

# The Italian Air Force rehabilitation programme for air-sickness

## *Il programma di riabilitazione del mal d'aria dell'Aeronautica Militare Italiana*

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### Key words

Vestibular system • Motion sickness • Air sickness • Rehabilitation • Aircrews

### Parole chiave

*Sistema vestibolare • Chinetosi • Mal d'aria • Riabilitazione • Equipaggi di volo*

### Summary

Motion Sickness, or kinetosis, is a complex clinical syndrome usually classified according to the environmental situation evoking the symptoms. Among the various forms of motion sickness, air sickness has a significant impact on aircrew readiness and is often a cause for the grounding of aircrew. Unfortunately, standards for clinical testing to accurately predict the sensitivity of each individual to air-sickness are currently lacking. Furthermore, pharmacological prevention is contraindicated for aircrews, whose cognitive tasks involve a high level of vigilance. Therefore, a number of Air Forces have developed their own rehabilitation programmes to counteract air-sickness effects on flight personnel. These programmes may differ in several aspects, such as their duration, instruments used, costs and the technical characteristics of the rehabilitation team. However, reports in the specialized literature, refer to high rates of success, despite the above-mentioned differences. In the autumn of 2000, the Italian Air Force (ITAF) also began its own rehabilitation programme for air-sickness desensitisation. The programme was developed at the Aerospace Medicine Department of the ITAF Flight Test Centre, at the Pratica di Mare Air Force Base, Italy. The ITAF rehabilitation course lasts two weeks, and candidates are first classified according to their clinical history and to their reaction to the Coriolis Stress Test. Thereafter, subjects undergo a personalized desensitisation programme, involving increasingly more intense nauseogenic stimuli by means of various devices. At the same time, a psychological approach, based on autogenous training and cognitive-behavioural therapy, is adopted. The present report refers to data from 17 subjects treated from January 2001. The current clinical outcome is extremely encouraging, with a success rate of 88%. Nevertheless, several aspects of motion sickness rehabilitation are still under investigation, and further research programmes, aimed at improving the final clinical outcome and prolonging the benefits of rehabilitation, are needed.

### Riassunto

*Le chinetosi costituiscono un insieme di sindromi cliniche complesse che vengono abitualmente classificate secondo le condizioni ambientali che generano il disturbo. Tra le sue varie forme, il mal d'aria possiede un impatto significativo sull'efficienza degli equipaggi di volo ed è una frequente causa di non idoneità al volo. Purtroppo, al momento attuale non esiste una batteria di tests clinici in grado di predire con assoluta sicurezza i soggetti che risulteranno sensibili a stimolazioni nauseogeniche. Inoltre, un approccio farmacologico è controindicato negli equipaggi di volo, a causa dell'elevata incidenza di effetti collaterali come la sonnolenza, assolutamente incompatibili con tale attività. Pertanto, alcuni Centri di Medicina Aeronautica hanno sviluppato dei propri protocolli riabilitativi finalizzati a contrastare il problema del mal d'aria nel personale di volo. Tali programmi possono differire per diversi aspetti, come la durata, le apparecchiature impiegate, i costi e le caratteristiche dell'équipe di riabilitazione. Tuttavia, indipendentemente da tali variabili, i riscontri della letteratura specializzata sull'argomento permettono di osservare elevati livelli di successo terapeutico con tutti i principali protocolli in uso. Nell'autunno 2000, anche l'Aeronautica Militare Italiana ha iniziato un proprio corso di desensibilizzazione dal mal d'aria, che è stato sviluppato presso il Centro Sperimentale Volo - Reparto Medicina Aeronautica e Spaziale di Pratica di Mare. Tale corso dura 2 settimane ed i candidati vengono inizialmente classificati a seconda della propria storia clinica e della loro reazione al Coriolis Stress Test. Successivamente, i soggetti iniziano un protocollo riabilitativo personalizzato, che prevede stimolazioni nauseogeniche progressivamente crescenti su vari tipi di apparecchiature. Contemporaneamente viene effettuato un protocollo riabilitativo a carattere psicologico, basato sostanzialmente sul training autogeno e sulla terapia cognitivo-comportamentale. Questo studio analizza la risposta al trattamento osservata in 17 soggetti, che sono stati sottoposti a riabilitazione nel periodo gennaio 2001-giugno 2003. La percentuale di successo terapeutico è stata del 88% ed è pertanto altamente incoraggiante. Tuttavia, esistono ancora significativi margini per la ricerca applicata al miglioramento dei protocolli riabilitativi adottati, finalizzata principalmente all'incremento del rateo di successo terapeutico ed al prolungamento nel tempo dei benefici della riabilitazione.*

