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Motion Sickness Lessons from the Southern Ocean

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BACKGROUND: The objectives were to assess the prevalence, severity, and medication taken, and to look for predictive factors, in order to better identify characteristics of passengers at risk of motion sickness during transport from Hobart in Tasmania to the French polar stations in Antarctica.

METHODS: There were 239 passengers who were surveyed over 4 yr with 4 round trips per year using the Motion Sickness Susceptibility Questionnaire (MSSQ), Simulator Sickness Questionnaire (SSQ), state-trait anxiety test (STAI-Trait and STAI-State), and general parameters (age, gender, number of trips, jet-lag, direction of the trip), medication, calculation of the distance of each passenger's cabin to the Centre of Gravity (CoG.).

RESULTS: While the passengers had a low intrinsic sensitivity to motion sickness (MSSQ), 94% reported at least one SSQ symptom of motion sickness, and 38% vomited. Five associated factors were discovered: greater initial sensitivity (MSSQ), anticipation of being ill, younger age, higher level of anxiety at midtrip, and greater distance from the CoG. Of the passengers, there were 54% who took anti-motion sickness medication at different times of the trip, however, these passengers experienced more nausea. This could be due to self-selection since they were more sensitive to motion sickness.

CONCLUSION: We identified three predictive factors of motion sickness (greater intrinsic susceptibility, younger age, and greater cabin distance from the CoG). For preventive purposes, two associated factors of MS (anticipation of being ill, MSSQ score) were determined to classify three groups of risk of MS to improve passenger care during the trip.

KEYWORDS: seasickness, motion sickness, SSQ, boat, survey, MSSQ, anxiety, anti-motion sickness drugs, habituation, cabin position.

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well-know syndrom ?

Motion sickness is a well-known malady that has been reported since antiquity.[19] Its occurrence in a family and leisure context can be reduced by avoiding or stopping transportation. However, in an often unavoidable professional context, motion sickness can prove to be very disabling from a functional point of view, reducing performance of the personnel on board,[24] and inducing some risks from a medical perspective (dehydration, confusion, anxiety or panic attacks). The search for predictive factors to better screen subjects at risk remains a challenge to be solved, particularly for maritime professionals, including the military. The Motion Sickness Susceptibility Questionnaire (MSSQ) which measures individual differences in susceptibility is a useful predictive marker of seasickness[25] as well as of parabolic flight related space sickness.[5] Others factors like young age, female gender, vestibular pathology, and ethnic origin may also be considered as global predictive/susceptibility factors.[8,9,10] The Astrolabe is an oceanographic research vessel used to transport scientists and supply equipment to the Dumont d'Urville polar base, and then serves as a relay ship to other polar bases, including Concordia. This ship is particularly at risk of motion sickness due to its flat bottom design to allow ice crossing, relatively moderate size of 66 m in length for Antarctica conditions, and with a North-South direction of travel continuously across very rough seas. The passengers, mostly scientists going to bases, also have little or no previous seafaring experience, and their journey is often their first maritime travel of several days.

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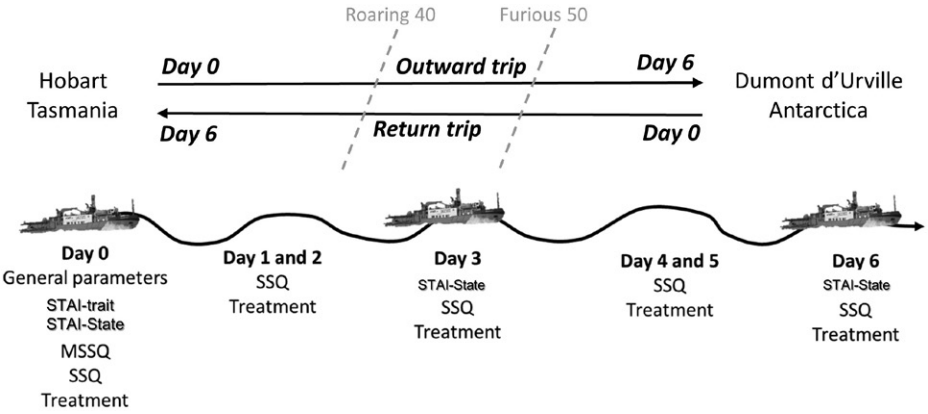

Fig. 1. Protocol during the trip: MSSQ (Motion Sickness Susceptibility questionnaire), SSQ (Simulator Sickness Questionnaire), Anxiety measured with STAI questionnaire (STAI-trait and STAI-State), general parameters (age, gender, cabin and berth positions, any medical treatments).

The Sickvest Project was selected by the French Polar Institute Paul Emile Victor to quantify the prevalence, medication on board, and the consequences of motion sickness for operational and passenger safety purposes. The second objective aimed to better identify people at risk and to propose recommendations to reduce this disabling syndrome onboard. Here we report the study which included 239 passengers surveyed before and during each sea voyage.

