CLINICAL FEATURES OF MAL DE DEBARQUEMENT: ADAPTATION AND HABITUATION TO SEA CONDITIONS

Carlos R. Gordon,* † Orna Spitzer, * Ilana Doweck,* ‡ Yehuda Melamed,* † and Avi Shupak*

*Motion Sickness and Human Performance Laboratory, Israel Naval Medical Institute, Haifa, Israel;
†Department of Neurology, Belfinson Medical Center, Petah Tiqva, and the Sackler School of Medicine, Tel Aviv University, Tel Aviv, Israel;
‡Department of Otolaryngology, Carmel Lady Davis Hospital, Haifa, Israel
Reprint address: Carlos R. Gordon, Motion Sickness and Human Performance Laboratory, Israel Naval Medical Institute, P.O. Box 8040, 31 080 Haifa, Israel

Abstract — A survey conducted among 116 crew members of seagoing vessels confirmed that mal de debarque ment (M-D) is a transient feeling of swinging, swaying, unsteadiness, and disequilibrium. None of the subjects requested medical attention, although there were isolated cases in which a strong sensation of swinging and unsteadiness caused transient postural instability and impaired the ability to drive. In most cases, the sensation of M-D appeared immediately on disembarking and generally lasted a few hours. In addition, subjects usually described bouts or attacks of M-D associated with changes in body posture, head position, or with closing of the eyes. M-D was reported by 72% of our subjects. Sixty-six percent of subjects reported a high incidence following their first voyages. A significant positive correlation was found between M-D and seasickness susceptibility. The nature of M-D may be explained within the framework of multisensorimotor adaptation and habituation to a new or abnormal motion environment. It is suggested that M-D represents a dynamic, multisensorimotor form of CNS adaptive plasticity.

Keywords — mal de debarque ment; motion; adaptation; habituation.

Introduction

Mal de debarque ment (M-D) is a transient sensation of swinging, swaying, unsteadiness, and disequilibrium that appears after disembarking from a ship (1). A similar phenomenon has been reported by pilots after simulator training flights (2–6). Apparent perception of motion has been reported by subjects who spent several days in a slowly rotating room (7). M-D has been included as one of the physiologic dizziness syndromes, other examples of which are motion sickness, space sickness, and height vertigo (8). Although the phenomenon is widespread among passengers disembarking from ocean-going liners and ferries, there are no specific reports which deal with the nature of M-D.

In a recent survey of 234 crew members of fairly small seagoing vessels (300–500 tonnes), we reported a high incidence of M-D (73%). Its occurrence appeared to be related to seasickness susceptibility, but not to experience at sea (9). In an early article on seasickness, Irwin (10) suggested that the explanation for M-D might be found in the process of short-term adaptation to ship motion. The assumption is that during a sea voyage, there is gradual and relatively rapid sensorimotor adaptation

Presented at the 63rd Annual Scientific Meeting of the Aerospace Medical Association, Miami Beach, FL, May 10–14, 1992.

Received 12 July 1994; Accepted 12 January 1995.
to the unusual moving environment. Back on land, these newly acquired sensorimotor patterns are no longer appropriate. This gives rise to M-D, which lasts until readaptation to conditions on land is achieved (11). A similar explanation has been proposed for the disequilibrium and unsteadiness which appear after space shuttle missions and flight simulator training (5,12–14). There is only one report of M-D persisting for months to years after disembarkation (15). This was explained in terms of probable failure to readapt to the natural conditions on land. No evaluation has been made of long-term habituation, that is, a lasting reduction in the response to repetitive stimulus exposures.

This study provides a detailed description of the nature of the phenomenon and evaluates the relevance to M-D of long-term habituation to sea conditions (during repeated sea voyages).

**Materials and Methods**

One hundred sixteen male crew members of seagoing vessels (300–500 tonnes) participated in the study. Subjects were of the ages 18 to 33 y (mean 20.4 y). They sailed once or twice a week, usually for 5 to 8 h per voyage, over a period that ranged from 1 to 120 mo (average 18 mo). None of the subjects had a history of any disease that might cause unsteadiness, disequilibrium, or vertigo. Subjects were asked to complete questionnaires regarding their experience of M-D, its features, and the effect of habituation to sea conditions, their susceptibility to seasickness, and their experience at sea.

