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Airsickness desensitisation for the Canadian Forces – A recommendation

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Abstract

Airsickness is associated with other forms of motion sickness. It is a common occurrence among aircrew trainees; the problem is most acute in the early stages of training. The identification of an alternative to pharmacological treatment of airsickness for individuals regularly exposed to provocative environments while carrying out skilled or potentially hazardous tasks, is an important issue. Airsickness desensitisation has been proposed and employed by various nations as the program of choice for prevention of airsickness during early training. With the newly acquired trainers (Harvard II and the Hawk) in the Canadian Forces (CF), it is important at this time to re-evaluate the CF airsickness desensitisation program at 15 Wing. The purpose of this recommendation is to provide a scientific update on habituation to nauseogenic motion stimuli, to clarify a number of misconceptions and to provide a recommendation on an improved airsickness desensitisation program based on current valid scientific information. A number of vestibular screening tests on oculomotor and postural function that could be achieved with relative ease are proposed as part of the initial assessment for potential pathological predisposition to airsickness. It is also recommended that the current biofeedback and relaxation therapy be deleted. Ground based desensitisation should be reduced to a 2-3 week period of twice daily exposures to Coriolis stimuli of progressively increasing intensity. This is followed immediately by 10-15 hours of exposure in which incremental habituation to the more complex and provocative manoeuvres are carried out. Quantitative evaluation of the subject's progress for both ground based and in flight desensitisation is recommended. An alternative ground based desensitisation procedure using the human centrifuge is proposed.

Résumé

Le mal de l'air est associé à d'autres formes du mal des transports. C'est une affection courante chez le personnel navigant stagiaire; le problème est particulièrement aigu pendant les premières phases de l'entraînement. La recherche d'une alternative au traitement pharmacologique du mal de l'air pour les personnes régulièrement exposées à des environnements prédateurs et qui exécutent des tâches requérant des habiletés ou potentiellement dangereuses est un enjeu important. La désensibilisation au mal de l'air a été proposée et employée par plusieurs pays comme programme de choix pour prévenir le mal de l'air au cours des premières phases de l'entraînement. Compte tenu des nouveaux avions d'entraînement (Harvard II et Hawk) des Forces canadiennes (FC), il est maintenant important de ré-évaluer le programme de désensibilisation au mal de l'air des FC à la 15^{e} Escadre. La présente recommandation vise à fournir une mise à jour scientifique sur l'accoutumance à des stimuli de mouvement nauséeux pour clarifier un certain nombre de préjugés et pour formuler une recommandation sur un programme amélioré de désensibilisation au mal de l'air à partir de données scientifiques actuelles valides. Un certain nombre de tests de dépistage vestibulaires sur la fonction oculomotrice et la fonction d'équilibration ont pu être menés assez facilement, et ils sont proposés comme partie intégrante de l'évaluation initiale d'une prédisposition pathologique potentielle au mal de l'air. Il est aussi recommandé que la thérapie actuelle sur la relaxation et la rétroaction biologique soit supprimée. La désensibilisation au sol devrait être ramenée à une période de 2 à 3 semaines d'expositions deux fois par jour aux stimuli de Coriolis d'intensité progressivement croissante. Suivent alors immédiatement 10 à 15 heures d'exposition selon une accoutumance progressive à des manœuvres plus complexes et plus énergiques. L'évaluation quantitative des progrès du sujet tant en désensibilisation au sol qu'en vol est recommandée. On propose aussi une autre alternative au programme de désensibilisation au sol en proposant une centrifugeuse humaine.

Executive summary

Airsickness, a form of motion sickness, is a common problem in early flying training. A practical solution to counter this problem in the early stages of military flight training is by gradual habituation (desensitisation) to the provocative stimulus both on the ground and in the air. Various schemes of the desensitisation procedure have been proposed. The purpose of this report is to provide a scientific update on our knowledge on habituation to provocative motion stimuli and to clarify some common misconceptions and to provide a recommendation on an improved airsickness desensitisation program based on current scientific information. A number of simple screening tests on the function of the organs of balance are recommended to be included in the initial assessment to ensure that there are no underlying clinical problems that could precipitate airsickness. Ground based habituation should be reduced to a 2-3 week period of twice daily exposures to prescribed provocative stimuli of progressively increasing intensity. This is followed immediately by 10-15 hours of dual flying in which flight manoeuvres involving complex provocative stimuli are carried out. Evaluation methods of the subject's progress in ground based and in flight desensitisation are presented. An alternative ground based desensitisation procedure using the human centrifuge is proposed. The biofeedback and relaxation therapy phase in the current program should be eliminated.