## Introduction

Motion Sickness (MS), or kinetosis, is a complex clinical syndrome, characterized by various initial symptoms and signs, such as sweating, pallor, drowsiness, paresthesia, and others, which induce nausea and vomiting over sufficiently prolonged exposure to appropriate stimulation. In some cases, prodromic symptoms are missing, and the patient immediately experiences distress accompanied by retching and vomiting.

From an etymological point of view, it is interesting to observe that the term “nausea” comes from ancient Greek  $\nu\alpha\upsilon\varsigma$  (ship), since exposure to a “new” environment, such as sea motion, triggered off MS symptoms in a large number of individuals.

MS is usually classified according to the environmental situation that evokes the symptoms. Thus, it will be classified as sea-sickness, car-sickness, air-sickness (AS), and so on. The clinical differences between such conditions are related to the specific environments causing different nauseogenic stimuli, with a variable number of individuals affected and a variable period of time for symptoms. The physical characteristics of the stimuli, in terms of frequency, intensity, direction and duration of the acceleration have been found to be the critical factor in the onset of MS symptoms<sup>1-6</sup>. Typically, the low stimulus frequencies (i.e., <1 Hz) are those mainly involved in generating MS, while higher frequencies can evoke several other symptoms, but rarely nausea and vomiting. As far as concerns the intensity of the stimulation, its ability to cause MS can be predicted by the “motion sickness dose value” (MSDV) formula:

$$\text{MSDV}_z = (a^2 t)^{1/2}$$

where “z” indicates that, in this case, acceleration on the z axis is involved (i.e., vertical), and “a” is the acceleration calibrated for the stimulation frequency as determined by linear integration over the motion period  $t$ <sup>7</sup>. From a practical point of view, this formula can be related to the MS incidence by the equation percentage of unadapted adults who may vomit =  $1/3 \text{MSDV}_z$ .

Therefore, a double magnitude of the motion, or a four-fold increase in the duration of exposure, will double the incidence of vomiting.

Table I shows the incidence of various forms of MS reported in the literature, and clearly demonstrates how variations in stimulation parameters (i.e., exposure to different environments) can influence the clinical findings<sup>8-11</sup>.

However, apart from a few subjects who will be highly sensitive (or insensitive) to practically all forms of stimuli, in most cases, the incidence of MS is limited to one or two nauseogenic situations, implying that

**Table I.** Incidence of vomiting due to motion sickness according to different environmental situation\*.

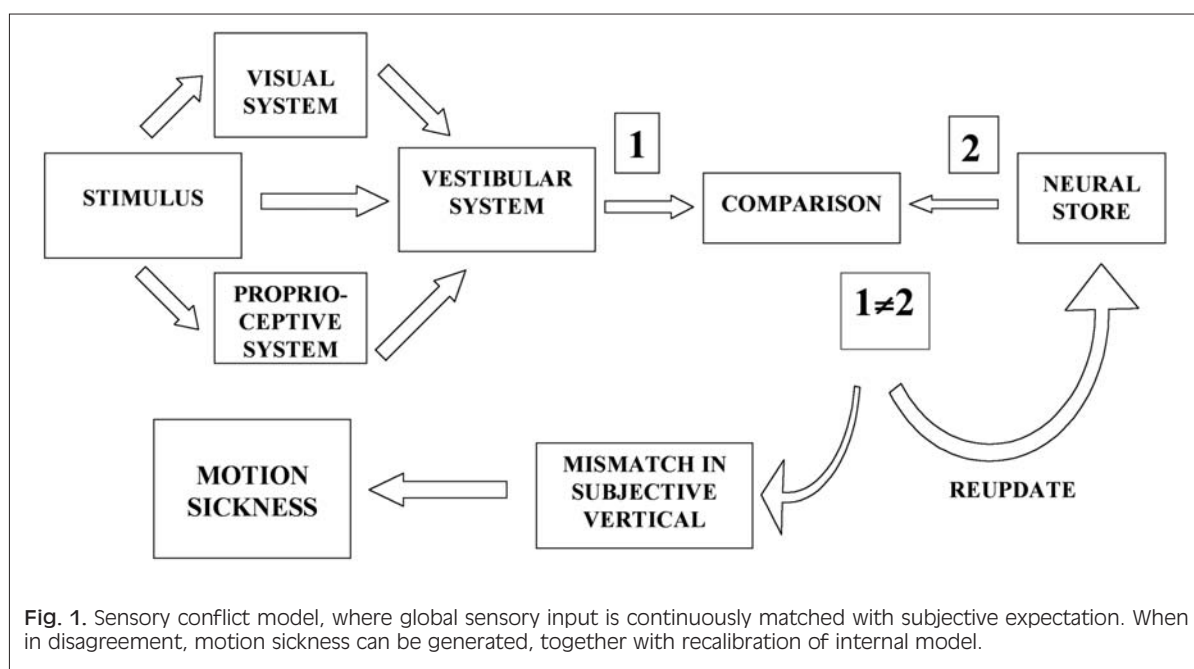
Environmental situation	Incidence	Source
Sea-sickness	62%	Turner & Griffin 1995
Space-sickness (SAS)	75%	Oman et al. 1990
Air-sickness	32%	Lucertini 2001
Car-sickness	33%	Reason 1967

