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The role of lifestyle factors, biological sex, and racial identity for (visually induced) motion sickness susceptibility: Insights from an online survey☆

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ABSTRACT

Motion sickness (MS) and visually induced motion sickness (VIMS) are common side-effects when travelling or when using visual devices, respectively. A variety of individual factors may determine one's susceptibility to MS/VIMS. Here, the role of lifestyle factors including video-game usage, physical activity, diet, and substance use on self-reported susceptibility to MS/VIMS was investigated. Additionally, the roles of biological sex and racial identity on the overall prevalence of MS/VIMS were analyzed. A total of 711 responses to an online survey were collected from adults between the ages of 17–49 years. Methods of analyses included correlations, comparison tests, and multiple regressions. The results showed that, overall, VIMS is a prevalent issue for most participants, with approximately 24 % of users reporting nausea at least sometimes when using visual displays. Although some lifestyle factors (video game usage, assorted dietary elements) were identified as potentially relevant for MS/VIMS susceptibility, these factors only explained a minimal amount of the variance in MS/VIMS susceptibility. Significant sex differences were found, with female participants reporting higher susceptibility for MS/VIMS than male participants. Additionally, East Asians participants reported higher MS susceptibility. Our findings do not suggest that lifestyle factors are prominent predictors for the susceptibility of VIMS and MS.

1. Introduction

Motion sickness (MS) and visually induced motion sickness (VIMS) are common phenomena while travelling or when interacting with visual devices and displays (for overviews see [1–4]). Typical symptoms of MS/VIMS include headache, nausea, cold sweating, dizziness, pallor, fatigue, and drowsiness (sopite syndrome) [5,6]. Although traditional MS and, to lesser extent, VIMS have been well-known challenges for decades, the looming advent of fully automated vehicles as well as the increasing popularity and accessibility to Virtual Reality (VR) technologies make MS and VIMS a timely problem [7,8]. About 60 % of passengers are estimated to be prone to MS in cars [9], whereas the prevalence of VIMS in real-world situations has not yet been determined but can be as high as 60 % in laboratory studies [10]. Thus, MS/VIMS can jeopardize the overall success and acceptance of these novel technologies, making solutions to prevent MS/VIMS crucial. To develop effective countermeasures against MS/VIMS, it is important to understand which factors affects an individual's susceptibility. In the past, various factors have been discussed to affect MS/VIMS susceptibility, including age [11], biological sex [12], and racial identity [13]. In the present survey, we will further explore factors that may contribute to an individual's MS/VIMS susceptibility, with a specific focus on lifestyle factors including video game history, fitness, diet habits, and substance use (nicotine, alcohol, cannabis).

2. Background

2.1. Sex, racial identity, and MS/VIMS susceptibility

Females tend to report higher levels of MS [14,15] and VIMS [16–18] than males. This is true for both observational [19,20] and laboratory studies [21]. For instance, while observing seasickness, it was noted that female participants were 2.6 more likely to vomit compared to male participants [22]. However, the role of sex has been a controversial topic (see [3], for a thorough discussion), questioning the generalizability of this finding. For instance, reported that sex-related differences in VIMS rating when using VR headsets disappeared when the interpupillary distance of the headset was adjusted properly [76].

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Racial identity has been speculated to have an impact on MS susceptibility, with Asians being at a higher risk of experiencing MS compared to White participants [16,23,24]. For instance, in a study by Klosterhalfen et al. [13], participants were instructed to tilt their heads while being physically rotated, a procedure that is known to be highly nauseating. White participants were found to persevere through this stimulation for a longer duration compared to Chinese participants, suggesting that Chinese individuals are more susceptible to MS. It was also noted that Asian American were more susceptible to MS than White and Black participants while being physically rotated [25]. These findings suggest that there may a biological/genetic basis that contributes to susceptibility to MS [25,26]. However, given the limited number of studies investigating the relationship between racial identities and MS/VIMS, further research is needed to consolidate this finding.

2.2. Lifestyle factors and MS/VIMS susceptibility

2.2.1. Repeated exposure and video game history

Habituation is known to be a successful method to mitigate MS/VIMS [27,28], but the dynamics and transferability of habituation are not well understood [29]. There have been studies suggesting that frequent engagement in visual technologies such as video games could be associated with reductions is VIMS [30–34]. In an experimental study, Keshavarz et al. [35] compared non-gamers (individuals who rarely/never played video games) to gamers (individuals who sometimes/often played video games) and found that non-games discontinued the experiment significantly earlier and showed a significant increase in VIMS symptomatology compared to gamers. However, Rangelova et al. [36], found that 79 % of their participants experienced VIMS despite having a history of playing video games, reported contrasting findings. Thus, the relationship between gaming experience and self-reported MS/VIMS remains unclear.