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Sommaire

Le mal de l'air, une forme de mal des transports, est un problème courant lors des premières phases de l'entraînement au pilotage. Une solution pratique pour contrer ce problème dans les premières phases de l'entraînement militaire au pilotage consiste à s'accoutumer progressivement (se désensibiliser) au stimuli nauséeux, tant au sol qu'en vol. Diverses procédures de désensibilisation ont été proposées. Le présent rapport vise à fournir une mise à jour scientifique de nos connaissances relativement à l'accoutumance à des stimuli de mouvement énergiques et à clarifier certains préjugés répandus afin de formuler une recommandation sur un programme amélioré de désensibilisation au mal de l'air sur la foi de données scientifiques actuelles. Il est recommandé d'inclure un certain nombre de tests de dépistage simples sur le rôle des organes de l'équilibre dans l'évaluation initiale pour assurer qu'il n'y a pas de problèmes cliniques sous-jacents pouvant précipiter l'apparition du mal de l'air. L'accoutumance effectuée au sol devrait être ramenée à une période de 2 à 3 semaines d'exposition deux fois par jour à des stimuli provocants d'intensité croissante. Suivent immédiatement de 10 à 15 heures de vol en double commande au cours desquelles sont exécutées des manœuvres de vol comprenant des stimuli provocants complexes. Les méthodes d'évaluation des progrès des sujets dans le cadre des programmes de désensibilisation au sol et en vol sont présentés. Une autre procédure de désensibilisation au sol suggérée est l'utilisation d'une centrifugeuse humaine. Il faudrait éliminer la phase de thérapie de réflexion et de rétroaction biologique du programme actuel.

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Introduction

The current CF (Canadian Forces) airsickness desensitisation program, located at 15 Wing Medical Squadron, Moose Jaw, was established in 1981 and the design of the program was based on the RAF (Royal Air Force) and USAF (United States Air Force) programs available at the time of inception [1]. It consists of subject identification and selection followed by biofeedback relaxation therapy, ground based and in flight desensitisation. With the newly acquired trainers (Harvard II and the Hawk) in the CF, it is timely to re-evaluate the currency of the CF airsickness desensitisation program. The purpose of this report is to provide a scientific update on habituation to nauseogenic motion stimuli, to clarify a number of misconceptions and to provide a recommendation on an improved airsickness desensitisation program based on current valid scientific information. This report is written with reference to 3773 3FA21 (DCIEM ALS), 6681-4 (A1 ASCS) Comments on Canadian Forces Airsickness Desensitisation program at 15 Wing Moose Jaw – Briefing Package, and in conjunction with the author's site visit to 15 Wing Medical Squadron, in April 2001 at the request of 1CAD.

Background

Prevention of airsickness can take several forms: elimination or reduction of the cause (the motion environment); isolation of the body from the cause (voluntary and involuntary movements of the head and body); or minimizing the effects of the cause. In the military operational environment, elimination of the cause is impossible, unless the affected individual withdraws from service. However, isolation of the body from the cause is possible, for example, navigators can organize their activity so that unnecessary head/body movements are restricted during provocative motion. Some pharmacological treatment can minimize the effects of the cause. The most suitable and effective non-pharmacological intervention for airsickness in the military environment appears to be habituation to the nauseogenic stimuli.

Individuals who are subjected to a motion stimulus that provokes nausea and vomiting tend, with repeated exposure, to become increasingly resistant to its nauseogenic effect. Physiologically, the term habituation is distinct from adaptation. Habituation refers to the effects of repeated exposure to the stimulus, in this case, angular or linear acceleration or a combination of both. Furthermore, habituation is used to describe the situation where a change in susceptibility to airsickness involves conscious mental activity (such as learning the characteristics of the motion environment so as to predict future movements). Habituation may occur to a specific combination of motion cues and not all provocative stimuli. On the contrary, adaptation refers to the effects, which occur in a prolonged single exposure. It is usually reserved for situations where continuous exposure to a stimulus brings about reduced sensitivity through a change in the appropriate sensory organs. Such adaptation has not been shown to occur with motions causing motion sickness and would not explain adequately the manner in which motion sickness susceptibility varies with exposure to provocative motions. In the context of behavioural measures, adaptation has often been used to refer to the increase in tolerance to a nauseogenic stimulus that occurs over a period of days or weeks of repeated exposures. In this report, the increased tolerance to nauseogenic stimuli is referred to as habituation.

The phenomenon of habituation to motion sickness invokes other questions that have not been resolved. This is partially due to the fact that the acquisition of habituation, similar to motion sickness susceptibility, shows individual variation. For example, what factors determine the rate of habituation? To what extent can habituation gained from one environment apply to another? Are there long-term effects? What are the neurophysiological mechanisms that underlie such responses? Certainly, long-term habituation has not been shown to occur with motions causing motion sickness, and would not explain adequately the manner in which motion sickness susceptibility varies with exposure to provocative motions.

Various desensitisation schemes have been shown to be helpful for those who do not develop sufficient protective habituation during the course of normal flight training [2, 3, 4, 5, 6, 7, 8]. All involve habituation to some type of nauseogenic ground based motion stimuli. They vary in the extent to which in flight desensitisation is incorporated into the program and the utilization of different forms of biofeedback, autogenic feedback and relaxation therapy.