\* Reference source indicated in third column.

sensitivity to one form of MS does not automatically mean a higher risk of succumbing to others.

The occurrence of MS can be considered in relation to the evolution of human beings, when a complex sensory arrangement was developed in order to obtain correct signals on equilibrium and orientation. This was attuned to the habitats of humans, and included correct signals during standing, walking, running etc. Problems started when humans began to be exposed to “unusual” environments such as the sea, wheeled vehicles, or aircrafts, where the motion characteristics were significantly different from those for which our sensory organs were geared. As shown in Figure 1 (right), an internal model is progressively evolved in our brain from birth, on the basis of previous information about equilibrium and orientation. The actual sensory input coming from the sensory organs (Fig. 1, left) is continually matched with this internal model and if such incoming stimulation agrees with the expectations of the internal model, for such a specific situation (i.e., if the sensory input indicates what the brain is expecting at that moment), equilibrium is reached. On the contrary, if the sensory input is different from that expected ( $1 \neq 2$  in Fig. 1), a vector is generated. Under specific conditions, this can evoke MS, and can simultaneously re-update the internal model<sup>12</sup>. This is a possible explanation for the phenomenon of adaptation to MS, and is in agreement with the observation that student pilots are usually affected by AS during the early stages of their flight training, but not later, due to recalibration of the internal model after a few hours’ exposure to the new aviation environment<sup>8</sup>. However, in order to generate MS, only a mismatch between sensory input and what is expected by the internal model is still not sufficient. In fact, it is essential that such discrepancy also involves the subjective sense of vertical, which is the subjective direction of gravito-inertial force<sup>12</sup>.

All subjects with normal vestibular function are potential candidates for MS, while only those few patients with a total bilateral loss of vestibular function will be insensitive to any nauseogenic stimulation<sup>13</sup>.



Within a normal sample, the degree of each individual's sensitivity will possibly change, but none will be entirely resistant to any nauseogenic stimulation. This can be observed with all forms of stimuli, including purely visual types. The central role of the vestibular system is also indicated in Figure 1, which shows how the different sensory inputs first interact with the vestibular system before being compared with the internal model<sup>14</sup>; thus, an adequate vestibular function is required for the development of MS symptoms. On the contrary, visual defects, as in blindness, do not alter the individual's sensitivity to a moving environment<sup>15</sup>.

From an epidemiological point of view, a high inter-individual variability characterizes all syndromes involving a moving environment and can be related to various factors, such as sex, age etc.<sup>16-22</sup>. However, such a finding is not only strictly related to the sensitivity to MS, but also involves two other essential factors in rehabilitation:

- adaptability, which is the subject's sensitive ability to become resistant to the nauseogenic environment/stimulation;
- retentivity, which is the individual's ability to prolong his/her own adaptation over time.

These three factors (sensitivity, adaptability, retentivity) represent the essential baselines for epidemiological studies on MS and rehabilitation. Unfortunately, it is not possible to predict that all subjects that will be sensitive to MS, and this is also true, both for adaptability and retentivity. Thus, reliable meth-

ods of preliminary investigation and selection of individuals are currently lacking<sup>22-24</sup>. In fact, even workers employed in a moving environment, such as aircrews or sailors, are not usually tested for MS sensitivity. Furthermore, current clinical investigations do not usually add significant information on adaptability and retentivity.