2.2.2. Physical activity and fitness routine

Fitness routine has been previously linked to MS/VIMS susceptibility [37]. For instance, in a study by Cheung et al. [38], an increase in MS susceptibility was noted in those who completed an aerobic training program. Although the reasoning for this was unclear, it was suggested that increased activity of the autonomic nervous system due to aerobic exercise may be associated with increased MS [39]. A large survey conducted by Caillet et al. [40] suggested that those who participated in physical activity before the age of 18 and continued with their activity were less susceptible to MS, particularly when they engaged in balance-focused activities. In contrast, the role of physical activity and fitness routine has not yet been investigated in the context of VIMS.

2.2.3. Diet

Nausea and stomach awareness are well-known symptoms of MS/VIMS. To understand the relationship between diet and MS, [41] recorded the diet of pilots 24 h before flying. Overall, foods high in sodium, thiamin, and protein were correlated with increased airsickness while meals high in vitamins A, C, and iron reduced airsickness. Additionally, a meal that is composed of mainly carbohydrates may help to reduce symptoms of MS/VIMS like nausea and gastric dysrhythmia when consumed before a potentially nauseating task. This could be due to the onset of digestion, which is a parasympathetic response and can encourage normal gastric functioning [42]. Overall, these studies suggest that dietary planning before being exposed to MS-inducing stimuli could be useful in reducing symptoms and susceptibility. Although there is some indication that certain food groups such as carbohydrates may reduce MS, there is still much to explore with how various food groups or dietary patterns are associated with MS and VIMS.

2.2.4. Alcohol, nicotine, and cannabis

It is well known that consumption of alcohol affects components of the vestibular organs that can lead to symptoms similar to MS/VIMS such as dizziness, nausea, and vomiting [43]. There is also evidence of alcohol's short-term [44] and long-term impact on gait and balance [45]. Concerning MS/VIMS susceptibility, a survey by [46] found no significant effect of alcohol drinking habits on MS susceptibility, although a trend showed for those who consumed less alcohol to be slightly more susceptible. Helland et al. found similar results in a study, where higher blood alcohol content in participants reduced the level of VIMS to a certain extent [47]. That being said, studies that investigate the association between alcohol consumption and MS/VIMS susceptibility is still very limited.

With regards to nicotine, a study by Golding et al. found that nicotine intake increased MS susceptibility, whereas overnight deprivation decreased it [48]. Similarly, Zingler et al. noted that higher nicotine concentration led to increased postural sway and higher dizziness scores [49]. In addition to nicotine, it can be argued that cannabis may have an impact on MS/VIMS susceptibility. For instance, a study by Choukèr et al. [50] reported that lower endocannabinoid blood levels were associated with higher MS during parabolic flights. Cannabis has often been used for its anti-emetic properties, with many reports of its use for decreasing chemotherapy-induced nausea and vomiting [51]. Chronic cannabis users tend to have lower levels of fatty acid amide hydrolase, which is an enzyme that breaks down endocannabinoids. Thus, they have higher levels of endocannabinoid, specifically anandamide [52,53]. Although a few studies suggested that cannabis may reduce MS susceptibility, its effect on VIMS remains unknown.

3. The present study

The main objective of the present study was to identify factors that may determine individual susceptibility to MS/VIMS, with a particular focus on sex, racial identity, as well as a variety of lifestyle factors including video game history, fitness, diet habits, and substance use. Additionally, the present study aimed to provide insights into the prevalence of MS and VIMS under real-world conditions across a broad spectrum of users. Although this study was mostly exploratory, several hypotheses were generated based on previous findings. First, we hypothesized that individuals who often play video games (specifically genres that involve fast-paced visual movements) may be less susceptibility to VIMS [35]. Second, we hypothesized that individuals who often practice in or have a history of being engaged in balance-focused physical activity may report experiencing less MS/VIMS [38,40]. Third, we expected that increased nicotine and alcohol consumption may be associated with higher susceptibility to MS/VIMS [43 –45,47], whereas increased cannabis consumption might be linked to lower MS/VIMS susceptibility [51 –53].