The desensitisation that results from repeated exposure to a provocative stimulus tends to be fairly specific to that type of stimulus. The basic principle is that there should be a gradual and incremental exposure to the provocative stimulus. For example, the rate of habituation depends largely on the amount of Coriolis cross-coupled[1] stimulation received by the subjects (depends on their head movement activity). Incremental levels of exposure and carefully controlled head movements were shown to achieve a reasonable degree of habituation in a matter of hours [9]. Typical desensitisation therapy for pilots involves a 2-3 week period of twice-daily exposures to Coriolis cross-coupled stimuli of progressively increasing intensity. This is followed by 10-15 hours of dual flying in which the process of incremental habituation to the more complex provocative motion stimuli of flight is carried out [3].

Biofeedback, autogenic feedback training and relaxation therapy

When operant conditioning[2] is used to train human subjects to control autonomic responses, the process is called biofeedback. It usually involves a variety of relaxation techniques (Jacobsonian contraction and slow relaxation, diaphragmatic breathing and relaxing mental imagery). It also involves biofeedback instrumentation of recording blood pressure, heart rate, body temperature, skin surface temperature and skin conductance. These recordings were made while the subject was experiencing incremental increases in Coriolis vestibular simulation. However, a consistent and reliable relationship between motion sickness and these physiological measures does not exist [10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20].

Biofeedback training for motion sickness desensitisation has been primarily based on a series of studies by Cowings and colleagues [21, 22, 23, 24]. The beneficial role of various autonomic biofeedback strategies has been emphasised by various research groups [8; 24], but

[1] Coriolis cross-coupled stimulation is referring to the vestibular effect of tilting the head during whole body rotation.
[2] Operant conditioning – is one of the classical psychological behaviour conditioning exercises when a subject's response to a stimulus is reinforced. For example, a hungry rat is placed in a dimly lit box that has a movable lever connected to an electric switch. When the rat by chance presses the switch, a pellet of food is made available to the rat. The hungry rat eats and soon presses the lever again.

has not been found useful by others [25]. Furthermore, there are several methodological concerns with this series of studies that question the validity of using biofeedback training. For example, in Cowings' studies, physiological responses were measured in subjects who were required to make a series of paced head movements of 45^0 in 4 different directions (forward, backward, right and left) while rotating around the spinal axis, (a similar procedure was used in the CF ground based desensitisation training). In Cowings' study, 150 head movements were made by the end of the first 5 minutes of rotation, and as many as 1500 head movements by the end of the study, depending upon when the subject chose to terminate, while their autonomic responses such as blood pressure and heart rate were monitored. In order to interpret these results, it is necessary to measure the physiological effects of the physical exertion associated with making these head movements. Lawson and Lackner [26] measured the heart rate response increase while stationary subjects performed the same series of head movements. The average heart rate increase during head movements while stationary was statistically indistinguishable from that observed by Cowings for the rotating situation.

Moreover, individuals vary greatly in the extent to which they can benefit from biofeedback training. Training conducted in a laboratory may not transfer to operationally relevant situations, which involve active participation of other tasks [27, 28, 29, 30, 31]. It appears that biofeedback and other behavioural techniques can modify the physiological responses of some individuals and ameliorate the anxiety that accompanies certain noxious situations, but it remains to be seen whether these responses bear a direct relationship to the symptoms of motion sickness. It is recommended that the biofeedback or autogenic feedback portion of the CF desensitisation training be deleted from the current program as it lacks scientific validity.

Ground based desensitisation

The suggestion of ground based vestibular exercises to reduce susceptibility to airsickness has been proposed since 1943 by Popov [32]. It was proposed that this type of vestibular exercise could be achieved through gymnastic activity on a trampoline. As mentioned earlier, for the past 50 years, it has been shown that individuals who are subjected to a motion stimulus that provoked nausea and vomiting tend, with repeated exposure, to become increasingly resistant to its nauseogenic effect. This habituating response is often observed in a variety of situations such as on-board ship, space flight and in a number of laboratory stimuli. Specifically, in the laboratory, habituation to Coriolis stimulation has been shown to demonstrate a gradual decline in intensity and an increase in tolerance to the nauseogenic effects of the cross-coupled stimuli.

The Coriolis effect can easily be demonstrated when an individual rotates his head about the spinal axis, the ω_2 axis, while the head is rolling laterally in the frontal plane or pitching in the sagittal plane, the ω_1 axis. This produces an instantaneous stimulus to the semicircular canals, about a third axis, that can be disorienting, disturbing and nauseating. If the subject is blind folded, a false sensation of pitch (in the case of rolling the head laterally in the frontal plane) may be produced by the cross-coupled stimulus to the semicircular canals. The stimulus can be calculated from vector algebra as the vector cross product, or cross-coupling, of the ω_1 and ω_2 velocity vectors; hence, the popularity of the term "cross-coupled effect".