From a practical point of view, a more realistic method is to allow each individual to become adapted to the specific nauseogenic environment, and to treat only those few cases (slow adaptors) who have not adapted after an adequate exposure time.

Within the general population, the pharmacological approach to MS plays a major role in the prevention of symptoms. However, drowsiness is a common side-effect of most drugs employed for this purpose (for review, see Refs. 25, 26). Therefore, typical targets for pharmacological therapy are subjects (such as passengers), not involved in tasks where alertness is required. In other cases, such as in slow-adapting aircrews, rehabilitation techniques are usually preferred, due to the operational implications of MS symptoms and the need to avoid possible side-effects related to the use of medication.

Within the Italian Air Force (ITAF), a rehabilitation programme was recently developed in Pratica di Mare AFB, Italy, to desensitise personnel presenting AS, referred to our Centre for examination.

The present report shows the current state of the art of this programme for AS rehabilitation.

## Cases and methods

The data presented here refer to part of the case records obtained at our Centre, from January, 2001. A total of 17 male patients were examined (age range 18-27 years), all referred to our Centre on account of AS. These subjects were assessed in an initial phase with a Coriolis Stress Test (CST), taking into consideration the following series of experiments carried out by means of a rotating chair:

1. Clockwise rotation at 90°/sec for 2 minutes;
2. Anticlockwise rotation at 90°/sec for 2 minutes;
3. Clockwise rotation at 150°/sec for 3 minutes;
4. Anticlockwise rotation at 150°/sec for 3 minutes.

During each test, the patient was asked to jerk his head forwards and backwards with eyes closed, thus inducing the Coriolis phenomenon, with the whole movement taking place every 4 seconds. The four tests were separated by 5-minute intervals, during which the patient maintains a seated position. The test was then interrupted and defined as positive, in the case of an advanced state of malaise of the patient, who either asked for interruption of the stimulation (subjective parameter), or when vomiting occurred (objective parameter).

Our rehabilitation protocol, on the other hand, foresees two forms of approach:

- Physical: based on de-sensitisation of the vestibular system obtained with exercises of a nausea-inducing character (head movements in pitch and roll during rotation to induce the Coriolis phenomenon), usually carried out on a rotating chair. In this case, the patient undergoes rehabilitation sessions that are progressively longer (15-20 min.), with an ever-increasing speed of rotation of the chair ( $\leq 120^\circ/\text{sec.}$ ). During most rehabilitation sessions, the patient is asked to keep his/her eyes closed to inhibit visual fixation and increase the potential nauseogenicity of the exercise. Moreover, the patient's emotional state is continually monitored according to a "misery scale", defining various levels of malaise from 0 (opti-

mum condition) to 10 (occurrence of vomiting).

- Psychological: based on teaching relaxation techniques aimed at preventing the onset of neuro-vegetative symptoms using 3 of the 6 exercises in the lower scales of the autogenous training of Schultz (weight, heat and breathing)<sup>27</sup>, as well as on a cognitive-behavioural treatment aimed at interrupting the vicious circle that often occurs between the unpleasant event (kinetosis) and the psychological attitude of the patient<sup>22 28 29</sup>.

This type of multidisciplinary approach is not unlike that used by several Schools in the treatment of tinnitus, following the observations of Jastreboff and Hazell<sup>30</sup>, or in the treatment of so-called "motorist vestibular disorientation syndrome", described by Page and Gresty<sup>31</sup>.

Rehabilitation from kinetosis is a very tiring procedure based on inducing nausea through specific exercises and is, therefore, only recommended for highly motivated individuals. In addition, considering the high degree of influence – even transitory – involved in these experimental methods on the neuro-vegetative equilibrium, it is essential that the subject being treated is, from a cardiovascular viewpoint, rated as normal (in our specific case records, the problem did not arise inasmuch as the patients, aircrew members, had already been judged as suitable candidates). Duration of the treatment, according to our protocol, is 2 consecutive weeks (10 working days). It is not surprising, therefore, that use of this method is usually limited to personnel following their profession in one of the classical environmental "at risk" situations (airmen, mariners etc.).