4. Methods

4.1. Participants

A total of 770 healthy individuals participated in this online survey. Participants were removed in cases where 20 % or more of the responses were missing (n = 52) or when participants reported a vestibular disorder (n = 7), providing a final sample of 711 participants (see Tables 1 and Table 2). Participants' age ranged from 17 to 49 years; older participants were not included in the survey to minimize the impact of

Table 1
Distribution of participant number and age separated by biological sex.

Biological Sex	n	M_{Age} (years)	SD_{Age} (years)
Females	544	21.06	4.71
Males	152	21.96	5.01
Prefer Not to Disclose	5	19.75	1.50
Did Not Disclose	10	21.8	4.54
Total	711	21.2	4.8

Table 2
Number of female and male participants separated by racial identity.

Racial Identity	Female (*n*)	Male (*n*)	Total (*n*)
White	152	48	200
South Asian	151	42	193
East Asian	74	20	94
Black	41	4	45
Middle Eastern	35	10	45
Indigenous	1	0	1
Other	81	24	105
Prefer not to disclose	7	1	8
Did not Disclose	2	3	5
Total	544	152	711*

* Note: 15 participants chose not to disclose their sex and are therefore not included in this table.

sensory decline (e.g., vision, hearing, vestibular) that naturally occur with aging and may impact the experiences of VIMS and MS [54]. Thus, age was not further considered during the data analysis. Participants were recruited from the community and Toronto Metropolitan University. This research complied with the American Psychological Association Code of Ethics and was approved by the Institutional Review Boards at the University Health Network and Toronto Metropolitan University.

4.2. Online survey design

The online survey was created using Qualtrics (https://www.qualtrics.com) and consisted of three main parts: The first part considered general demographics such as age, sex, and racial identity. The second part inquired about one's susceptibility to MS/VIMS using established questionnaires, representing the dependent variables of this study. The third part contained different questionnaires to inquire video game history, fitness, diet habits, and substance use (see appendix A - supplementary material for full survey).

4.3. Dependent variables

4.3.1. MS susceptibility

The short form of the Motion Sickness Susceptibility Questionnaire (MSSQ-short; [55]) was administered to measure the participant's susceptibility to MS. The MSSQ in a common tool for estimating one's susceptibility to MS [56–58]. Participants indicated how often they experienced MS during specific events on a 4-point Likert scale ranging from 0 (never) to 3 (often). The MSSQ measures susceptibility to MS during childhood (MSA) and adulthood (MSB). A total MSSQ score can be calculated by summing MSA and MSB [55].

4.3.2. VIMS susceptibility

The short form of the Visually Induced Motion Sickness Susceptibility Questionnaire (VIMSSQ) [59] was used to measure participants' susceptibility to VIMS. Participants indicated how often they experienced nausea, fatigue, dizziness, eyestrain, and headache while using a variety of visual devices (i.e., smartphones, tablets, VR headset, etc.) on a scale ranging from 0 (*never*) to 3 (*often*). The VIMSSQ also inquires whether VIMS symptoms have limited the use of any visual device. A total score was generated by summing up the item scores with a maximum score of 18. Higher scores indicated greater susceptibility to VIMS.

4.4. Predictive variables

4.4.1. Video game experience

A customized questionnaire was used to measure participant's video game experience and individual gaming history. This included (1) the number of hours per day spent playing video games, (2) the type of video game genre played (i.e., action, first-person shooter), and (3) their preferred gaming device.

4.4.2. Physical activity

To assess participants' level of fitness, a customized questionnaire was used to assess the different categories of personal fitness by asking individuals to indicate how often they engage in equipment-based aerobic, non-equipment-based aerobic, balance & flexibility, and weight-lifting & muscle strengthening exercises. Participants recorded their responses on a 7-point scale ranging from 0 (*never*) to 6 (*more than once per day*). Additionally, the International Physical Activity Questionnaire-Short (IPAQ-short; [60]) was used to gain a more detailed understanding of an individual's physical activity. This questionnaire inquired about the intensity, frequency, and duration of different levels of physical activity. Scores for the IPAQ are calculated using metabolic equivalent task (MET) minutes per week. Total scores were calculated as the MET level x time period of exercise (in minutes per day) x number of days per week [61].