METHODS

The Sickvest Project, sponsored by IPEV (French Polar Institute Paul Émile Victor) and started in 2014, was an observational survey conducted on board the vessel *Astrolabe*. This is a flat-bottomed ship carrying 48 passengers in 13 cabins. It is 66 m long and 12.80 m wide with a 4.80-m draft. The *Astrolabe* is equipped with 13 passenger cabins: the 4 cabins closest to the center of gravity (less than 6 m away), the 4 intermediate cabins (between 6 and 10 m), and the 5 cabins farthest away (more than 10 m) can be grouped together. Four round trips per year are organized during the Austral summer to carry scientists from Hobart in Tasmania to the Dumont D'Urville station in Antarctica and return (**Fig. 1**). Passengers staying in Antarctica come and go back mainly by boat on the *Astrolabe*. However, some arrive by plane and leave by boat or vice versa. In the same way some stay on base for a few months to a year. Consequently, some of the passengers make two crossings with a delay between the inbound and outbound journeys, depending on the time they have to work in Antarctica; some of them did in and outbound trips while others only outbound journeys, if they came by plane first. For reasons of inclusion in the on-site study and anonymity, we cannot combine the round trips of the same passengers, so that we asked for the number of trips already done in the year or during previous campaigns.

Subjects

This study was approved by the Ethical Committee agreement NORTH WEST III (A14-D53-VOL. 22) and was registered on ClinicalTrials.gov. Each investigator on board was also the doctor aboard ship. Participation in the study was offered to all *Astrolabe* passengers and crews during the security briefing upon arrival on the boat. They were given a video of approximately 15 min to describe the study. Volunteer subjects were between the ages of 18 and 70 who had received their medical fitness to travel to Adélie Land or to carry out a campaign oceanographic research aboard the *Astrolabe*. The sample in this study was composed of 239 subjects whose general characteristics are summarized in **Table I**.

Table I. General Characteristics of the Sample: Means (SD) or Percentages (*N* = 239).

VARIABLE	MEAN (± SD) or %
Age (yr)	40.7 ± 12.1, range 20–74
Gender (M and F)	77% M ; 23% F
Any Motion Sickness Symptom (at Least 1 Item of the SSQ)	94%
Nausea at Some Point	69%
Vomited at Some Point	38%
Anti-MS Drug Treatment	54%
MSSQ Part A	5.2 ± 4.9
MSSQ Part B	4.1 ± 4.3
MSSQ Total Score	9.3 ± 8.4
MSSQ Percentile	37.4 ± 28.3
Past trips (Number)	0.13 ± 0.34
Anxiety Trait Baseline	33.1 ± 7.2
Anxiety Begin	28.8 ± 8.8
Anxiety Midtrip	29.4 ± 8.2
Anxiety End	25.7 ± 6.1

Procedures

The data collection was by a booklet of 20 pages, in which subjects were asked to answer several questionnaires on different neuropsychological components and all responses were anonymous (see Fig. 1). The booklet included various questions and questionnaires. The signed consent sheet was detached from the main booklet upon arrival on the boat. Questions were asked about the general characteristics of the subjects (age, sex, height, weight, medical history, usual medical treatments, cabin and berth numbers, how they felt about

their risk of motion sickness symptoms during travel, past trips). The Motion Sickness Susceptibility Questionnaire (MSSQ)[7] was used as translated into French and validated for French language.[18] This questionnaire has two parts: experiences with motion sickness in childhood and as an adult in the last 10 yr. The Spielberger's anxiety questionnaires[21] were also employed: STAI-trait anxiety, to be completed upon arrival on the boat and STAI-state anxiety at the time of measurement, to be completed on the 1st day, midway through the trip, and on the last day of the crossing. The Simulator Sickness Questionnaire (SSQ) in French was completed daily to assess symptoms related to motion sickness. It consists of 16 items (including nausea, vomiting, asthenia, pallor, vertigo, belching, etc.) with values from 0 to 3 depending on their intensity.[15] The SSQ was our primary measure of overall degree of motion sickness. The SSQ of Kennedy et al.[15] is one of the most widely used symptom checklists for motion sickness. The SSQ includes other items apart from nausea, stomach awareness, sweating, etc., that are relevant to motion sickness in general. Symptoms such as fatigue (Sopite), headache, dizziness, vertigo, etc., are widely accepted motion sickness symptoms. They will occur in response to cross-coupled motion, translational motion, off vertical axis rotation (OVAR), etc. Eyestrain can be more common with visually induced motion sickness (VIMS), but can still occur with classic 'motion sickness. At lower levels of sickness, the SSQ is arguably more sensitive than simply asking about nausea and stomach awareness. There was also an additional item on vomiting. Other questions concerned use of any medical treatments, including antimotion sickness drugs. Finally, from the ship's plans of the *Astrolabe*, the distance of each passenger's cabin to the Centre of Gravity (CoG) of the vessel was calculated to determine whether this distance was an influence on symptoms, a topic of debate in the literature.[6]

Statistical Analysis:

The statistical analysis was carried out with IBM SPSS statistics v 25.0. The methods used were descriptives, correlational analysis, multiple linear regression, ANOVA, and Student *t*-tests. In ANOVA, factor labels were: Days (voyage days from day 0 to day 6), Trip direction (out from Hobart vs. return from Antarctica). All tests of significance were two-tailed.