The incidence of M-D and its clinical features were evaluated as follows:

1. The incidence of the phenomenon (occurrence and frequency) using a 4-point scale (Yes, very often; Yes, occasionally; Yes, only once; Never).
2. Latency: The time from disembarkation till the onset of the phenomenon (in min).
3. Duration of the phenomenon from onset (in min).
4. A search for additional associated factors in M-D, such as rough seas and prolonged voyages.
5. A detailed description of symptomatology was obtained by medical interview from 30 subjects who had experienced M-D.

The effect of habituation was evaluated by asking the subjects whether the incidence of M-D changed in relation to the number of voyages; that is, whether the condition was experienced more frequently during their earlier or later voyages, or whether there was no difference.

Individual susceptibility to seasickness was evaluated as follows:

1. Present susceptibility to seasickness was graded on a 7-point scale (not susceptible to very susceptible) according to Wiker et al (16,17).
2. Nausea and vomiting during the most recent voyages in rough seas were graded on a 5-point scale.
3. The subject's susceptibility to seasickness in comparison with other crew members was graded on a 3-point scale.
4. Susceptibility to motion sickness in the past was graded on a 4-point scale.

Experience at sea was recorded in months.

**Results**

Figures 1 to 3 show the incidence, latency, and duration of M-D. Seventy-two percent of the subjects (83 individuals) reported having experienced M-D. Fifteen percent experienced it very often, 28% occasionally, and 29% only once. Twenty-eight percent of the survey participants had never experienced the phenomenon.

Latency to onset of the phenomenon ranged from immediately on returning to land to 2 d after leaving the ship. Forty-six percent of the subjects who had experienced the phenomenon reported that it occurred immediately on their return to land or 1 min later. Eighty percent of the subjects reported that it appeared
within 1 h of disembarkation. There were only seven cases in which onset was delayed for more than 2 h.

Duration of the phenomenon ranged from 1 min to 2 d. In 88% of the subjects, the phenomenon did not last for more than 6 h. Only two subjects reported a duration of more than 24 h.

With regard to additional associated factors, 40% reported having experienced the phenomenon particularly after sailing in rough seas. Forty-five percent reported that it generally occurred after long voyages.

None of the subjects requested medical attention or visited our clinic of his own accord to complain of symptoms. From a detailed clinical interview of 30 subjects, it was clear that they all naturally related the M-D symptomatology to the previous voyage and knew it to be transitory. In addition to its appearance immediately on disembarking, 25 of the 30 subjects reported experiencing fluctuations or aggravation of the phenomenon, actually describing bouts or attacks of a swinging sensation related to eye closure, tilting the head, or lying down. No subject reported nausea or vomiting. Eighteen subjects reported that the sensation could be alleviated or relieved by returning to their ship. Only three subjects reported episodes of a strong sensation of motion, instability, and difficulty driving, particularly after a prolonged voyage in rough seas.

Regarding habituation, 66% of the subjects reported that the incidence of M-D was higher after their earlier voyages. Thirty-one percent reported that its incidence remained unchanged with repeated voyages (that is, the same incidence after earlier and later voyages). Only two subjects reported that the incidence of M-D was higher after later voyages.

Kendall correlation coefficients were calculated between M-D and experience at sea, and between M-D and seasickness susceptibility parameters.

No correlation was found between experience at sea and the occurrence of M-D. That
is, both more and less experienced crew members had the sensation to a similar degree.

With regard to the occurrence of M-D and correlation with the parameters of seasickness susceptibility, a significant positive correlation ($P < 0.005$) was found between the occurrence of the phenomenon and susceptibility to seasickness in the past, present seasickness susceptibility (score on the questionnaire adopted from Wiker et al (17)), nausea, and vomiting. That is, the higher the susceptibility to seasickness, the more frequent was the occurrence of M-D.

The following are three representative cases selected from the 30 subjects interviewed.

**Case 1**

A 20-year-old seaman with 1 y sailing experience described a phenomenon in which he continued to feel the movements of the boat after disembarking. There were no symptoms other than a sensation of “continuing to move and swing on land as if at sea,” which appeared immediately on landing and subsided gradually until it eventually disappeared about 2 h later. His natural inclination was to relate this to sailing conditions and seasickness. That is, after a voyage in a rough sea, during which he suffered from frank seasickness (vomiting), the sensation was stronger and more prolonged than when he landed after sailing in a calm sea and had felt well during the voyage. He noted that the intensity and frequency of the M-D decreased following later voyages. His medical history, as well as a detailed neurootological examination conducted when he was not experiencing M-D, was unremarkable. He had moderate susceptibility to seasickness, vomiting in seas with 2 m waves.