4.4.3. Diet and alcohol

The Food Frequency Questionnaire-short (S-FFQ; [62]) was adapted and used to inquire about individual diet patterns including alcohol consumption. The S-FFQ asks participants about the frequency of consumption of specific food items [63]. In the present study, the S-FFQ has been modified from 34 to 14 items, with each item covering a food category (i.e., carbohydrate, dairy, red meats, etc.). Participants were asked to record their responses on a 7-point scale ranging from 0 (*never*) to 6 (*more than once per day*). The 14 food types were grouped into 8 different food categories during statistical analysis: fruits and vegetables, legumes, animal proteins, carbohydrates, dairy, fats, sweets, and alcohol. Participants were also asked to indicate which type of diet pattern they follow (i.e., vegan, vegetarian, etc.).

4.4.4. Nicotine and cannabis use

Two separate questions addressing the frequency of nicotine and cannabis consumption on a 7-point scale ranging from 0 (*never*) to 6 (*more than once per day*) were included in the online survey.

4.5. Procedure

Participants were invited to complete the online survey hosted on https://www.qualtrics.com. Participants were first presented with a brief description of the study and accepted the consent form. They were then asked to complete the survey in a single session, although the survey remained active if they accidentally closed their web browser and exited the survey. All responses remained anonymous with IP address tracking turned off.

5. Results

5.1. MS and VIMS prevalence

Detailed results for the VIMSSQ and MSSQ are provided in Table 3. The averaged total MSSQ scores were very similar to the population norms established by Golding [55], although the female participants MSSQ scores in our sample were slightly higher. Regarding the VIMSSQ, scores for female participants were similar to those reported in previous studies (8.39 vs. 8.06; [64]), whereas the scores for male participants were notably lower in the present study compared to previous work (6.18 vs. 9.27).

For the VIMSSQ, eyestrain was identified as the most common symptom with 71.8 % of participants experiencing it at least sometimes (see Fig. 1). This was followed by headaches (62.3 %), fatigue (52.8 %), and dizziness (28 %). Although nausea was the least frequently reported symptom, almost a quarter of the participants (23.3 %) reported having experienced nausea when using visual displays at least sometimes.

Fig. 2 shows the responses to the MSA (left) and MSB (right). During

Table 3
Descriptive statistics for MS/VIMS susceptibility measures.

Variable		Present study						Comparative data	
	Sex	*M*	*SD*	min	median	max	*se*	*M*	*SD*
VIMSSQ	Female	8.39	3.64	0	8.5	17	0.16	8.78[a]	3.25
	Male	6.18	3.14	0	6	16	0.25	9.27	4.06
MSSQ	Female	15.92	11.02	0	6	27	0.85	13.97[b]	10.37
	Male	11.91	10.77	0	3	24	0.44	11.13	8.78

[a]Lucakova et al., 2023; [b]Golding, 2006.
Note. VIMSSQ = visually induced motion sickness susceptibility questionnaire; MSSQ = motion sickness susceptibility questionnaire.

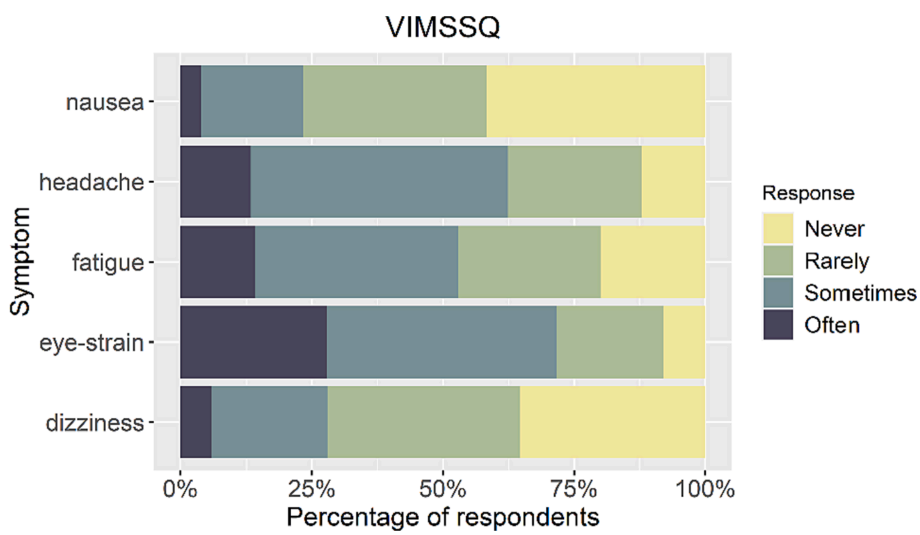

Fig. 1. Relative frequency of visually induced motion sickness (VIMS) symptoms.