An underlying assumption in the use of ground based treatment of airsickness is that the tolerance acquired to the cross-coupled stimulus will transfer to the airborne environment. However, the airborne value of the increased tolerance to cross-coupled stimulation is not predictable and has not been systematically investigated. Furthermore, it has been reported that when ground based tolerance training is not immediately followed by in flight desensitisation, previous tolerance acquired, appears to afford no protection for subsequent exposure to the same nauseogenic stimuli.

As mentioned previously, for the cross-coupled stimulus to occur, head movements out of the plane of rotation must be made under conditions of sustained rotation. While these circumstances may occur in low speed aerobatic aircraft, the rotational rates in high performance aircraft are relatively low and often involve increased acceleration. Furthermore, the nauseogenic effects of head movements made during increased acceleration, and during G transition (alternating between high and low G), as in traffic circuit patterns are more prevalent These conditions cannot be simulated in typical ground based Coriolis stimulation as described above, but it can be simulated, to a certain degree, in the human centrifuge.

There are some minor benefits from current ground based Coriolis stimulation. Physiologically, ground based Coriolis stimulation involves a semicircular-otolith conflict between the angular head movements and the expected change in the direction of gravity vector. Psychologically, it serves to reduce the anxiety, anticipation and erroneous expectation of airsickness. Furthermore, it allows the individuals to recognise their specific development of motion sickness symptoms. This might account for some apparent value of acquired tolerance to cross-coupled stimuli in overcoming airsickness.

It is important to note that after prolonged exposure to the provocative Coriolis stimulus, the return to the previous environment produces a reinstatement of the disturbances elicited during the initial period of exposure. In other words, the execution of head movements in a stationary environment immediately following prolonged rotation with cross-coupled stimulation frequently provokes stomach awareness, pallor, cold sweating, nausea and even vomiting. The more rapid the transition from rotation to stationary environment and the higher the preceding rate of rotation will lead to higher incidence of sickness symptoms. This is particularly provocative if the symptoms induced during rotation persist and that the head movements are identical to those involved in the acquisition of Coriolis habituation. All aircrew undergoing airsickness desensitisation training should be aware of this "reinstatement of the disturbance."

In flight desensitisation

Motion stimuli tend to provoke sickness when motion elicits patterns of sensory stimulation that do not conform to those expected on the basis of past experience. Therefore exposure to the nauseogenic flight manoeuvre is essential. In flight training also provides the aircrew with the opportunity to improve their ability to predict the spatial sensory patterns that are generated by the spatial consequence of their actions. This ability is crucial to resolve the sensory conflicts or neural mismatch in an altered gravitoinertial environment so that it is less able to provoke airsickness. Although there has been no in flight experiment to determine the degree of improvement in tolerance to aircraft manoeuvres that results from tolerance gained either from cross-coupled stimuli or other ground based training, in flight desensitisation is likely to be the most important element in airsickness desensitisation. Further, there are inevitably aspects of aircraft motion that cannot readily be reproduced on the ground and subjects need to acquire the confidence that they are resistant to sickness in the air, rather than in laboratory devices. It has been reported that pilots do not find themselves to be totally immune to airsickness at the start of their flying training. It is necessary to build up tolerance to airsickness gradually [6].

Unconventional treatments

There are many unproven treatments offered for motion sickness. A variety of herbal (ginger-root) and homeopathic (Cocculus, Nux Vomica, Petroleum, Tabacum, Kreosotum, Borax and Rhus Tox) remedies have been proposed. These remedies have not been found consistently effective and the various purported evidence is confusing at best. Various forms of acupuncture[3] therapy are available as an alternative treatment for motion sickness. Commercial devices such as "Sea Band", "Relief Band", and other forms of acupressure therapy have been investigated under controlled scientific studies [33, 34]. They were found to be ineffective in reducing nausea and vomiting as induced by motion in humans. The acupressure therapy was based on studies investigating tachygastria and tachyarrthmia[4] induced by circularvection induced sickness. Typically, a stationary subject is exposed to a drum with alternating black and white stripes (optokinetic drum) rotating around the subjects. The tachygastria or tachyarrthymia as an indication of nausea and symptoms of motion sickness has primarily been reported by one group of researchers. However, other studies using either identical or equally effective motion stimuli failed to support the positive correlation of changes in gastric activity with the incidence and severity of motion sickness [35]. In addition, it has never been reported to occur in motion-induced sickness.

Other attempts using acupressure wristbands to treat nausea and vomiting during pregnancy or in patients receiving chemotherapy provided contradictory results at best. It is possible for the alternative remedies to appear beneficial by a combination of the placebo[5] effect and habituation to the environment. Therefore, it is prudent to avoid any purported effective commercial devices until controlled scientific validation is available.