RESULTS

Descriptives are presented in Table I. Subjects in this study were less susceptible to motion sickness than the general population, with MSSQ percentile scores (mean ± SD) 37.4 ± 28.3, where the norm in the general population is 50 by definition (comparison with norm 50, 1-sample test, $t = 6.81$, df 233, $P < 0.001$, 2-tailed). Three crewmembers were included in the study. Crewmembers were already experienced in these types of rough conditions but we could not extract a subgroup of the few crewmembers recruited, since the survey was anonymous by intention.

The most common antimotion sickness medications used were scopolamine (patch or tablets) (25.5%), antihistamines (19.7%), scopolamine and antihistamine (8%), and domperidone (one person, less than 1%). Of passengers, 46% did not take any drug. Drugs were predominantly self-administered and often after the onset of symptoms. Some people took a scopolamine patch the first day of the trip or during the trip but not preventively the days before. It was notable that those who took antimotion sickness medications were more likely to think they might become sick (Chi-squared = 6.97, df 1, $P < 0.01$, 2-tailed) and had significantly greater susceptibility to motion sickness as revealed by their higher mean MSSQ percentile scores (used antimotion sickness drug: 44.4 + 28.2 vs. no drug: 29.4 + 26.3; independent *t*-test t = 4.17, df 232, $P < 0.001$, 2-tailed).

Trip direction appeared to be a factor in the evolution of motion sickness during the voyages. The peak for motion sickness occurred shortly after leaving port in Hobart on outward voyages. By contrast the peak for motion sickness was more delayed when considering voyages returning from Antarctica. This is shown in **Fig. 2**. ANOVA showed no overall significant differences in degree of motion sickness in terms of trip direction. However, there were significant effects for time (Days) and interaction Days × Trip direction (ANOVA: Days: $F = 12.50$, df 6, 672, $P < 0.001$; Trip-direction: $F = 1.53$, df 1112, P = ns; Days × Trip-direction: $F = 8.83$, df 6, 672, $P < 0.001$). The effect for Days simply reflected the onset of peak sickness followed by a decrease (probably due to habituation). The Days × Trip Direction interaction was due to the different timing of peak sickness in terms of trip direction (see Fig. 2).

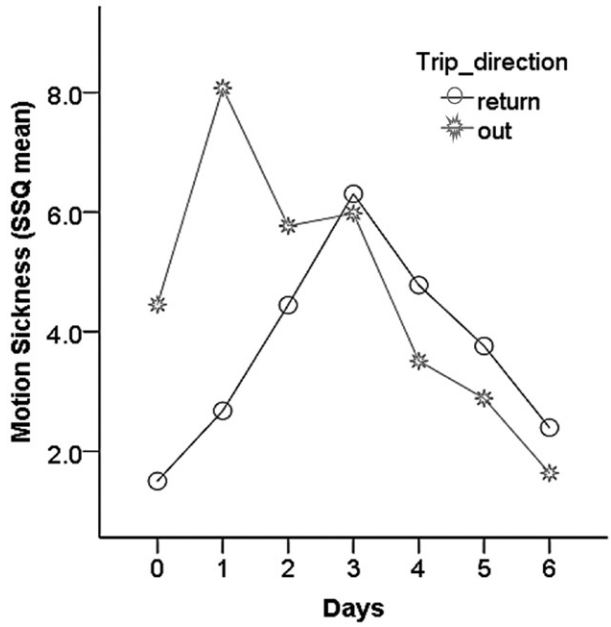

Fig. 2. Motion sickness peaks earlier on Outward voyages than Return voyages due to different sea conditions. High sea states are encountered early after leaving port in the outward voyages. By contrast Antarctic pack ice in the early part of return voyages produces relatively calmer sea states and less seasickness early on. See text for more details.

Table II. Correlations of Selected Variables with Simulator Sickness Questionnaire (SSQ) Mean Score Over Days 0–6 as Measure of Averaged Motion Sickness.