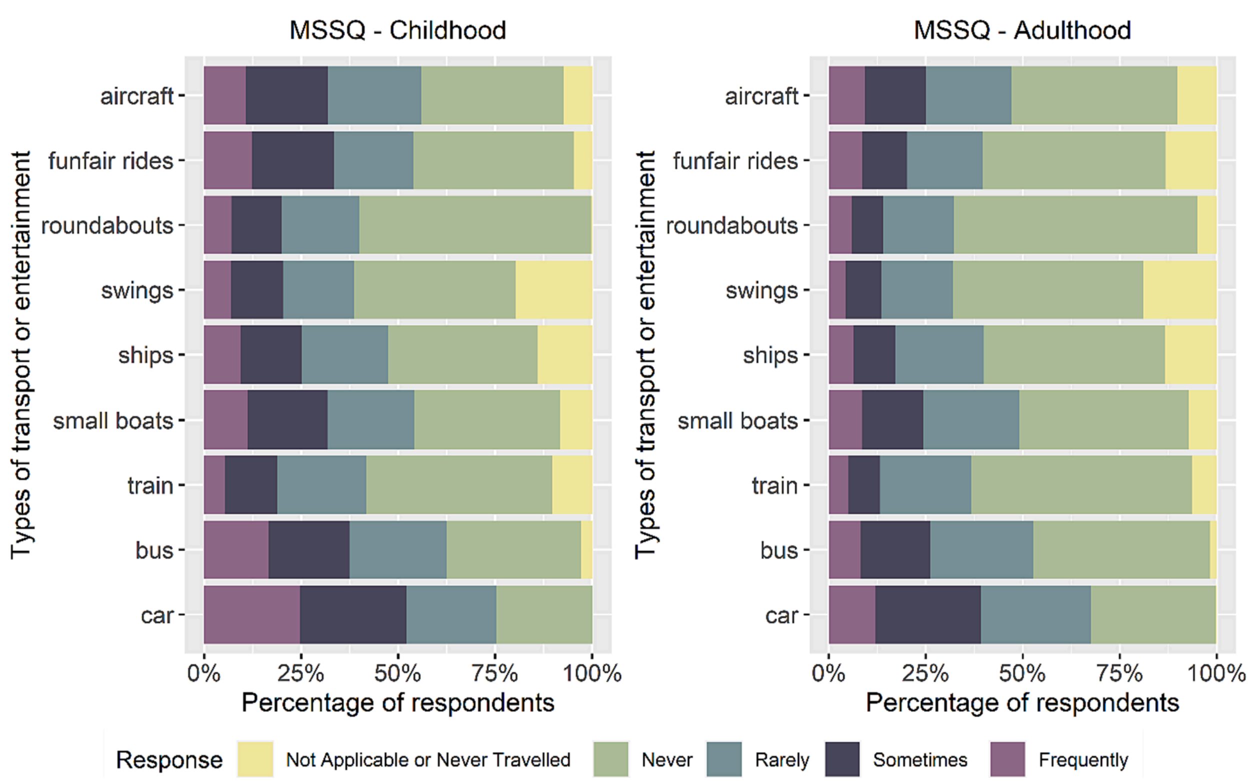

Fig. 2. Relative frequencies of the MSSQ child (left) and adulthood (right).

adulthood, MS was reported at least sometimes in cars (39.2 %), buses (26.6 %), small boats (24.5 %), and on aircrafts (24 %). Overall, there was a slight decrease in the frequency of symptoms experienced in adulthood compared to childhood.

5.2. Relationship between predicting factors and MS/VIMS susceptibility

A Spearman's rank correlation was conducted to determine the association between and within the predictors and dependent variables (see Table 4). Results showed a strong positive correlation between the VIMSSQ and MSSQ, suggesting that individuals who reported a higher MS susceptibility score are also more susceptible to experiencing VIMS and vice versa. Additionally, there was a moderate and significant negative correlation between sex (i.e., females given the value "0" and males the value "1") and MS/VIMS susceptibility, suggesting that female participants reported higher VIMSSQ and MSSQ scores (see also Section 5.3. for further sex-related differences in MS/VIMS susceptibility). There was also a weak but significant correlation between VIMSSQ scores and the number of years playing video games, indicating that VIMS decreased as the number of years played increased. Additionally significant, positive correlations were noted between MSSQ scores and alcohol and dairy. No other correlations were significant.