Using motion sickness drugs during desensitisation

There is evidence that drugs used for the amelioration of motion sickness such as scopolamine given prior to motion may increase adaptive rate, but following withdrawal of the drug, tolerance to motion falls below that acquired by equivalent habituation under placebo [36].

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[3] Acupuncture – puncture of the tissue with long needle or applying pressure on the body surface, for relief of pain and discomfort.

[4] An increase in the dominant frequency of the myoelectrical activity of the stomach from 3 cpm (cycle per minute) to 4-9 cpm regular activity is defined as tachygastria. A series of premature control potentials followed by a compensatory pause and a 4-9 cpm irregular activity is defiend as tachyarrhythmia.

[5] Placebo – An indifferent substance in the form of medicine, given for the suggestive effect or pleasing the patient.

Presumably, this decrease in tolerance to nauseogenic motion may also applied to other motion sickness drugs such as promethazine.

Success rate

The success rate in treating airsickness in aircrew is not always as certain as it is portrayed. Emphasis on the success rate of the program should focus on the number of participants who actually attain Wings standard. Studies of desensitisation programs have been based on subjective evaluation and have often involved small numbers of individual pre-selected groups so that an experimental conclusion may not be firmly established. In the CF study between 1981-1991, only one pilot progressed to jet training and 11 pilots progressed to multi-engine aircraft or helicopter training [1]. It is unclear whether the assignment to these less stressful aircraft was by choice or by natural selection, because they achieved marginal success in the desensitisation training or a recurrence in airsickness under fast jet environments.

It is inappropriate to compare the results of the different military desensitisation programs since each of them includes some form of pre-selection as mentioned previously. Each program also includes some forms of modification that are different from each other. For example, the current RAF program also uses linear Gz oscillation and angular oscillation in addition to cross-coupling stimulus. Continued follow-up on CF pilots who have advanced through the desensitisation training will enhance the credibility and visibility of the program.

Recommendations

Initial assessment

It is important that during this stage of assessment, the pilot who succumbs to airsickness should be given an opportunity to "arm" himself or herself with accurate knowledge about airsickness. This knowledge will dispel common myths and misconceptions and to recognise that airsickness, similar to disorientation, is a normal physiological response to an unfamiliar environment. For example, the subject should be familiar with the signs and symptoms of airsickness. The cardinal signs of airsickness are: pallor and/or flushing in the facial area, cold sweating, vomiting or retching. The cardinal symptom of airsickness is nausea. There are other signs and symptoms associated with airsickness and commonly occur in an orderly sequence as follows: stomach awareness, stomach discomfort, pallor, cold sweating, drowsiness/yawning, feeling of bodily warmth, increased salivation, nausea and vomiting/retching. The common after-effects are headache (especially in the frontal region), apathy, anorexia, general malaise, dizziness, light-headedness or disorientation, flatulence, feeling miserable or depressed, especially with motion of long duration.

It will also be beneficial to acquire some practical behavioural and environmental countermeasures in order to minimize the impact of airsickness in their early phase of flight training. Pilots and flight surgeons should refer to the Handbook of Airsickness for the Canadian Forces Air Navigation School (CFANS) [37]. Although the handbook is written primarily for CFANS, it is equally applicable to pilots and other aircrew. Copies can be obtained through 1CAD or directly from DCIEM.

For pilots who exhibit frequent and unusual susceptibility to airsickness, it is advisable to rule out underlying vestibular anomalies that might predispose the subject to airsickness. For example, an absent or defective vestibulo-ocular reflex has potential to provoke spatial disorientation and motion sickness. However, there is no "quick and simple" screening test for pilots and there is no "Gold Standard". A typical clinical test battery includes electrooculography (EOG) calibration, saccade test, spontaneous and gaze evoked nystagmus test, positioning and positional test and the Caloric test. Such extensive testing would be extremely costly and time consuming for initial medical screening of pilot who is susceptible to motion sickness. However, for preliminary clinical investigation, a detail medical history of dizziness bouts, head injury or suspected cases of vestibular neuritis could be solicited from the subject. In addition, the following vestibular screening tests on oculomotor and postural function that could be achieved with relative ease can be implemented. However, positive results from any of these tests would not imply that the subject's vestibular function is abnormal but would mean that comprehensive clinical tests should be performed. For flight surgeons that are not familiar with these tests, step-by-step procedures are provided below.

Vestibular function tests

1. Dynamic visual acuity test

(i) Measure the subject's best-corrected visual acuity with an acuity chart with head still.

(ii) Measure acuity with head passively rotated first horizontally, then vertically at a frequency of 2 Hz (to prevent visual following to stabilize the eyes). Rotation should not stop at the turn around point.

(iii) Normal individuals may lose one line of acuity.

(iv) Patients with complete loss of labyrinthine function usually lose about 5 lines.