**Case 2**

A 19-year-old seaman with 6 mo sailing experience reported a sensation of swinging, “like being on a boat,” after every sea voyage. He had a past and present history of seasickness, regularly vomiting in a sea with 80 cm waves. He described the sensation as one of swaying, unsteadiness, and dizziness. There was no nausea or vomiting. The phenomenon was very marked following his earlier voyages, producing definite instability and a lack of coordination when walking or driving, because his legs “behaved as if they were still at sea.” The sensation lasted about 24 h. During this period, he also experienced bouts or attacks of M-D that appeared in particular when he was standing and tilted his head (while taking a shower), or when he changed position in bed as he lay with his eyes closed. His medical history, as well as a detailed physical and neurootological examination conducted when he was not experiencing M-D, was unremarkable.

**Case 3**

A 25-year-old seaman with 5 y sailing experience, who had never suffered from seasickness, reported having experienced M-D on two occasions. The first was following a 3-d voyage. After 1 h on land, he began to feel a transient swinging of his head and a rocking sensation as he sat and read a newspaper. He noted that he was able to elicit this “head sensation” by slowly tilting his head. A swaying sensation and a feeling of being unsteady on his legs also appeared when walking. These sensations completely disappeared on returning to his ship at the quayside. His second experience of M-D occurred immediately after disembarking from a 2-h sail in a yacht. He described a marked sensation of unsteadiness and swinging, as well as a lack of coordination, when standing, walking, or driving. ("I had to concentrate hard to drive properly, especially when pressing my feet on the pedals.") All sensations subsided gradually, until their complete disappearance about 3 h later.

**Discussion**

This study confirms the findings of our previous survey (9), that M-D is a transient feeling of swinging, swaying, unsteadiness, and disequilibrium. Although none of our subjects
requested medical attention or complained of any serious disability, there were isolated cases of a strong sensation of swinging or rocking, particularly after a rough sea voyage, which caused postural instability and impaired subjects' ability to drive. However, sufferers were aware of the transient nature of the phenomenon and of the connection with the voyage immediately preceding its appearance, and so they had not requested medical attention. None of the subjects was examined while experiencing M-D, and the presence of objective dis-equilibrium or incoordination is therefore still a matter for investigation. A significant decrement in postural stability tests has been found in pilots after flight simulator training (5,6). These post-effects may temporarily restrict a pilot's flying activities or impair the ability to drive, as reported by our subjects.

In most cases, the sensation of M-D appeared immediately on disembarkation or within 1 h, generally lasting only a few hours. It was unusual for symptoms to persist for more than 6 h. On specific inquiry during the medical interview, most subjects also described bouts or attacks of M-D associated with changes of posture or head position, or closing the eyes. None of our subjects complained of persistent M-D (lasting for months to years), a rare condition described by Brown and Baloh (15).

M-D was experienced by 72% of our 116 subjects and by 73% of the 234 crew members who participated in a previous survey (9). These findings confirm the high incidence of the phenomenon among seafarers and ships' passengers. Both experienced and inexperienced crew members reported the sensation of M-D; but the higher the susceptibility to seasickness, the more frequent was the occurrence of the phenomenon. The incidence of M-D was higher after earlier voyages and decreased following later voyages.

The nature of M-D, its appearance immediately after disembarking in the majority of cases, and its limited duration fall into line with the concept of a short-term multisensory-motor adaptive response to ship motion, and the subsequent post-effect process of readaptation to conditions on land after disembarking. In this sense, the development of M-D might be explained within the framework of the neural mismatch and sensory rearrangement model of motion sickness (1,11). This is the prevalent explanation for the development of motion sickness, as well as the process of adaptation and habituation to unnatural motion stimuli.

During a sea voyage, passengers and crew are exposed to a series of unnatural and conflicting vestibular, visual, and proprioceptive stimuli. These may not only cause seasickness, but also elicit the rapid appearance of an adaptive response to ship motion by activating a postulated "neural motion comparator." The function of this comparator is to match current and stored sensory information, eliciting new, adaptive sensorimotor response patterns. On disembarkation, the latter are not appropriate to conditions on land, giving rise to M-D. There is no adaptation in the classic sense employed in sensory physiology, that is, a decline in the response of the peripheral receptors to continuous prolonged stimulation. The term "adaptive response" employed here refers to the acquisition of new sensorimotor response patterns that reduce the neural mismatch. This process has been referred to by Reason and Brand (1) as "perceptual adaptation." The intensity and duration of the adaptive response, or M-D, depends on how unnatural the stimulus and its duration.

