences in the subjective reaction to vibrations, performance is usually reduced under these conditions. Visual performance decreases mainly at between 10 and 25 Hz, and manual dexterity is reduced at 5 Hz or less. See Chapter 18 for a comprehensive review of the effects of vibration and high accelerations.

Tilt effects. Pitch and roll cause man and other objects not fastened down to move in all directions. This represents a safety problem, and disturbs performance and well-being. Visual performance in particular can be severely affected by these angular accelerations (Neuman, 1976).

Studies on the Effects of Motion Sickness on Human Performance

Laboratory studies

Two types of simulator have been used for laboratory studies investigating the effects of motion sickness on performance: rotating environment devices and ship or vertical motion simulators. The most important research using the rotating environment was conducted in the Pensacola Slow Rotating Room. The nauseogenic stimulus here is the combination of head movements and rotation (the 'Coriolis effect'). The movement of the head about an axis which itself is being rotated produces inertial torque, stimulating the semicircular canal as though the head was turning about a third axis. The effect is that the subject is surprised by a sensory input signaling the head is doing something other than the expected movement. Hence the information from the semicircular canals does not correspond to the movement of the visual field, or the information from the otolith apparatus. It is this extreme discrepancy that causes motion sickness to develop quite rapidly (Guedry & Ambler, 1972).

The Pensacola studies are of particular interest because they were conducted over prolonged periods (up to a month). The tasks which were tested included grip strength, ataxia tests, ball tossing, dart throwing, card sorting, opening combination locks, dial setting, arithmetic computation, and a conceptual reasoning test. In one of these studies (Guedry *et al.*, 1964), four subjects were rotated for two weeks and their performance was measured before exposure, during rotation, and immediately after exposure. An extensive battery of performance tests was administered. No serious performance deficits were detected. Clark & Graybiel (1961) exposed six subjects for two days in the slow rotating room. The general picture from this study is inconclusive, as the authors themselves noted:

> 0The comparisons showed frequent occasions when severe symptoms were associated with poor performance, or, indeed, no performance. On the other hand there were also many cases in which high

> performance was associated with such symptoms as nausea, dizziness, general malaise, and even vomiting. These comparisons further support the notion *that canal sickness may reduce a subject's motivation to a very low level, but if the subject is willing or able to try, he can usually make good scores.* (our italics)

In a third study, Graybiel *et al.* (1965) exposed aviators to rotation for 12 days and used considerably more stressful stimuli than those in previous experiments. Although all the subjects experienced motion sickness, none failed to carry out all of the tests. 'After making allowance for practice effects and time-to-time variance, it is obvious that significant changes in performance were either absent or small.

Some of the earlier studies using ship or vertical motion simulators were conducted in the Psychology Department at Rochester University (Alexander *et al.*, 1945, 1955; Johnson & Wendt, 1964). In these studies, subjects were exposed to wave-like motion for 20 minutes, and were then put through eight performance tests. Only one task was affected by motion sickness.

Most of the controlled laboratory studies have been conducted on the ONR (US Office of Naval Research) ship motion generator. Abrams *et al.* (1971) used this device to study the effects of various sea conditions on human behavior and performance. Four groups of subjects were trained on various tests, and were subsequently tested during 64 hours of exposure to simulation of various sea states. An additional group, not exposed to motion, provided baseline data. Performance data were collected on simulated operational tasks and psychological tests. Motion itself did not have a significant effect on performance. It was only when motion sickness occurred that performance deficits were found. Moreover, the authors noted that 'these performance deficits were related to the subjects' desire to terminate the experiment'.

A later study (Malone, 1981) deals with the effect of simulated ship motion (Surface Effect Ship) on crew habitability. US Navy volunteers were subjected to 40 hours in a closed motion generator. Performance tasks representative of shipboard activities were administered. The '... degredation in performance due to mechanical interference was not judged to be significant... During the time subjects experienced motion sickness, task performance generally ceased as subjects became unable or unwilling to continue their assignment.'

Field studies

Most data from field studies are derived from surveys and retrospective evaluations. Based on these studies, it is generally agreed that seasickness degrades performance (Reason & Brand, 1975; Wiker, Pepper, & McCauley, 1980). A recent survey conducted in the British Navy revealed that 80% of seasickness sufferers report a decrement in their ability to work (Pethybridge, 1982). Gal (1974) asked 118 sailors in the Israeli Navy about their ability to perform their duties while seasick. He found that 20% were totally incapable of doing their job, while 45% could perform their duties, but to a standard that was unsatisfactory. Similar results were obtained in Rolnick's studies (1984, 1985; Rosenbaum & Rolnick, 1983). In some of these studies, evaluation of performance was carried out by the sailors' officers or by their fellow-sailors (the peer rating technique).