2. Post head shake nystagmus

(i) With Frenzel goggles (magnifying glasses with light source to illuminate the eyes) in place, the patient is instructed to shake his head vigorously but carefully about 30 times side to side (rotating about the dorsoventral or yaw axis) with the chin pitched slightly down (about 20°).

(ii) Nystagmus following the "head shake" is sought (If Frenzel glasses are not available, one should still be able to observe some nystagmus).

(iii) Normal individuals have at most a beat or two of horizontal nystagmus.

With a unilateral loss of labyrinthine functions there will be a vigorous nystagmus with slow phase directed initially toward the lesion side followed by a reversed phase with slow phase directed toward the intact side. Post head shake nystagmus after head shaking in vestibular patients reflect the decay of activity within the velocity storage mechanism.

3. Halmagyi manoeuvre induced nystagmus

(i) Head only impulsive rotation test.

(ii) Rapid passive, low amplitude (10-20 deg), intermediate velocity (120-180 deg/s), high acceleration (3000-4000 deg/s^2), unpredictable rotation of the head with respect to the trunk is performed in a randomized order.

(iii) They are delivered by an examiner who holds the patient's head firmly, and at random, rapidly rotates the patient's head either to the L or R. The patient's task is to fixate on a target at approximately 1 metre away or at the nose of the examiner.

(iv) To examine contributions from COR (cervical ocular reflex) or visual reflex, the compensatory eye movement responses that occurred in the first 150msec after the onset of head acceleration are analyzed.

(v) Plots of horizontal vestibulo-ocular reflex (hVOR) gain (eye velocity is plotted as a function of head velocity).

In a normal subject the mean horizontal VOR at 120°/s head velocity is 0.94±0.08

Patients with unilateral vestibular deficits the horizontal VOR in response to ipsilateral head impulses are severely deficient.

Eye velocity gain decreases with increasing head velocity and appears to saturate at about 0.2 Hz.

Horizontal VOR in response to contra-lesional impulse is only mildly deficient with a maximum velocity gain of 0.92

4. Tests for ataxia

(i) Standing on Preferred Leg (SOPL): This test of standing steadiness requires subjects to first determine which leg they prefer to stand on. Subjects will be asked to stand, fold their arms against their chest, close their eyes, lift their non-preferred leg and lay it about two-thirds of the way up the standing leg's calf. They are instructed to remain in that position for 30s. If they move their pivot foot, removed their raised foot away from the standing leg, or grossly loose their erect body position, the trial ends and the time up to that point (in seconds) will be recorded as the score of that trial.

(ii) Standing on Non-Preferred Leg (SONL): The procedure for this test is identical to that of SOPL test except that subjects stood on their non-preferred leg. In both SOPL and SONL tests, the best three of five trials before and after simulator training are used for data analysis.

(iii) Sharpened Romberg: Subjects will be instructed to stand heel-to-toe, with the weight equally distributed on both feet, chin parallel to the floor, arms folded against their chest and eyes closed. This posture is to be maintained for a maximum of 60s or until the subject wither moved a foot or lost balance.

(iv) Walking on Floor Eyes Closed (WOFEC): Subjects will be instructed to stand erect with the heel of their preferred foot touching the toe of their non-preferred foot so that both feet are in a straight line. They fold their arms against their chest, close their eyes and walk 12 heel-to-toe steps. A trial ends if they fail to touch heel to toe, side step, or grossly lose their erect posture. The number of steps taken, up to 12, is recorded as the score for a trial. Subjects complete 5 trials or 3 perfect trials in a row.

Ground based desensitisation procedure

It has been shown that the number of motion challenges, rather than the severity of malaise level, is the more important factor determining the rate of habituation [38]. The desensitisation program should be modified to reduce the proportion of motion challenges achieving overt nausea. This will shorten the time to recover from motion sickness, thus allowing a greater number of motion challenges to be completed per day and enabling faster treatment progress.

Reducing the proportion of desensitisation sessions, which are continued to high malaise level, may have an additional advantage for some individuals. It is known that some individuals may sensitise rather than desensitise upon repeated exposure to severe sickness levels. For example, anticipatory nausea and vomiting have been observed in some patients undergoing repeated chemotherapy treatments. It has been shown that repetition intervals longer than a week could impede habituation [39, 40, 41].

It is recommended that the ground based phase involve twice-daily sessions lasting approximately 30 minutes when the subject is exposed to cross-coupled stimulus by means of head movements in the rotating chamber. The ground based phase should be shortened to 2-3 weeks. The exact procedure is listed as follows.

1. A staircase profile of motion stimulation will be used, beginning with a chair velocity of 30°/s (5RPM), the subjects executed standardised head movements in each of the four cardinal directions with their eyes closed or being blind folded. These head movements will be performed in sets, with each set consisting of five head movements (Front - pointing chin to chest, Right - roll head towards right shoulder, Back - tilt the head backwards, Left - roll the head left towards left shoulder, Front - pointing chin to chest again). After each head movement, the subject returns the head to an erect position. Each set of head movements is separated by 20 seconds of no head movement with the head remaining in the erect position.