VARIABLE	R	*P*	VARIABLE	R	*P*
Age	−0.13	*	Anxiety Trait	0.12	*ns*
Gender	0.06	*ns*	Anxiety Begin	0.20	**
Past Trips	−0.06	*ns*	Anxiety Midtrip	0.39	***
Expect Sick	0.24	***	Anxiety End	0.26	***
MSSQ Total	0.37	***	Cabin Dist. CoG	0.23	***
Drug Anti-MS	0.23	***			

For the correlation analysis of the different variables, the Simulator Sickness Questionnaire (SSQ) mean score over days 0–6 was used as the measure of averaged Seasickness. Other analyses (not given for brevity) were performed using various other measures of motion sickness. These included peak sickness, mid-voyage sickness averages, nausea alone ratings, subscales of the SSQ, total vomiting episodes, possible habituation slope angles after peak sickness, etc. However, they added no obvious advantage nor gave any additional insights as measure of motion sickness compared with the averaged SSQ mean score over the whole voyage days 0–6. There was a good correlation between the average number of times that a person vomited over the whole voyage days 0–6 and the SSQ mean score over days 0–6 (r = 0.58, $P < 0.001$). The averaged SSQ measure also had the advantage of capturing the greatest amount of data concerning level of motion sickness in a single variable for subsequent analyses. Correlations of selected variables with the SSQ are summarized in **Table II**. The main variables associated with greater seasickness were: greater initial motion sickness sensitivity (MSSQ), anticipation of being ill, younger age, further distance between the CoG of the boat to the cabin, and higher level of anxiety, especially at midtrip. The strongest association of seasickness was with the MSSQ shown as scatterplot in **Fig. 3A**. The use of antimotion sickness medication was associated with greater levels of motion sickness.

The distance of the cabin from the vessel's CoG was significantly correlated with the average intensity of the symptoms during the crossing (see Table II and Fig. 3B). A specific analysis of the symptoms according to the axis of the berth in relation to the structure of the vessel did not reveal any significant difference between the upper and lower berth positions, nor was there any obvious relationship with orientation of bunks to ship axis.

Multiple linear regression was employed to predict motion sickness (SSQ averaged over days 0–6) as the dependent variable. All the variables shown in Table II were entered as possible predictors, together with another variable (binary) Trip Direction. It could be argued that variables such as state anxiety during the voyages should be omitted since they seem to be a consequence or cause of motion sickness rather than a cause, and they are not what might be termed baseline 'predictors.' However, they were entered simply for completeness of a possible model. This initial analysis produced a significant model (adjusted R square = 0.25, ANOVA $F = 4.75$, df 11,113, $P < 0.001$). Higher MSSQ was a significant predictor with greater cabin distance to CoG and older age being marginal predictors. All other predictors failed significance. A simplified multiple regression was then run, entering only the predictors MSSQ, cabin distance and age which produced a significant model and similar results (Multiple R = 0.53, raw R square = 0.28, adjusted R square = 0.26, ANOVA $F = 16.33$, df 3126, $P < 0.001$). The predictor weightings were in decreasing order MSSQ (beta = 0.48, $P < 0.001$), greater cabin distance to CoG (beta = 0.21, $P < 0.01$), older age (beta = −0.18, $P < 0.05$) (i.e., negative loading direction so the younger are more sick). This simplified regression model is shown in Fig. 3C. A variety of other regression models were employed including stepwise, but these did not alter the main conclusions above. The reason for the fact that some variables (anxiety, expectancy to be sick) which showed significant bivariate correlations with motion sickness (see Table II) dropped out from the multivariate analysis was doubtless due to collinearity, as revealed by inspection of the whole correlation matrix (for brevity not shown). For example, 'Expectancy to be Sick' significantly correlated with MSSQ, but MSSQ was the better predictor of motion sickness.

Lastly, we examined the previously identified baseline variables and concluded that the best practical combination was the question (Do you think you'll be sick) and MSSQ. Both parameters helped us to establish three groups of susceptibility to motion sickness onboard *Astrolabe*. Each susceptibility group was determined based on its mean SSQ score for the entire crossing (mean SSQ days 0–6). None of these factors, applied alone, resulted in three significantly different groups, consequently, two predictive factors were applied in combination: "Do you think you will be sick during the crossing" and the MSSQ score. To the question: "Do you think you will be sick during the crossing?", 164 responded "YES," 53 "NO," and 22 "DON'T KNOW" (DK). These groups were not significantly different from each other, but the average of SSQ for the DK group was close to that of the YES group. The group that did not know if they were going to be ill was therefore included in the group that thought they would be ill. We then applied the MSSQ variable to obtain three groups. Passengers who thought they would be sick during the crossing (YES) were arbitrary and empirically separated into two groups: group 1 with passengers with a MSSQ score greater than 10 and group 2 with passengers with a MSSQ score less than 10. For the NO group, passengers with a MSSQ score greater than 15 were allocated to group 2 and those with a MSSQ score less than 15 were allocated to group 3. This distribution made it possible to obtain three groups that were significantly different from each other regarding the intensity of their symptoms during the crossing (average SSQ Day 0–6). One-way ANOVA between the three groups, with averaged SSQ as the measure of motion sickness, was significant ($F = 14.42$, df 2,209, $P < 0.001$), with post-hoc testing showed that each of the 3 groups were significantly different from one another ($P < 0.05$ to $P < 0.001$).