Very few experiments (in contrast with the retrospective surveys) have been conducted under real sea conditions. Brand (1967) examined subjects in a life-raft exposed to the waves. They found large performance deficits in the groups exposed to seasickness. Warhurst & Carasani (1969) evaluated the effects of ship roll on performance aboard a US Navy vessel. The authors chose a very mild stimulus which did not produce clear symptoms of motion sickness, as they were interested in the 'more subtle effects on performance resulting from long time exposures of the subject to such (roll) motion'. Performance was observed by the scientists who accompanied the crew on the voyage. Unfortunately, no clear data are provided in this report. However, their conclusion was that 'Roll motion is stressful to all shipboard personnel', and that 'An intensity of roll which causes a build-up of fatigue may allow unimpaired performance for a given time, after which performance may be sharply degraded by an "energy deficit".' Questionnaire data showed a clear decrement in motivation as a function of duration of exposure to roll motion.

The US Coastguard recently conducted a series of experiments to assess effects of ship motion on crew performance (Wiker *et al.*, 1979; Wiker, Pepper, & McCauley, 1980). Since this work might serve as a useful model for further research, we shall describe it in some detail. The main study involved three types of vessel: a 378 ft endurance cutter, a 95 ft patrol boat, and an 89 ft semi-submersible platform. The three vessels steamed side by side through slight seas. Six different tests were administered, it first being demonstrated that they were applicable to within subject design (see the PETER Project, Kennedy, & Bittner, 1980, p.19). After a one week familiarization period, the battery of tests was administered for six consecutive days in the following manner: two days of testing at the dockside, followed by three days of testing at sea, and concluded by a final test at the pier. The results were very clear. Although each of the vessels encountered the same waves, motion sickness occurred only on the 95 ft patrol boat. The 89 ft semi-submersible platform (a radical change from traditional monohull ship design) produced only very minor levels of sickness, equivalent to those produced by the much larger endurance cutter (Wiker, Pepper, & McCauley, 1980). Accordingly, performance deficits (as compared with the dockside) were found only on the 95 ft patrol boat, and were observed in all of the tests. These performance deficits were also associated with a profound change in mood, which again manifested itself mainly on the 95 ft patrol boat.

A study conducted in the USSR (Sapov & Kuleshov, 1975) assessed the effects of seasickness on the efficiency of the crew of a surface vessel. They found significant decrements in physical, mental, and job performance. The effect was mainly on the quality of performance.

Many different tests evaluating performance have been used in these studies. This fact accounts, at least partially, for the conflicting findings. These tests measured different types of ability: cognitive, visual, auditory, motor, etc. It is generally agreed that visual and motor tasks might be more susceptible to motion effects than auditory and simple cognitive tasks (Neuman, 1976). Some of the tests used required the execution of head movements. The execution of head movements under motion conditions can aggravate motion sickness, and the use of such a task is therefore more problematic. The length of the task is also of importance. Some of the tests used lasted only a few minutes (such as the complex counting and mathematical tests in the Pensacola studies), while others continued for hours, such as the Radar tests in the Surface Effect Ship Study (Malone, 1981).

Many of the performance tests were designed for the specific experiment. These were constructed in order to simulate existing operational systems, such as sonar or radar target detection, missile tracking, etc. Such tests do not usually have well-established normative data, and even more important, very little is known about the reliability of the tests. It is possible that part of the ambiguity regarding performance under motion sickness conditions can be attributed to the lack of standard and reliable performance tests. The need to develop reliable performance tests has recently been emphasized by Kennedy. The PETER Project (Kennedy & Bittner, 1980) was designed to develop such a battery of tests, some of which have already been used in motion sickness research (Wiker, Pepper, & McCauley, 1980). The use of such a reliable battery of tests should help clarify the issue of performance under motion sickness conditions.

HELPLESSNESS UNDER MOTION SICKNESS CONDITIONS

Up to this point, it would appear from the review that the findings presented in the literature are somewhat inconsistent. While many of the laboratory studies are inconclusive, most of the data from the less controlled studies at sea suggest performance may be seriously impaired under motion induced sickness.

Using a psychological frame of reference, Rolnick (1984) argued that these conflicting results can be explained using the 'learned helplessness theory' (Seligman, 1975). This theory provides an explanation for the debilitating consequences of experiencing uncontrollable events in humans and animals.

According to this hypothesis, learning that outcomes are uncontrollable results in three deficits: motivational, cognitive, and emotional. The motivational deficit consists of retarded initiation of voluntary responses, and is seen as a consequence of the expectation that any response will be futile. The cognitive deficit consists of difficulty in learning that responses produce outcomes. Finally, the learned helplessness model argues that the depressed affect is also a consequence of learning that outcomes are independent of response.