At the end of the rehabilitation period, the patient again has to undergo a CST, aimed at laboratory assessment of the eventual benefits obtained.

## Results

The initial CST test was positive in all cases, due to interruption, on account of severe malaise on the part

Table II. International data on air-sickness desensitisation\*.

Author	Year	No. Subjects	Duration (weeks)	Flight	Psychol. approach	Success rate
Levy et al.	1981	20	2	Y (5 m.)	Y	85%
Giles & Lochridge	1985	37	1	N	Y	95%
Stott	1990	66	4	Y (15 m.)	N	79%
Stott	1990	17	4	N	N	94%
Lucertini & Lugli	2003	13	2	N	Y	92%

\* Some of main characteristics of each protocol are indicated (Authors, year publication, n. treated subjects, duration of rehabilitation course, presence (Y)/absence (N) of real-flight activity within protocol, presence (Y)/absence (N) of psychological support during rehabilitation, final success rate of each treatment). ( ) n. flight missions, when real-flight activity is included in rehabilitation programme.

**Table III.** Final outcome of subjects investigated in present study. Individuals are classified according to flight activity.

Aircrew category	Number of subjects	Healed in laboratory	Healed in flight (long term)	Healed in flight (short term)
Pilots	3	3 (100%)	3 (100%)	3/3 (100%)
Student pilots	12	10 (83%)*	10 (83%)*	5/6 (83%)
Navigators	2	2 (100%)	2 (100%)	1/2 (50%)
Total	17	15 (88%)*	15 (88%)*	9/11 (82%)

\* Only 9 out of 10 student pilots in column no. 3 are part of the sample indicated in column no. 4. This finding can also be observed in the total data (last row).

Healed in laboratory: number (and percentage) of individuals negative at final CST at end of rehabilitation. Data of final success rate obtained in real-flight environment are divided according to duration of follow-up (short term: <1 year; long term: = 1 year). Long-term follow-up (fifth column) shows data from only 11 subjects.

of the patient, or due to onset of vomiting. Table II shows data obtained immediately after rehabilitation, comparisons being made with similar data obtained from the international literature<sup>32-35</sup>. The overall efficiency of the various rehabilitation protocols adopted at the various centres appears to be excellent, independently of the duration and the precise characteristics of the treatment used.

It is also interesting to note how, in the specific instance of our present case records (Table III), one of the student pilots affected by AS, with a negative CST at the end of rehabilitation (therefore, apparently successfully rehabilitated), still continued to suffer from AS during subsequent flights. At the same time, another individual, positive to the CST post-rehabilitation (therefore, apparently a rehabilitation failure), never suffered, thereafter, from kinetosis.

Table III (fourth column) also shows the long-term outcome of our treatment (i.e., follow-up >1 year). The study population was, by then, reduced to 11 individuals, due to the definitive grounding of 6 student pilots during the flight school course, which in 5 cases was unrelated to AS. As indicated in the Table, in 2 individuals, long-term recurrence of AS symptoms was observed, that resolved spontaneously within a few flight missions.

## Discussion

MS is a very common disorder, causing significant impairment of physical fitness and readiness in affected individuals, a factor which is stressed when frequent exposure to nauseogenic environments cannot be avoided, particularly in those performing highly demanding tasks, such as aircrews, parachute jumpers, sailors. Moreover, AS is a major cause of exclusion for student pilots during their training course (cfr. 8, 22).

Thus, due to the limitations related to the pharmaco-

logical approach, some aeromedical centres have developed different rehabilitation programmes, which in ITAF laboratories focus on the treatment of AS. These programmes may differ as far as concerns duration, available instruments (including the opportunity for real-flight activity) and the rehabilitation team involved (physicians, psychologists, technicians, aircrew members), as indicated in Table II for AS<sup>32-36</sup>.

The aim of these programmes is to obtain a complete and permanent resolution of MS symptoms in each subject. Unfortunately, this cannot always be achieved, due to factors related to individual characteristics and to the particular environments where he/she is to be exposed.

Besides the inter-individual variability of the clinical outcome, in any therapeutic approach (rehabilitation from MS included), other factors may influence the final results of these programmes, such as prolonged absence from potentially nauseogenic motion sources, which paradoxically are the environmental situations that best prolong the benefits of rehabilitation, acting on retentivity.