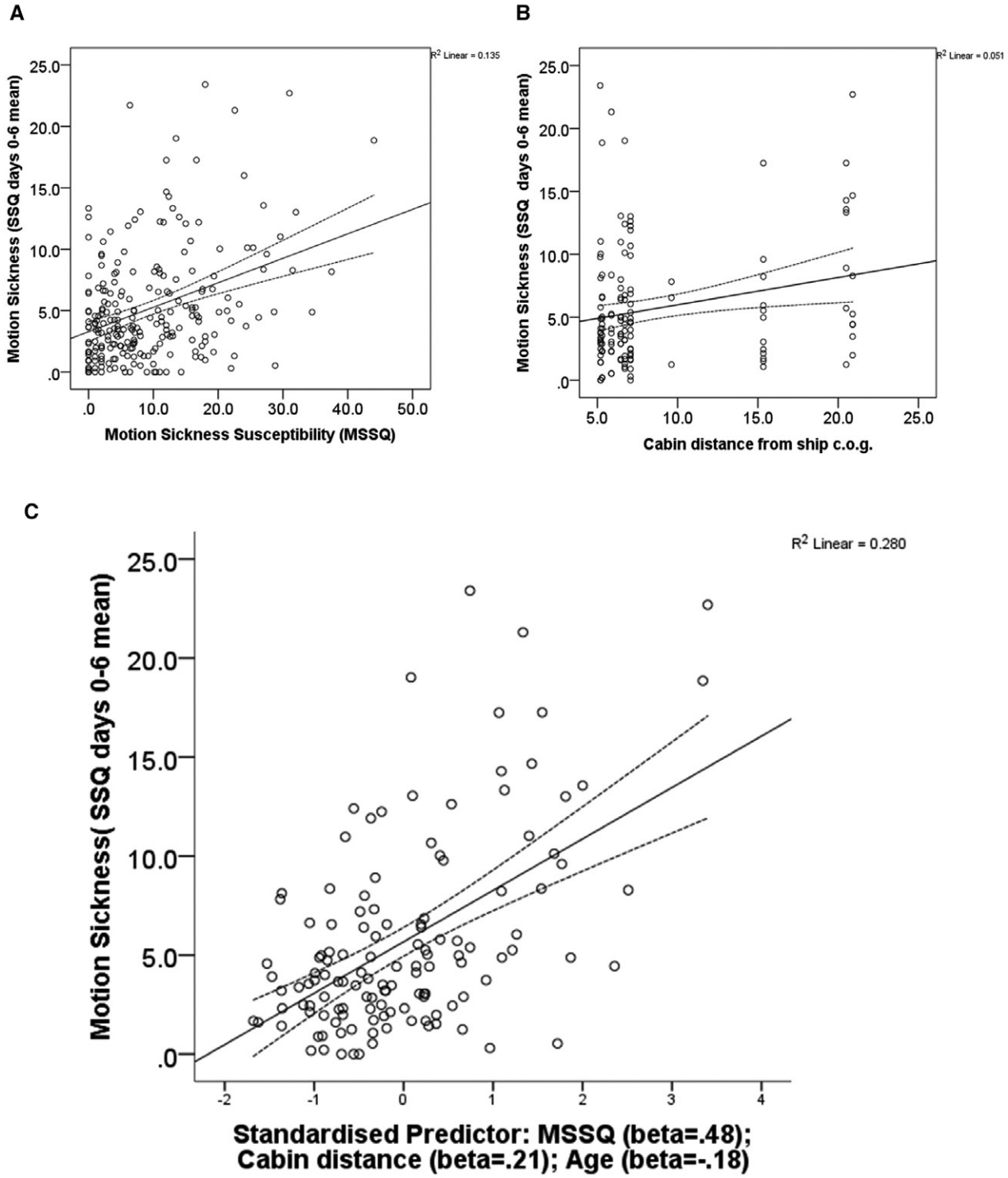

Fig. 3. Scatterplot representing the correlation between the level of sea-sickness (SSQ) and the susceptibility of MS (MSSQ) (3A), the influence of the distance of the cabin from the center of gravity (in meters) on the average symptoms during the crossing (3B). A simplified Multiple Linear Regression Model is shown (3C) where higher MSSQ, greater Cabin distance to CoG and younger Age, predict more Motion Sickness (SSQ score averaged over voyage days 0–6). The dotted lines indicate 95% Cis.

DISCUSSION

A major finding of our study was that 94% of passengers suffered at least from one symptom of motion sickness at some stage and up to 40% of them vomited. The SSQ score, taken as the measure of motion sickness, was maximal one day after departure for the outward trip and on day 3 for the return trip. The maximum score for the outward trip was higher than the

maximum score for the return trip but overall sickness was not significantly higher. Five associated factors for seasickness were observed: higher intrinsic individual motion sickness susceptibility (MSSQ), younger age, higher level of anxiety at midtrip, greater anticipation of being, and longer distance between the CoG and the cabin. An algorithm including two of these parameters (MSSQ, and a question "Do you think you'll be sick") may help to define people at high risk of motion sickness on *Astrolabe* in order to better allocate preventative actions.