Our suggestion is that the decrement in performance is found mainly in field studies, where the situations give rise to perception of uncontrollability and helplessness. The sailor is exposed for a long time to aversive stimulation over which he has no control. Thus he develops apathy, passivity and depression. These psychological responses are associated with a low performance level. Laboratory studies, on the other hand, normally involve voluntary participation, and more important, the subject usually knows he can terminate the experiment whenever he wishes to do so. In these cases, there might be no perception of helplessness, and therefore no performance degradation.

Literature dealing with seasickness always mentions some kind of helplessness at sea. Descriptions emphasizing not only the nausea syndrome, but also another syndrome characterized as 'psychic depression', can be found in studies from the period of World Wars I and II. Byrne (1912) stated: 'Psychic depression is frequently so extreme, and cerebral functions so completely arrested, that self-control becomes an impossibility. Many of the numerous cases of suicide that occur at sea have for their immediate cause this psychic depression.' Quix (1922) defined psychic disorders in seasickness as a 'state of depression manifesting itself through slow ideation, lack of inclination to work, abulia, weakness, fatigue, a feeling of uneasiness, and apathy that can lead to melancholy.' Hill (1936) stated 'sleep has an important bearing, so far unexplained, upon the problem of seasickness ... The generalized inhibition which accompanies it is not limited to the period of sleep, but usually continues for some time afterwards. Drowsiness, apathy ...' are signs of motion sickness. Schwab (1954) pointed out that motion sickness 'involved a large number of minor symptoms that build up before actual nausea and vomiting occur. The first symptom is rather a subjective one, and is described as an uneasy feeling with a certain amount of lack of interest in the task being done, the book being read, or the person with whom one is talking.' Wendt (1944), who was one of the pioneers in the laboratory research of motion sickness, wrote that there is a 'subclinical phase' in motion sickness which involves mild emotional depression and loss of motivation. He hypothesized that the loss of motivation affects subjects' motor coordination and mental efficiency.

Perhaps the best documentation of the helplessness experienced under motion sickness conditions is provided by the diary written by one of the researchers conducting an experiment in the slow rotating room, who was exposed to a motion sickness situation along with his subjects. The following extract is taken from the experimenters' log book (Graybiel & Knepton, 1976).

> ... a decreased ability to concentrate and swift recall from memory ... word selection is slower than usual.
>
> ... I am in stupor — drowsy and inattentive (state).
>
> ... after 6 hours (exposure) entirely lethargic, loss of will power ... unable to concentrate on subject matter. 4 hours later, still lethargic, drowsy, sleepy, difficult to carry on mental activity.
>
> I am lethargic and apathetic, with no desire to talk or think.

Graybiel & Knepton (1976), who quote this diary, suggest this is an example of what they term 'the sopite syndrome', centered around drowsiness, which 'does not always precisely fit what the subject experiences. The subject sometimes loses interest in the work ... and indicates his desire to stop.' Other signs of this syndrome are lack of participation in group activities and a disinclination to either physical or mental work. The authors suggest the sopite syndrome may be experienced in the virtual absence of other symptoms, or after other symptoms have disappeared. Therefore they conclude this syndrome is independent of the nausea syndrome, and must be explained by other factors.

In a comprehensive review of studies on motion sickness. Money (1970) claims 'the feeling of mental depression is very severe in some individuals ... and it is not unusual to hear someone recall that during motion sickness he wished to die so that the misery would end. It is possible that the mechanism that produces this depression is also operative in longer lasting mental disorders. It is therefore surprising that no attempt has been made to reveal the nature of this mechanism that conveniently gives rise to a severe but readily reversible depression ...'

Although the 'depressive syndrome' mentioned above can be considered as simply another symptom of motion sickness, some observations suggest it can be separated from the 'nausea syndrome'. Our claim is that it develops in subjects in whom the seasickness situation gives rise to the perception of uncontrollability and helplessness. In these cases, a significant decrement in performance can be expected. In agreement with this assumption is the finding that decrement in performance at sea (as evaluated by the peer rating technique) was not correlated with physiological signs of seasickness such as emesis, cold sweating and pallor, but was significantly correlated with the feelings of helplessness (Rolnick, 1984).

Controllability is a very broad-ranging term (Thompson, 1981). Its relevance to motion sickness will be presented below, both in the sense of direct control over the motion stimuli and over the general situation at sea.

Motion sickness usually occurs under passive, uncontrollable motion. When on board a ship or an aircraft, or in a car, we are exposed to uncontrollable accelerations and are liable to develop motion sickness. On the other hand, we rarely become sick when performing active, controlled movements.