2. After each set of head movement, the subjects report their well being using a numeric score in the range of 1 to 7 [39].

1 = No symptoms;

2 = Any symptoms, however slight;

3 = Mild symptoms, e.g. stomach awareness but no nausea;

4 = Mild nausea;

5 = Mild to moderate nausea;

6 = Moderate nausea but can continue;

7 = Moderate nausea, want to stop.

Subjects memorized this rating method before the commencement of the trial. They will be informed that although the scale is ordinal, they do not have to follow the scale in the written sequence, but rather to pair symptoms they experience at a particular instant with a specific level on the scale.

3. The rotation velocity will be increased in 15°/s (2.5RPM) steps after 40 head movements (or 8 sets of head movements) are completed at each step. The session will be terminated when the subject reports a score of 7 (nausea and want to stop) or a terminal velocity of 150°/s (25RPM) is reached. This Staircase profile has been performed previously in our laboratory and by other investigators [41, 42, 43]. In the afternoon session, the direction of yaw rotation will be be reversed from that of the morning session.

4. A quantitative measure of the cross-coupled stimulus dose should be maintained to monitor the subject's progress in desensitisation. The cross-coupled stimulus dose (D) can be quantified by summing the product of rotational speed in RPM and the number of head movements made at that speed over the duration of the treatment session [7]. Because the subject generally reaches the same symptom end-point in each session, the scores achieved represent the cross-coupled stimulus tolerance and can be plotted against time (D versus time in Day 1, Day 2, etc) through the entire treatment program to indicate the habituation progress.

Alternative ground based desensitisation stimulus

In high performance aircraft, the sustained turn rate of aircraft is not often of sufficient magnitude to generate a strong cross-coupled stimulus to the semicircular canals during head movements, especially during the commencement of the turning maneuver. It has also been suggested that when a head movement is executed during angular acceleration in the initial phase of a turn or roll, the vestibular effect is not likely to be disorienting or nauseogenic despite the fact that a cross-coupled stimulus to the semicircular canal is present. However, when decelerating from a steady turn, the disorientation and disturbing effects of the cross-coupled stimulus exacerbate. Under high G and rapid G-transition, the physical magnitude of the cross-coupling effect would be more intense and disorienting. It is rare for an aircraft to execute maneuvers involving angular motion without associated changes of gravitoinertial force. Therefore an effective means of simulating the nauseogenic environment, for example, during circuit traffic pattern, would be the human centrifuge.

When a centrifuge is in operation, it consists of two dynamic elements moving around two orthogonal axes of rotation, the planetary arm of the centrifuge and the roll axis of the gondola. These two curvilinear motions give rise to the Coriolis effect. The Coriolis effect, which affects the centrifuge rider stems from the roll motion of the gondola moving the subject's head alternately toward and away from the center of rotation of the planetary arm during acceleration and deceleration. The magnitude of the effect is a function of the angular velocity of the planetary arm and the radial velocity of the head (hence, it affects the organ of balance). It has also been reported that nauseogenic and perceptual effects during deceleration were much stronger than effects during acceleration [44]. Therefore, repeated exposure to

+Gz (up to +4Gz) with gradual onset rate at +0.1Gz/s and decelerating at 1Gz/s would be ideal in simulating "circuit" flying in the air.

The current CF High Sustained Gz Course (CF HSG Course) requires that Harvard II, Hawk, Tutor and CF-18 pilots subjected to +4 Gz profiles each in the DCIEM human centrifuge. The airsickness desensitisation training could be implemented into the CF HSG course for pilot trainees who are susceptible to airsickness. The first profile will be a gradual onset rate (+0.1Gz/s) to +1.4Gz baseline. It serves as a familiarization run and a chance to experience mild disorientation and discomfort during acceleration and deceleration. The subject remains in a relaxed state until the baseline G is reached and the subject is instructed to hold it for 30 seconds. The subject then releases the enable switch and wait until the centrifuge comes to a full stop. Subsequent profiles involves rapid onset rate to +2.0, 3.0, 4.0Gz, and each lasts for 30 seconds. Once the pilot releases the enable switch, the centrifuge returns to baseline. The centrifuge will be brought to a stop when the subject indicates their readiness to come to a full stop. These profiles in succession will provide the subject with gradual experience on different severity of Coriolis cross-coupling, combined with the experience of G transition and sustained +Gz.

In flight desensitisation procedure

The In flight phase of the desensitisation should follow the ground based training phase immediately (the next day). Pilots who will be conducting the in flight desensitisation procedure should be external to the training unit of the subject. The subject will experience these demonstrated manoeuvres strictly as a passenger (remain passive, and without active control of the aircraft). Flying instructions will be forbidden, hence no evaluation of the subject's flying performance or skill acquired during the desensitisation flights will be made. The syllabus is divided into 5 phases (5 different flights) and each phase is assigned a severity index based on the provocation of the manoeuvre in inducing nausea and discomfort.