The population included in this study was less susceptible to motion sickness than the general population (37.4 percentile instead of 50) according to normative data.[7,18] This characteristic is found for passengers on scientific parabolic flights[9] and can be explained by similar factors here. A natural self-selection bias is doubtless related to the fact that people who are highly sensitive to motion sickness are unlikely to engage in a research project that requires a trip in very rough conditions. In addition, the population is predominantly male and of average age around 40 yr rather than younger, both of which can reduce susceptibility to motion sickness.[7]

Ninety-four percent of passengers experienced at least one symptom of motion sickness despite being an already low susceptibility group. This doubtless reflects the very difficult sea conditions encountered. Gahlinger et al.[6] reported a prevalence of 74% during the first 2–3 d of the sea crossing to Antarctica, however the threshold of having been sick was not precisely explained nor the boat specifications (flat-bottom or not). A difference between travel directions was noted in our study. The maximum SSQ score, reflecting the intensity of motion sickness, is reached in the first 24 h after departure from Hobart in Australia, whereas it is lower and then progressively maximal on day 3 after departure from Dumont d'Urville in Antartica. The day 0 score corresponds to the assessment made on the first day at the beginning of the crossing and measurement depends on the time of the boat's departure in the morning or in the evening. Thus, the Day 1 score is achieved after the first night, i.e., between 10 and 24 h after the start of the trip. The maximum motion sickness at the beginning of the crossing from Hobart may be due to various factors: the emotional factor of fear of a first rough crossing, the initial fatigue of passengers who accumulate about 30 h of air travel with little sleep, (sleep deprivation is known to worsen motion sickness and slow habituation[14]), the time difference of 10 h from Europe and those who board on arrival or the next day, the immediate rough sea condition after passing the Gulf of Hobart. All these factors can explain the high level of motion sickness, without prior maritime experience to provide any protective adaptation, with little information and medications often taken too late at the beginning of the crossing or after the first symptoms occurred. Motion sickness was somewhat lower (below significance overall) during the return trip with a maximum at day 3 which can be explained by less tiredness (absence of jet lag and acclimatization with better quality sleep on the Durmont d'Urville base), the absence of first crossing effects, and often a first day of the trip in calm seas during crossing the ice zone on the outward passage from Antarctica.

The most common antimotion sickness medications used were scopolamine (patch or tablets) and antihistamines. These were predominantly self-administered. Surprisingly, the incidence of seasickness was greater in those reporting use of antimotion sickness drugs. Over 30 years ago Lawther and Griffin[17] made an identical observation on very large surveys of sea passengers which contributed to the ISO engineering standard for motion sickness (ISO, 1997). They conjectured "…that people who know that they are susceptible to seasickness take medication more readily…."[17] Unfortunately, they had no evidence to support their conjecture. Herein, the present study solves their lack of supporting evidence since it showed that those who took antimotion sickness medication were significantly higher in intrinsic motion sickness susceptibility as revealed by the MSSQ, and also were aware of this at baseline since they were more likely to think they might become seasick. No drugs were preventively taken on board before the beginning of the trip and no recommendation went in that direction. Moreover, drug intake could not be controlled in this observational study since it was delivered on request by the passengers according to the appearance of clinical symptoms throughout the trip. We did not aim to perform a pharmacological study comparing the efficiency of each drug.

One interesting point is related to the habituation process since, whatever the direction of the crossing, and even at the end of the return trip where the sea is rougher up to Hobart, the SSQ score decreased over the last 3 d to reach its minimum on the last day. Habituation is a phenomenon reported at sea,[22] for pilots,[11] and passengers on parabolic flights[5] where repeated exposure reduces motion sickness and is equivalent to desensitization. The underlying neurophysiological mechanism remains debated and can be played out at different brain stages: 1) brain stem with an adaptation of the time constant of storage of head movement velocity; and 2) the temporal-parietal multisensory cortex with a reweighting mechanism by a change in preference for the use of a sensory modality.[5] A role for temporal resynchronization of visuo-vestibular information at the cerebral cortex has also been suggested.[20] Emotional components may also be involved in the habituation observed here, i.e., the arrival in Antarctica in the ice or the return to Hobart and to the civilization, which represent two contexts where emotion and the desire to arrive induce positive feelings in passengers. Although the emotional effect on motion sickness is poorly documented,[1,16] an interaction between the visuo-vestibular system and the emotional system is reported[4,12] and may play a role in reducing or increasing motion sickness.

Variables predicting motion sickness were identified in this study using multi linear regression analysis: higher MSSQ susceptibility test score, longer distance of the cabin from the CoG of the ship, and younger age. Higher susceptibility and younger age are in agreement with the data in the literature.[24] However, age was a weak predictor of MS despite statistical significance. The relatively weak influence of age in this study was perhaps because of insufficient numbers of very old and of very young people, resulting in a statistical range restriction effect. Expectancy to be sick and anxiety, which both had significant bivariate correlations

with sea sickness, were not significant predictors in the mutiple linear regression model, perhaps due to collinearity. The influence of gender on motion sickness, which is a frequently reported factor, was not demonstrated here as a predictive factor in our study, perhaps reflecting the fact that our sample was more than 2/3 male, minimizing the gender effect.