The role of controllability in motion sickness was studied in the laboratory by Rolnick (1984). Subjects were exposed to well-known nauseogenic motion stimuli ('Coriolis' and 'sudden stop' techniques). Two experimental conditions were used. In one, the subjects could control the motion stimuli by means of a joystick; in the second, they were exposed passively to the same motion stimulus. The results indicated that those subjects who did not have control over the motion stimulus felt significantly worse than those who did have control. A similar phenomenon might be observed in cars and aircraft. Although the driver or pilot is subjected to the same accelerations as the passengers, the former rarely suffers from motion sickness as does the passive passenger (Fukuda, 1976).

Sailors at sea cannot have direct control over the motion stimulus. However, it has been shown that even perceived control, or simply the belief that one has control, might reduce the behavioral and emotional reaction to aversive stimulation (Thompson, 1981). Rolnick (1980, 1984) showed that sailors who had more perception of control over their military service felt less helpless at sea. It was also demonstrated that if a sailor believes there is something he can do to reduce his sickness, he is less helpless and performs his duties better.

Seligman recently emphasized the importance of *attributions* in learned helplessness (Abramson, Seligman, & Teasdale, 1978). Rosenbaum & Jaffe (1983) suggested the magnitude of helplessness is influenced by people's attributions about their ability to control their internal reactions to stressful situations. Following this reasoning, Rosenbaum & Rolnick (1983) showed that self-control ability, as measured by Rosenbaum's scale (Rosenbaum, 1980), can lessen the decrement in performance under seasickness conditions. Similar findings were reported by Gal (1974), who found an 'active-coping' personality disposition was positively correlated with level of performance under motion sickness conditions.

In summary, motion sickness generally does not have a direct effect on performance. However, as an uncontrolled, aversive event, it can give rise to a profound helplessness reaction which is manifested through cognitive, emotional and motivational deficits. When the subject perceives he has no control and is helpless, performance deficits occur. On the other hand, a sense of control and certain personality dispositions can lessen these manifestations of helplessness, and thus reduce the effects on performance, regardless of the severity of the nausea syndrome. Thus controllability and helplessness might serve as mediating variables between motion sickness symptoms and the level of performance.

PREVENTION AND TREATMENT

There are various approaches to reducing the salience of motion sickness in the military: human factors engineering; personnel selection; the use of drugs; behavioral means; desensitization, behavior therapy and biofeedback. None of these measures can completely prevent the development of motion sickness, but each may significantly reduce its incidence and severity, or delay the onset of symptomatology.

Human Factors Engineering

Effective measures in the design of any vehicle can reduce provocative motion. In regard to naval craft, one can consider special hull design and motion attenuation devices, among others. Critical stations should be located near the ship's effective center of rotation (Bittner & Guignard, 1985), where one can prevent the vertical displacement component of the ship's angular acceleration. This component is one of the main sources of seasickness (McCauley, *et al.*, 1976). Secondly, aligning the operator with the longitudinal axis of the ship's hull may result in lessened motion sickness effects and improved performance (Bittner & Guignard, 1985). Third, an external visual frame of reference should be provided. This principle is derived from the sensory rearrangement theory, and has been suggested by many authors (Reason & Brand, 1975; Money, 1970). Rolnick & Bles (1989) demonstrated that an artificially generated wide angle projected horizon can prevent performance deficits under tilting conditions.

Personnel Selection

Most navies and air forces select their personnel from a large pool of candidates. It is therefore possible to reduce the salience of motion sickness in the military by the application of selection procedures which will identify highly susceptible personnel. Various tests have been examined as predictors of motion sickness susceptibility. In contrast to an early hypothesis (De Wit, 1953), it is now agreed that the commonly used clinical vestibular tests (based on caloric or rotatory stimulation of the semicircular canals) are not useful in differentiating between susceptible and non-susceptible candidates (Guedry, 1978; Dobie, 1974). Similarly, personality tests are not a useful predictor of susceptibility (Reason & Brand, 1975), although susceptibility is correlated to some extent with factors such as neuroticism (Wilding & Meddis, 1972; Guedry & Ambler, 1972), introversion (Kottenhof & Lindahl, 1960) and hypochondriasis (Marschall & Rolnick, 1986). However, these correlations are quite low, and are not useful for practical purposes.

Various simulators which produce motion sickness, or actual exposure to sea or air conditions, are the most practical techniques for predicting motion sickness susceptibility (Guedry, 1978; Rolnick, Arwas, & Lubow, 1986; Bles, de Jong, & Oosterveld, 1984; Lentz, 1984). While personality inventories are not useful in predicting susceptibility, they may be very important in predicting the tendency to develop helplessness and performance deficits under motion sickness conditions. As has been mentioned earlier, there is some evidence that 'self-control' and 'active coping' are correlated with level of performance under motion sickness conditions (Rosenbaum & Rolnick, 1983; Gal, 1974).