Although initially resulting as healed, 2 patients in the present series (one student pilot and one navigator) showed recurrence of MS symptoms after a prolonged absence from flight activity. This led to a reduction in our long-term success rate from 88% to 82% (Table III). Therefore, in selected cases, a second rehabilitation programme can be hypothesized.

In our study population, the mild discrepancy between laboratory findings and the effective flight data appears to be of particular interest. In fact, one subject apparently rehabilitated according to laboratory parameters (final CST negative), actually continued to suffer from AS during effective flying, while another apparently unsuccessful case (final CST still positive) reported no further significant episodes of AS. This finding further confirms the current impossibility to fully reproduce identical



flight conditions, within a laboratory, as also reported by Kennedy et al.<sup>23 24</sup>

Due to these factors, in our rehabilitation course, each patient undergoes nauseogenic stimulations under different environmental conditions in order to adapt his/her psycho-physical response to as many stimuli as possible. Therefore, in addition to the standard rotating chair (which includes off-axis rotation), a flight simulator and a linear accelerator are used. The final goal is to train each patient to face a broad range of effective conditions during his/her future flying activity.

The psychological aspects of our approach are also aimed at giving our patients further instruments to counteract MS under heterogeneous conditions<sup>22 32-34</sup>.

In psychological terms, the symptomatology present during episodes of kinetosis is very similar to what, in the psycho-physiological field, is defined as emotional activation, being the immediately response of the organism which experiences an emotion and an activation of the autonomous nervous system, clearly expressed by a defence/offence reaction. The main cerebral region responsible for activation of emotional behaviour is the limbic system, in particular the amygdala<sup>37</sup> which would appear to have the capacity to store emotional memory, according to the meaning that these events have, for each individual, in terms of pleasantness/unpleasantness, danger/safety. All new experiences reach that level when faced by association with past events and, if the present and past situations have elements in common, that is enough to trigger off an emotional response with similar characteristics. This would explain why very often in experiences of kinetosis an association is created between the sensation of feeling ill and certain odors, environments etc. so that the occurrence, even of one of these elements, can trigger off this phenomenon.

Rehabilitation enables the patient to be aware that also some types of "negative" thinking can activate new episodes of kinetosis. Concentrating on what one is thinking is the first step towards change. Such recognition can also function as an alarm bell to query

one's usual way of thinking and to begin to think in a different way. Therefore, it is necessary to reconstruct, in the individual experience of each patient, what type of thought has accompanied the experience of kinetosis. To substitute the negative thoughts connected with the fear of feeling ill with other more positive thoughts aimed at breaking the chain of events that inevitably leads to this condition<sup>28 29</sup>.

Together with training of thoughts, patients are encouraged to learn muscle-relaxation techniques, aimed at deactivation of the emotional response to MS<sup>27</sup>. During rehabilitation, the patient is taught to become aware of the sensations that accompany the gradual onset of kinetosis and to learn how to use these sensations as a signal to relax<sup>38</sup>. Once learned, the relaxation responses become anticipatory, having the effect of creating a short circuit in the emotional response. Rehabilitation has provided a new and different response for future use. In fact, during the sessions on the rotating chair, through muscle relaxation and a positive way of thinking, together with the adaptation of vestibular sensors, the state of sickness begins to be interrupted and causes the related circuit of kinetosis and, therefore, the emotional archive of the amygdala to expand.

In our opinion, this multidisciplinary approach, which implies various physical forms of desensitisation of the vestibular organs combined with psychological tactics, can be indicated as a good compromise between various needs, such as time, costs and final results. Moreover, it can be applied to heterogeneous populations and syndromes, sea-sickness and others included.

However, some aspects still need further research and elucidation. One of these is the possibility of adding pharmacological support in those activities where highly demanding cognitive tasks are required, such as in aviation, or for the development of techniques to prolong the retentivity of rehabilitation.

Nevertheless, at least as far as aircrews are concerned, our data show that problems related to AS can be rapidly and efficiently resolved with a relatively simple and short-term rehabilitation protocol.

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■ Acknowledgements: Authors are grateful to W.O.s G. Angelino, P. Carrozzo, A. Rossi and R. Vitalone for technical contribution in ITAF research and rehabilitation programmes on motion sickness, and to Mrs. D. Cook Turano for review of English manuscript.

■ Received: March 4, 2004  
Accepted: April 26, 2004

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