The influence of cabin position on motion sickness is still debated in the literature. We found that the axis of the beds in relation to the axis of the boat had no influence on the symptoms. The same was true between the upper berth and the lower berth. On the other hand, passengers with the cabins furthest away from the center of gravity of the boat were the sickest during the crossing. Several studies on this point have been published with contradictory findings: for example, the U.S. Navy reported no association between cabin position and symptoms.[2] The influence of swell on motion sickness is mainly related to vertical acceleration. But pitching motion of a boat also produces a translational component which is experienced at locations away from the center of rotation, which is usually the center of gravity of the vessel. Logic dictates that the cabins furthest from the center of gravity suffer the most from pitching and consequent translational motion. This is evidenced by the English Channel Ferry study.[17] It was based on data from 5000 passengers and showed a strong association between passenger location and symptoms. However, a more recent study on very large cruise liners found no such association.[6] One explanation for the contradictions between studies is that the position of the cabin may have an influence on motion sickness that is greater for smaller ships, such as in our study. Accelerometric tools were available in the bridge of the Astrolabe measuring boat motion in real-time helping navigation and safety, but are not recorded. Unfortunately, an accelerometer with a recording module placed on board in one of the cabins suffered from shaking during each trip with data losses which did not allow meaningful analysis. However, in view of the strength of the correlation, we included the position of the cabins in our recommendation guide in order to adapt the distribution of the cabins for the passengers according to their susceptibility. This is in fact what is done by major shipping companies where cabins in the middle of the vessel are often more expensive than others.[6]

We developed an algorithm with a decision tree from two associated factors (question: "do you think you will be ill on board the *Astrolabe*?"; and the MSSQ with two threshold values at 10 and 15). The 10 and 15 thresholds were empirically chosen as a good level of discrimination. This also fit with the 3 main groupings of cabin positions from CoG for allocating predicted risk groups. We used the most important potential baseline correlates of motion sickness as predictors and simplified it to two predictors: "Do you think you will be sick?" and the MSSQ. The algorithm quickly and easily scored passengers to define three susceptibility groups (low, medium, high), in particular the passenger group most at risk. These thresholds might be adjusted in the future following cumulative data recording. This screening could help to better prepare future passengers of the *Astrolabe* by proposing a more targeted and efficient countermeasure for each one. For example, to propose desensitization to motion sickness[19,23] before departure combined with placement in the cabins closest to the center of gravity and pharmacological and nonpharmacological therapeutic care throughout the crossing with the on-board doctor.

In conclusion, this study showed a very high prevalence of motion sickness for passengers despite their low intrinsic sensitivity to motion sickness, on a specific boat in the harsh conditions of the Southern Ocean. Five factors associated with sea sickness were identified and a decision algorithm based on two factors was developed which should allow a better screening of the future passengers most at risk, to improve their management.

Our observations concerning the effects of antimotion sickness drugs and length of and direction of voyage on motion sickness were preliminary and informal because we had no control over the timing and dosage of the antimotion sickness drugs (some were taken before and some after onset of motion sickness symptoms) and no data concerning the day-to-day accelerations of the ship. Those who took antimotion sickness drugs were more likely to have both higher MSSQ and SSQ scores, suggesting a greater initial susceptibility to motion sickness in those taking the antimotion sickness drugs. Motion sickness ratings were higher on the outbound direction and, correspondingly in the earlier days of the voyage, but more formal research is needed to evaluate the significance of these effects.

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REFERENCES

1. Biernacki MP, Dziuda L. Mood and simulator sickness after truck simulator exposure. Int J Occup Med Environ Health. 2014; 27(2): 278–292 https://doi.org/10.2478/s13382-014-0251-2.
2. Bruner JMR. Seasickness in a destroyer escort squadron. U S Armed Forces Med J. 1955; 6: 469–190.
3. Chan G, Moochhala SM, Zhao B, Wl Y, Wong J. A comparison of motion sickness prevalence between seafarers and non-seafarers onboard naval platforms. Int Marit Health. 2006; 57(1–4): 56–65.
4. Coelho CM, Balaban CD. Visuo-vestibular contributions to anxiety and fear. Neurosci Biobehav Rev. 2015; 48: 148–159 https://doi.org/10.1016/j.neubiorev.2014.10.023.
5. Dilda V, Morris TR, Yungher DA, MacDougall HG, Moore ST. Central adaptation to repeated galvanic vestibular stimulation: implications for pre-flight astronaut training. PLoS One. 2014; 9(11): e112131 https://doi.org/10.1371/journal.pone.0112131.