Drugs

Many pharmacological preparations are effective in preventing or delaying the onset of motion sickness symptomatology. The most effective drugs used against motion sickness are scopolamine and antihistaminics such as dimenhydrinate (e.g. Dramamine), promethazine, cyclizine, meclizine and cinnarizine. Both the antihistaminics and scopolamine have central nervous system depressant properties. None of them is entirely specific against motion sickness. All have side effects, such as drowsiness and sedation, which substantially limit their use by military personnel.

A transdermal application of scopolamine has recently been introduced. Studies conducted in our laboratory and by other investigators have shown that this method of administration is highly effective against motion sickness, and is not associated with a decrement in performance abilities (Price, *et al.*, 1981; Attias *et al.*, 1987; Gordon *et al.*, 1986). A combination of scopolamine and sympathomimetics such as amphetamine or ephedrine, which are also highly effective against motion sickness, have been found to prevent undesired drowsiness and sedation (Wood *et al.*, 1984). Other frequent side effects of scopolamine are dry mouth and blurred vision, and there have been occasional reports of hallucinations and toxic psychosis (MacEwan, Remick, & Noone, 1985). Because all of the side effects mentioned may significantly impair performance, this issue must be taken into account when considering the use of each pharmacological treatment in military personnel.

The effect of drugs on adaption is not completely understood. It is possible scopolamine can affect the normal process of adaptation (Marion, *et al.*, 1985; Wood *et al.*, 1986). This fact may constitute a serious disadvantage in chronic users such as naval crew members.

Behavioral Measures

The main rule in this preventive approach is to attempt to minimize the mismatch between the information coming from the various motion sensors (see Etiology, above). Intra-labyrinthine conflicts can be reduced by preventing unnecessary head movements, either by special mechanical means or by adopting a supine position (Johnson & Mayne, 1953). Visual inertial conflicts can be avoided by controlling the direction of gaze. Aboard ships, it is useful to obtain visual information from the outside world. In cars and trucks, it is important to maintain a forward-looking direction (Reason & Brand, 1975).

There are many observations in support of the notion that engaging in an attention-demanding task can alleviate the symptoms (Correia & Guedry, 1967). Although other experiments (Rolnick, Golan, & Rosenbaum, 1986) show it is sometimes quite difficult to divert one's attention from the symptoms, many sailors find this cognitive technique to be the most effective (Rolnick, 1984).

Desensitization, Behavior Therapy and Biofeedback

There is a normal process of adaptation to motion sickness conditions. Reason & Graybiel (1970) suggested the application of 'adaptation training' for future astronauts as a means of preventing space motion sickness. Dobie (1974) initiated a desensitization program in the British RAF. This program, which has been running for more than ten years now, is based on gradual exposure to various provocative stimuli. Aircrew grounded due to severe airsickness are referred to this desensitization program. According to the British data, their success rate (return to active flying) is more than 80% (Bagshaw & Stott, 1985).

It is not clear whether such desensitization training might be useful in reducing seasickness, since the spectrum of stimuli at sea is extremely wide, while it is known that the adaptation process is highly stimulus specific—namely, it does not transfer from one stimulus to another (Reason & Brand, 1975). The biofeedback approach suggests that rather than concentrating on the stimulus, it might be more useful to focus on the response; i.e. the training should be focused on teaching the individual a new competitive response to the motion stimuli. In accordance with this suggestion, many navies and air forces now employ various kinds of behavior therapy to help military personnel cope with motion sickness. Levy, Jones, & Carlson (1981) described the USAF program, in which pilots were provided with a combination of relaxation training and biofeedback. They noted an 84% rate of return to flying duty for previously disabled aircrew. Cowings & Toscano (1982) at NASA/AMES conduct a similar program for astronauts. Their work indicates that biofeedback training can help prevent motion sickness produced in a vertical oscillator. Research in this direction continues in the German Air Force (Kemmler, 1984) and in the US Navy (Dobie *et al.*, 1987), with promising results.

De Wit, G. (1953). Seasickness (motion sickness). *Acta Otolaryngologica*, Suppl. 108.

Dobie, T.G. (1974). *Airsickness in aircrew* (NATO AGARDograph No. 177). London, England: Technical Editing and Reproduction Ltd.

Dobie, T.G., May, J.G., Fischer, W.D., Elder, S.T., & Kubitz, K.A. (1987). A comparison of two methods of training resistance to visually induced motion sickness. *Aviation, Space, and Environmental Medicine*, **58** (9, Suppl.), A34-A41.

Fox, S. & Arnon, I. (1988). Motion sickness and anxiety. *Aviation, Space, and Environmental Medicine*, **59**, 728-733.

Fukuda, T. (1976). Postural behavior and motion sickness. *Acta Otolaryngologica*, **81**, 237-241.

Gal, R. (1974). *Coping process under seasickness conditions* (Israeli Navy Report).

Geeze, D.S & Pierson, W.P. (1986). Airsickness in B-52 crewmembers. *Military Medicine*, **151**, 628-629.