These concepts are supported by numerous behavioral and neurophysiological studies, which demonstrate adaptive vestibuloocular reflex (VOR) changes induced by consistent mismatch between related sensory inputs (eg, visual-vestibular) or between sensory input and related reflex motor output (eg, vestibulocular; 18–22). These changes appear to be associated with plastic changes of synaptic efficacy in relevant pathways of the central nervous system (23–25). We suggest that exposure to a new, abnormal moving environment (sea conditions) induces neurophysiologic changes, which are "adaptive" in the sense that they improve postural control in the new moving environment. They are "plastic" in the sense that they are retained until exposure to a new environment necessitates further adaptation on the subject's part. In this sense, M-D
is interpreted as a dynamic multisensorimotor form of adaptive plasticity. Although none of our subjects was examined while experiencing M-D, the involvement of the vestibular, visual, and proprioceptive systems is suggested on the basis of the medical interview. The swinging sensation per se, as well as the fact that specific head or body positions, or changes of position, aggravate the sensation of M-D, may reflect a role played by the vestibular system. Visual cues are also a contributory factor, and some of our subjects described the appearance of symptoms (bouts or attacks) merely as a result of closing their eyes. Involvement of the proprioceptive and motor systems is reflected in the sensation of “getting one’s sea legs” at the start of a voyage, and the feeling of unsteadiness and a lack of coordination after disembarking, which persists until readaptation to conditions on land is achieved. During this period, symptoms may be relieved by subjects returning to their ship.

The latency to the appearance of M-D in some cases may stem from the fact that specific vestibular, visual, or proprioceptive stimuli (e.g., head movements, eye closure, body position) are required to elicit the sensations described. This may also account for the occurrence of bouts or attacks of M-D.

Our subjects sailed once or twice a week for an average period of 18 mo. Most of them reported a high incidence of M-D following the earlier voyages, and its reduced occurrence as time went on. This fact may be partially explained by long-term multisensorimotor habituation to sea conditions. The term “habituation” is used to indicate a reduction in the response to a repeated stimulus, as opposed to short-term adaptation after a prolonged stimulus. Habituation takes place when there are time intervals between voyages, and when achieved it can remain active for as long as several weeks (26). The habituation process is related to central nervous system learning processes. Vestibular habituation to low frequency sinusoidal harmonic acceleration has been well documented in both monkeys and humans (27, 28). In a previous study conducted in our laboratory, low frequency VOR phase and gain changed in a population of cadets examined at the beginning of their regular naval service and 6 mo later (29). Lower VOR gain values at 0.01 to 0.08 Hz were associated with less susceptibility to seasickness, as reported after 1 mo of sailing. A significant increase in phase lead at 0.01 to 0.04 Hz after 6 mo of sailing was related to the process of habituation to sea conditions. The results of a further study were in accord with these findings: subjects with at least 3 mo experience at sea who were nonsusceptible to seasickness had lower gain values at 0.02 and 0.04 Hz and higher phase lead values at 0.01 to 0.08 Hz, in comparison with the VOR measurements of susceptible subjects (30). In a recent study, a decrease in the caloric nystagmus response was reported in subjects exposed to the open sea for 72 h and was also explained in terms of vestibular habituation (31).

Neurophysiological correlates of M-D, most probably reflecting the process of multisensorimotor adaptation and habituation to an abnormal motion environment, are the subject of current investigations.

Acknowledgment — The authors are indebted to Dr. Geoffrey Melville Jones of the Faculty of Medicine at the University of Calgary, Calgary, Alberta, Canada, for his invaluable comments on this article, and to Mr. Richard Lincoln for his assistance in the preparation of the manuscript.

REFERENCES

5. Kennedy RS, Lilenthal MG, Berbaum KS, Baltzley
Habituation, or decreased behavioral response, to odors is created by repeated exposure and several detailed characteristics, whereas adaptation relates to the neural processes that constitute this decrease in a behavioral response. As with all senses, the olfactory system...