The progress of the in flight desensitisation should depend on the subject's rate of habituation. If the subject reaches a rating of 7 at each manoeuvre in the first exposure, the manoeuvre will be repeated before the next phase. In flight desensitisation will be terminated if the subject failed to progress through the same manoeuvre for a third time or when the subject completed all 5 stages of progressively provocative manoeuvres. It is anticipated that the in flight desensitisation procedure lasts between 10-15 hours.

Subject's well being can be obtained using the identical numeric score in the range of 1 to 7 (as in the ground based desensitisation phase) after each sortie:

1 = No symptoms;

2 = Any symptoms, however slight;

3 = Mild symptoms, e.g. stomach awareness but no nausea;

4 = Mild nausea;

5 = Mild to moderate nausea;

6 = Moderate nausea but can continue;

7 = Moderate nausea, want to stop.

The progression of the different manoeuvres and their corresponding severity index are recommended as follows:

Severity Index = 1

1. "IFR" type of takeoff

2. Straight and level flights at various speeds

3. Low speed handling

4. Abrupt decelerating

5. Turns at 30°, 45°

Severity Index = 2

1. Turns at 60° angle of bank

2. Circuits flying (with rapidly changing angles of bank and provocative transition of Gz.

Severity Index = 3

1. Medium speed entries to maximum rate level turns

2. Stabilized turn and reversal (maintaining light buffet depending on the aircraft)

Severity Index = 4

1. Basic barrel roll while maintain a visible reference of the horizon

2. Barrel roll without the visual reference of the horizon for half of the barrel roll

3. Roll off the top

Severity Index = 5

1. Horizontal roll

2. Cuban eights

3. Wing-over

4. Slow roll

5. Vertical roll

6. Hesitation manoeuvres

Evaluation of in flight desensitisation progress

The subject's well being (based on the 7-point scale and the severity index for each sortie can be plotted graphically to provide an indication of the progress made by the subject and the amount of flying the subject has received. In other words, plots of severity index and well-being plotted against the days of sortie will provide an indication of the subject's progress throughout the in flight desensitisation phase.

Conclusions

Airsickness, a form of motion sickness, is a maladaptive response to unfamiliar real or apparent motion. Various scheme of airsickness desensitisation has been employed in the military environment. This report recommends an initial assessment including education of the affected aircrew, a screening for underlying vestibular anomalies, a shortened ground based desensitisation phase, which is followed immediately by a gradual introduction to various provocative manoeuvres. It is recommended that biofeedback; relaxation therapy and any unconventional treatments without proven scientific validity should be eliminated. Tolerance acquired from ground based Coriolis stimulation does not necessarily result in increased tolerance to provocative aircraft motion in the air. A potential similarity could occur between sensory mismatch at the vestibular organ level, rotational signal without the confirmation of the gravity receptor. In addition, the ground based phase provides the subject an opportunity to become familiar with the development of motion sickness symptom, which could lessen the anxiety, anticipation and fear. Repeated acceleration and deceleration profiles in the human centrifuge could serve as an effective ground based desensitisation stimulus. However, In flight exposure to various provocative manoeuvres is the most important element of the desensitisation program.

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14. ABSTRACT

(U) Airsickness is associated with other forms of motion sickness. It is a common occurrence among aircrew trainees; the problem is most acute in the early stages of training. The identification of an alternative to pharmacological treatment of airsickness for individuals regularly exposed to provocative environments while carrying out skilled or potentially hazardous tasks, is an important issue. Airsickness desensitisation has been proposed and employed by various nations as the program of choice for prevention of airsickness during early training. With the newly acquired trainers (Harvard II and the Hawk) in the Canadian Forces (CF), it is important at this time to re-evaluate the CF airsickness desensitisation program at 15 Wing. The purpose of this recommendation is to provide a scientific update on habituation to nauseogenic motion stimuli, to clarify a number of misconceptions and to provide a recommendation on an improved airsickness desensitisation program based on current valid scientific information. A number of vestibular screening tests on oculomotor and postural function that could be achieved with relative ease are proposed as part of the initial assessment for potential pathological predisposition to airsickness. It is also recommended that the current biofeedback and relaxation therapy be deleted. Ground based desensitisation should be reduced to a 2-3 week period of twice daily exposures to Coriolis stimuli of progressively increasing intensity. This is followed immediately by 10-15 hours of exposure in which incremental habituation to the more complex and provocative manoeuvres are carried out. Quantitative evaluation of the subject's progress for both ground based and in flight desensitisation is recommended. An alternative ground based desensitisation procedure using the human centrifuge is proposed.

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) Airsickness; motion sickness; desensitisation; training

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