Gordon, C., Binah, O., Attias, J., & Rolnick, A. (1986). Transdermal scopolamine: human performance and side effects. *Aviation, Space, and Environmental Medicine*, 57, 236-240.

Gower, D.W. Jr. Lilienthal, M.G., Kennedy, R.S., Fowlkes, J.E., & Baltzley, D.R. (1987). *Simulator sickness in the AH-64 Apache combat mission simulator* (USAARL Tech. Rep. No. 88-1). For Rucker, AL: US Army Aeromedical Research Laboratory.

Graybiel, A. & Johnson, W.H. (1963). A comparison of the symptomatology experienced by healthy persons and subjects with loss of labyrinthine function when exposed to unusual patterns of centripetal force in a counter-rotating room. *Annals of Otology, Rhinology and Laryngology*, **72**, 357-373.

Graybiel, A. Kennedy, R.S., Knoblock, E.C., Guedry, F.E., Hertz, W., McCleod, M., Colehour, J.K., Miller, E.F., & Fregly, A. (1965). Effects of exposure to a rotating environment (10 rpm) on four aviators for a period of 12 days. *Aerospace Medicine*, **36**, 733-754.

Graybiel, A. & Knepton, J. (1976). Sopite syndrome: a sometimes sole manifestation of motion sickness. *Aviation, Space, and Environmental Medicine*, **47**, 873-882.

Graybiel, A. & Knepton, J. (1978). Prevention of motion sickness in flight maneuvers, aided by transfer of adaptation effects acquired in the laboratory: ten consecutive referrals. *Aviation, Space, and Environmental Medicine*, **49**, 914-919.

Guedry, F.E. (1978). *Selection and prediction tests*. Paper presented at the Symposium for Space Motion Sickness, NASA, FL: Johnson Space Center, National Aeronautics and Space Administration.

Guedry, F.E., & Ambler, R.K. (1972). Assessment of reactions to vestibular disorientation stress for purposes of aircrew selection. In *NATO AGARD Conference Proceedings No. 109, Symposium on Predictability of Motion Sickness in the Selection of Pilots*. London, England: Technical Editing and Reproductions Ltd.

Guedry, F.E., Kennedy, R.S., Harris, C.S., & Graybiel, A. (1964). Human performance during 2 weeks in a room rotating at 3 rpm. *Aerospace Medicine*, **35**, 1071-1082.

Harvon, M.D. & Butler, L.F. (1957). *Evaluation of training effectiveness of the 2-FH-2 helicopter flight trainer research tool* (Tech. Rep. No. NAVTRADEVCEN 1915-00-1). Port Washington, NY: Naval Training Device Center.

Hill, J. (1936, October-December). The care of the seasick. *British Medical Journal*, 802-807.

Hixon, W.C., Guedry, F.E., Holtzman, G.L., Lentz, J.M., & O'Connell, P.F. (1979). *Airsickness during naval flight officer training: basic squadron VT-10* (NAMRL Tech. Rep. No. 1258). Pensacola, FL: Naval Aerospace Medical Research Laboratory.

Hixon, W.C., Guedry, F.E., Holtzman, G.L., Lentz, J.M., & O'Connell, P.F. (1980). *Airsickness during naval flight officer training: advanced squadron VT86-R10* (NAMRL Tech. Rep. No. 1272). Pensacola, FL: Naval Aerospace Medical Research Laboratory.

Hixon, W.C., Guedry, F.E., Lentz, M., & Holtzman, G.L. (1983). *Airsickness during naval flight officer training: fleet readiness squadrons* (NAMRL Tech. Rep. No. 1305). Pensacola, FL: Naval Aerospace Medical Research Laboratory.

Holling, H.E., McArdle, B., & Trotter, W.R. (1944). Prevention of seasickness by drugs. *Lancet*, **i**, 127-129.

Homick, J.L. & Miller, E.F. (1975). Apollo flight crew vestibular assessment. In R.S. Johnston & L.f. Dietlein (Eds.), *Biomedical Results of Apollo* (NASA SP-368, chap. 8). Washington, DC: National Aeronautics and Space Administration.

Homick, J.L., Reschke, M.F., & Vanderploeg, J.M. (1984). Space adaptation syndrome: incidence and operational implications for the space transportation system program. In *NATO AGARD Conference Proceedings No. 372, NATO AGARD Symposium on Motion Sickness: Mechanisms, Prediction, Prevention and Treatment (Williamsburg)* (Paper 36). Neuilly Sur Seine, France: NATO AGARD.

Johnson, C. & Wendt, G.R. (1964). Studies of motion sickness: XX. Effects of sickness on performance in code substitution and mirror drawings. *Journal of Psychology*, **57**, 81-84.