6. Gahlinger PM. Cabin location and the likelihood of motion sickness in cruise ship passengers. J Travel Med. 2000; 7(3): 120–124 https://doi.org/10.2310/7060.2000.00042.
7. Golding JF. Predicting individual differences in motion sickness susceptibility by questionnaire. P[illegible]ality and Individual Differences. 2006; 41(2): 237–248.
8. Golding JF. Motion sickness. Handb Clin Neurol. 2016; 137: 371–3 90 https://doi.org/10.1016/B978-0-444-63437-5.00027-3.
9. Golding JF, Paillard AC, Normand H, Besnard S, Denise P. Prevalence, predictors and prevention of motion sickness in zero-G parabolic flights. Aerosp Med Hum Perform. 2017; 88(1): 3–9 https://doi.org/10.3357/AMHP.4705.2017.
10. Golding JF, Patel M. Meniere's, migraine, and motion sickness. Acta Otolaryngol. 2017; 137(5): 495–502 https://doi.org/10.1080/00016489.2016.1255775.
11. Golding JF, Stott JRR. Comparison of the effects of a selective muscarinic receptor antagonist and hyoscine (scopolamine) on motion sickness, skin conductance and heart rate. Br J Clin Pharmacol. 1997; 43(6): 633–7 https://doi.org/10.1046/j.1365-2125.1997.00606.x.
12. Hilber P, Cendelin J, Le Gall A, Machado ML, Tuma J, Besnard S. Cooperation of the vestibular and cerebellar networks in anxiety disorders and depression. Prog Neuropsychopharmacol Biol Psychiatry. 2019; 89: 310–321 https://doi.org/10.1016/j.pnpbp.2018.10.004.
13. Huppert D, Benson J, Brandt T. A historical view of motion sickness-a plague at sea and on land, also with military impact. Front Neurol. 2017; 8: 114 https://doi.org/10.3389/fneur.2017.00114.
14. Kaplan J, Ventura J, Bakshi A, Pierobon A, Lackner JR, DiZio P. The influence of sleep deprivation and oscillating motion on sleepiness, motion sickness, and cognitive and motor performance. Auton Neurosci. 2017; 202: 86–96 https://doi.org/10.1016/j.autneu.2016.08.019.
15. Kennedy RS, Lane NE, Berbaum KS, Lilienthal MG. Simulator sickness questionnaire: an enhanced method for quantifying simulator sickness. Int J Aviat Psychol. 1993; 3(3): 203–220 https://doi.org/10.1207/s15327108ijap0303_3.
16. Keshavarz B, Stelzmann D, Paillard A, Hecht H. Visually induced motion sickness can be alleviated by pleasant odors. Exp Brain Res. 2015; 233(5): 1353–1364 https://doi.org/10.1007/s00221-015-4209-9.
17. Lawther A, Griffin MJ. The motion of a ship at sea and the consequent motion sickness amongst passengers. Ergonomics. 1986; 29(4): 535–552 https://doi.org/10.1080/00140138608968289.
18. Paillard AC, Quarck G, Paolino F, Denise P, Paolino M, et al. Motion sickness susceptibility in healthy subjects and vestibular patients: Effects of gender, age and trait-anxiety. J Vestib Res. 2013; 23(4,5): 203–209 https://doi.org/10.3233/VES-130501.
19. Ressiot E, Dolz M, Bonne L, Marianowski R. Prospective study on the efficacy of optokinetic training in the treatment of seasickness. Eur Ann Otorhinolaryngol Head Neck Dis. 2013; 130(5): 263–268 https://doi.org/10.1016/j.anorl.2012.03.009.
20. Shayman CS, Seo JH, Oh Y, Lewis RF, Peterka RJ, Hullar TE. Relationship between vestibular sensitivity and multisensory temporal integration. J Neurophysiol. 2018; 120(4): 1572–1577 https://doi.org/10.1152/jn.00379.2018.
21. Spielberger CD, Gorsuch RL, Lushene R, Vagg PR, Jacobs GA. Manual for the state-trait anxiety inventory. Palo Alto (CA): Consulting Psychologists Press; 1983.
22. Tal D, Bar R, Nachum Z, Gil A, Shupak A. Postural dynamics and habituation to seasickness. Neurosci Lett. 2010; 479(2): 134–137 https://doi.org/10.1016/j.neulet.2010.05.044.
23. Trendel D, Haus-Cheymol R, Erauso T, Bertin G, Florentin JL, et al. Optokinetic stimulation rehabilitation in preventing seasickness. Eur Ann Otorhinolaryngol Head Neck Dis. 2010; 127(4): 125–129 https://doi.org/10.1016/j.anorl.2010.07.006.
24. Zhang LL, Wang JQ, Qi RR, Pan LL, Li M, Cai YL. Motion sickness. CNS Neurosci Ther. 2016; 22(1): 15–24 https://doi.org/10.1111/cns.12468.
25. Zhang X, Sun Y. Motion sickness predictors in college students and their first experience sailing at sea. Aerosp Med Hum Perform. 2020; 91(2): 71–78 https://doi.org/10.3357/AMHP.5386.2020.

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AQ1: Medline indexes "Brain Res Bull" but cannot find a listing for this reference. Please check the reference for accuracy. (Ref. 8 "Golding, 2006")