5.2.1. Stepwise multiple regressions

To assess the importance of each of the predictive factors for VIMS and MS, we conducted multiple linear regressions to estimate the amount of variance explained by the predictive variables. Missing values were imputed using predictive mean matching to conduct multiple linear regressions without compromising the sample size. This was done using the Multivariate Imputations by Chained Equations (MICE) package in R. Predictive mean matching allows for distributions to be preserved as only plausible data is imputed and does not assume linearity or normality of the data [65].

Stepwise regressions were conducted to determine the best combination of variables that would explain the highest amount of variance in the VIMSSQ and MSSQ scores. The procedure included both forward and backward selection, where variables were added and removed alternatively until R^2 did not change considerably. The best model was selected based on the smallest Akaike's information criterion (AIC; [66,67]). Assumptions were checked and the presence of heteroscedasticity was addressed by adjusting the standard errors to protect from both type 1 and type 2 errors.

The combination of five variables including sex, legumes, fruits and vegetables, and fats was identified as the best model (see Table 5), accounting for approximately 8 % of the variability in the VIMSSQ scores. For the MSSQ, the years of video game experience, sex, alcohol, fats, and animal protein were the only relevant factors, accounting for 5 % of the variability (see Table 6).

Table 4
Spearman correlations between the VIMSSQ, MSSQ, and all predicting factors.

Variable	VIMSSQ	MSSQ
MSSQ	0.42***	–
Sex	-0.25***	-0.16***
IPAQ	-0.06	0.03
Video game usage (years)	-0.12*	-0.08
Video game usage (hours/week)	-0.07	-0.05
Fruit & vegetables	-0.10	-0.03
Legumes	0.07	0.03
Animal protein	0.03	0.04
Carbohydrates	0.00	-0.05
Dairy	-0.03	-0.08*
Fats	0.06	-0.04
Sweets	0.05	0.04
Alcohol	-0.01	0.11*
Nicotine	-0.03	0.01
Cannabis	0.02	0.06

Note. *** p <.001, ** p <.01, * p <.05.

Table 5
Results of a bidirectional stepwise regression for the VIMSSQ total score.

Variable	*β*	*ΔAIC*	*Adj. R²*
Sex	−2.329	43.5	0.062
Legumes	0.128	2.068	0.066
Fruits & vegetables	−0.179	3.29	0.072
Fats	0.206	1.755	0.075
Animal protein		−0.381	0.076
Cannabis		−0.363	0.076
Alcohol		−0.138	0.076
Video game (years)		−0.032	0.076
Dairy		−0.24	0.076
IPAQ		−0.221	0.076
Carbohydrates		−0.303	0.076
Sweets		−0.256	0.076
Video game (hours/week)		−0.023	0.076
Nicotine		−0.041	0.076

Note. R^2 = 0.081, Adj. R^2 = 0.075, RMSE = 3.510. VIMSSQ = Visually Induced Motion Sickness Questionnaire. IPAQ = international physical activity questionnaire score.
*** p <.001, ** p <.01, * p <.05.

Table 6
Results of a stepwise regression for the MSSQ total score.

Variable	*β*	*ΔAIC*	*Adj. R²*
Video Games (years)	−0.24	15.782	0.024
Alcohol	1.04	6.523	0.034
Sex	−2.93	4.865	0.042
Fats	0.65	1.545	0.046
Animal protein	−0.20	1.118	0.049
Dairy		−0.572	0.049
IPAQ		−0.168	0.049
Carbohydrates		−0.306	0.049
Legumes		−0.18	0.048
Fruits & vegetables		−0.016	0.048
Sweet		−0.169	0.048
Cannabis		−0.37	0.048
Video games (hours/week)		−0.083	0.048
Nicotine		−0.09	0.048

Note. R^2 = 0.056, Adj. R^2 = 0.049, RMSE = 10.948. MSSQ = Motion Sickness Susceptibility; IPAQ = international physical activity questionnaire score. *** p <.001, ** p <.01, * p <.05.