Johnson, W.H. & Mayne, J.W. (1953). Stimulus required to produce motion sickness. Restriction of head movements as a preventative of airsickness. Field studies on airborne troops. *Journal of Aviation Medicine*, **24**, 400-411.

Jongkees, L.B.W. (1967). On the otoliths: their function and the way to test them. In *Third Symposium on the Role of the Vestibular Organs in Space Exploration* (NASA SP-152, pp. 307-331). Pensacola, FL: Naval Aerospace Medical Institute.

Keinan, G., Friedland, N., Yitzhaky, J., & Moran, A.

(1981). Biographical, physiological, and personality variables as predictors of performance under sickness-inducing motion. *Journal of Applied Psychology*, **66**, 233–241.

Kemmler, R.W. (1984). Psychological components in the development and prevention of airsickness. In *NATO AGARD Conference Proceedings No. 372, NATO AGARD Symposium on Motion Sickness: Mechanisms, Prediction, Prevention and Treatment (Williamsburg)* (Paper 41). Neuilly Sur Seine, France: NATO AGARD.

Kennedy, R.S. & Bittner, A.C., Jr (1980). Development of performance evaluation tests for environmental research (PETER): complex counting. *Aviation, Space, and Environmental Medicine*, **51**, 142–144.

Kennedy, R.S. & Frank, L.H. (1984). *A review of motion sickness with special reference to simulator sickness* (NAVTRAQUIPCEN Tech. Rep. No. 81-C-0105-16). Orlando, FL: Naval Training Equipment Center.

Kottenhoff, H. & Lindahl, L.E. (1960). Laboratory studies on the psychology of motion sickness. *Acta Psychologica*, **17**, 89–112.

Lentz, J.M. (1984). Laboratory tests of motion sickness susceptibility. In *NATO AGARD Conference Proceedings No. 372, NATO AGARD Symposium on Motion Sickness: Mechanisms, Prediction, Prevention and Treatment (Williamsburg)* (Paper 29). Neuilly Sur Seine, France: NATO AGARD.

Lerman, Y. (1987). *Simulator sickness in a military tank driving simulator* (Israel Defence Forces Medical Corps Report) Israel.

Levy, R.A., Jones, D.R., & Carlson, E.H. (1981). Biofeedback rehabilitation of airsick aircrew. *Aviation, Space, and Environmental Medicine*, **52**, 118–121.

MacEwan, G.W., Remick, R.A., & Noone, J.A. (1985) Psychosis due to transdermally administered scopolamine. *Canadian Medican Association Journal*, **133**, 431–432.

Malone, W.L. (1981). *Effects of simulated surface effect ship motion on crew habitability—phase II. Volume one: summary report and comments* (PMS-304, Tech. Rep. No. 1070). Bethesda, MD: Naval Sea Systems Command.

Marion, W.F., Bongaerts, M.C.M., Christiaanse, J.C., Hofkamp, H.G., & Ouwerkerk, W. (1985). Influence of transdermal scopolamine on motion sickness during 7 days exposure to heavy seas. *Clinical Pharmacology and Therapeutics*, **38**, 301–205.

Marschall, P. & Rolnick, A. (1986). Individual differences in sympton reporting as predictors of reaction to motion sickness. Paper presented at the 21st International Congress of Applied Psychology, Jerusalem, Israel.

Matsnev, E.I., Yakovleva, I.Y., Tarasov, I.K., Alekseev, V.N., Kornilova, L.N., Mateev, A.D., & Gorgiladze, G.I. (1983). Space motion sickness: phenomenology, countermeasures, and mechanisms. *Aviation, Space, and Environmental Medicine*, **54**, 312–317.

McCauley, M.E., Royal, J.W., Wylie, C.D., O'Hanlon, J.F., & Mackie, R.R. (1976). *Motion sickness incidence: exploratory studies of habituation, pitch and roll, and the refinement of a mathematical model* (Tech. Rep. No. 1733-2). Santa Barbara, CA: Human Factors Research.

Miller, J.W. & Goodson, J.E. (1960). Motion sickness in a helicopter simulator. *Aerospace Medicine*, **31**, 204–212.

Money, K.E. (1970). Motion sickness. *Physiological Reviews*, **50**, 1–39.

Neuman, R.A. (1976). *Ship motion effects in the human factors design of ships and shipboard equipment* (NPRDC Tech. Rep. No. 77-2). San Diego, CA: Navy Personnel Research and Development Center.

Pethybridge, R.J. (1982). *Seasickness incidence in RN ships* (INM Report No. 37/82). Alverstoke, England: Institute of Naval Medicine.

Price, N.M., Schmitt, L.G., McGuire, J., Shaw, J.E., & Trobough, G. (1981). Transdermal scopolamine in the prevention of motion sickness at sea. *Clinical Pharmacology and Therapeutics*, **29**, 414–419.

Quix, F.H. (1922). Le mal de mer et le mal des aviateurs. *Monographies d'Oto-Rhino-Laryngologie Internationales*, **8**, 828–987.

Reason, J.T. (1968). Relations between motion sickness susceptibility, the spiral after-effect and loudness estimation. *British Journal of Psychology*, **59**, 385–393.

Reason, J.T. & Brand, J.J. (1975). *Motion sickness*. New York: Academic Press.

Reason, J.T. & Graybiel, A. (1970). Progressive adaptation to coriolis accelerations associated with 1 rpm increments in the velocity of the slow rotation room. *Aerospace Medicine*, **41**, 73–79.

Rolnick, A.(1980). Self controland coping with aversive situations. Unpublished MA Thesis, Tel Aviv University, Israel.

Rolnick, A. (1984). Uncontrollability and helplessness in motion sickness. Unpublished doctoral dissertation, Tel Aviv University, Israel.

Rolnick, A. (1985). *Seasickness incidence in the Israeli Navy* (Israel Navy Report C-101). Tel Aviv, Israel.

Rolnick, A., Arwas, S., & Lubow, R.E. (1986). Predicting behavior under seasickness conditions: the development of a selection procedure for the Israeli Navy. Paper presented at the 21st International Congress of Applied Psychology, Jerusalem, Israel.

Rolnick, A. & Bles, W. (1989). Performance and well-being under tilting conditions: the effects of visual reference and artificial horizon. *Aviation, Space, and Environmental Medicine*, **60**, 779–785.

Rolnick, A., Golan, N., & Rosenbaum, M. (1986). Learned resourcefulness and coping with sickness: laboratory experiments using nausea provoking stimulation. Paper presented at the 21st International Congress of Applied Psychology, Jerusalem, Israel.

Rosenbaum, M. (1980). A schedule for assessing self control behaviors: preliminary findings. *Behavior Therapy*, **11**, 109–121.

Rosenbaum, M. & Jaffe, Y. (1983). Learned helplessness: the role of individual differences in learned resourcefulness. *British Journal of Social Psychology*, **22**, 215–225.

Rosenbaum, M. & Rolnick, A. (1983). Self-control behaviors and coping with seasickness. *Cognitive Therapy and Research*, **1**, 93–98.

Sapov, I.A. & Kuleshov, V.I. (1975). Seasickness and efficiency of the crew of surface vessel. *Military Medical Journal*, **4**, 88–91.

Schwab, R.S. (1954). The nonlabyrinthine causes of motion sickness. *International Record of Medicine*, **167**, 631–637.

Seligman, M.E.P. (1975). *Helplessness: on depression, development, and death*. San Francisco, CA: Freeman Press.

Thompson, S.C. (1981). Will it hurt less if I can control it? A complex answer to a simple question. *Psychological Bulletin*, **90**, 89–101.

Tyler, D.B. (1946). The influence of a placebo, body position and medication on motion sickness. *American Journal of Physiology*, **146**, 458–466.

Tyler, D.B. & Bard, P. (1949). Motion sickness. *Physiological Reviews*, **29**, 311–369.

Warhurst, F. & Cerasani, A.J. (1969). *Evaluation of the performance of human operators as a function of ship motion* (Tech. Rep. No. 2828). Annapolis, MD: Naval Ship Research and Development Laboratory.

Wendt, G.R. (1944). *Report of National Research Council Committee on selection and training of aircraft pilots*. Washington, DC: National Research Council, Executive Subcommittee.

Wiker, S.F., Kennedy, R.S., McCauley, M.E., & Pepper, R.L. (1979). Susceptibility to seasickness: influence of hull design and steaming direction. *Aviation, Space, and Environmental Medicine*, **50**, 1046–1051.

Wiker, S.F., Pepper, R.L., & McCauley, M.E. (1980). *A vessel class comparison of physiological, affective state, and psychomotor performance changes in man at sea* (US Coast Guard Tech. Rep. No. CG - D 07 81). Washington, DC: US Coast Guard Office of Research and Development.

Wilding, J.M. & Meddis, R. (1972). Personality correlates of motion sickness. *British Journal of Psychology*, **63**, 619–620.

Witkin, H.A. (1949). The nature and importance of individual differences in perception. *Journal of Personality*, **18**, 145–170.

Wood, C.D., Manno, J.E., Manno, B.R., Redetzki, H.M., Wood, M., & Vekovius, W.A. (1984). side effects of antimotion-sickness drugs. *Aviation, Space, and Environmental Medicine*, **55**, 113–116.

Wood, C.D., Manno, J.E., Manno, B.R., Odenheimer, R.C., & Barnsfather, C.E. (1986). The effect of antimotion sickness drugs on habituation to motion. *Aviation, Space, and Environmental Medicine*, **57**, 539–542.