5.3. Sex- and racial identity-related differences

To analyze sex- and racial identity-related differences for MS/VIMS, a two-way ANOVA including the between-subjects factors sex (males, females) and racial identities (East Asian, South Asian, White) were conducted for the VIMSSQ and MSSQ. Black and Middle Eastern groups were compared with each other in a separate *t* test due to their small (but similar) sample sizes (n = 45). Note that the Indigenous group was excluded from analysis given the very small sample size (n = 1). Fig. 3. shows the distribution of VIMSSQ and MSSQ scores for male participants and female participants separately. Overall, a main effect of sex showed for the VIMSSQ, $F(1,481) = 27.78$, $p < .01$, $\eta_p^2 = 0.06$, and the MSSQ, $F(1,481) = 12.94$, $p < .01$, $\eta_p^2 = 0.03$, indicating that female participants reported a significantly higher susceptibility to MS and VIMS compared to male participants. Fig. 4 illustrates the distribution of MSSQ and VIMSSQ scores for the comparisons between East Asian, South Asian, and White participants as well as Black and Middle Eastern participants. Based on similar sample sizes, East Asian, South Asian, and White participants were compared with each other, while Black and Middle Eastern participants were compared separately. The two comparisons are separated by a black dashed line in Fig. 4. A main effect of racial identity was also found for the MSSQ, $F(2, 481) = 3.40$, $p = .04$, $\eta_p^2 = 0.01$. Post hoc tests (Tukey corrected) suggested that East Asians (*M* =

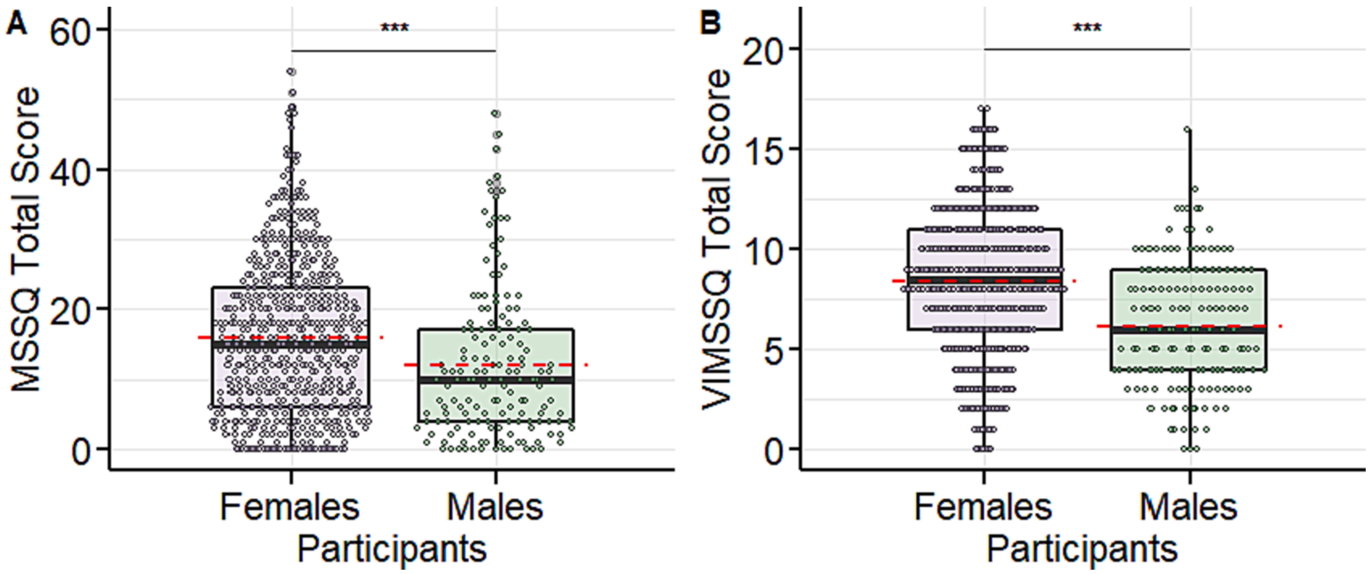

Fig. 3. Boxplots showing the distribution of MSSQ (left) and VIMSSQ (right) scores separated by sex. *Note.* Circles represent individual data points, and the red dashed line illustrates the mean. MSSQ = Motion Sickness Susceptibility Questionnaire, VIMSSQ = Visually Induced Motion Sickness Susceptibility Questionnaire. $^{***}p$ <.001. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

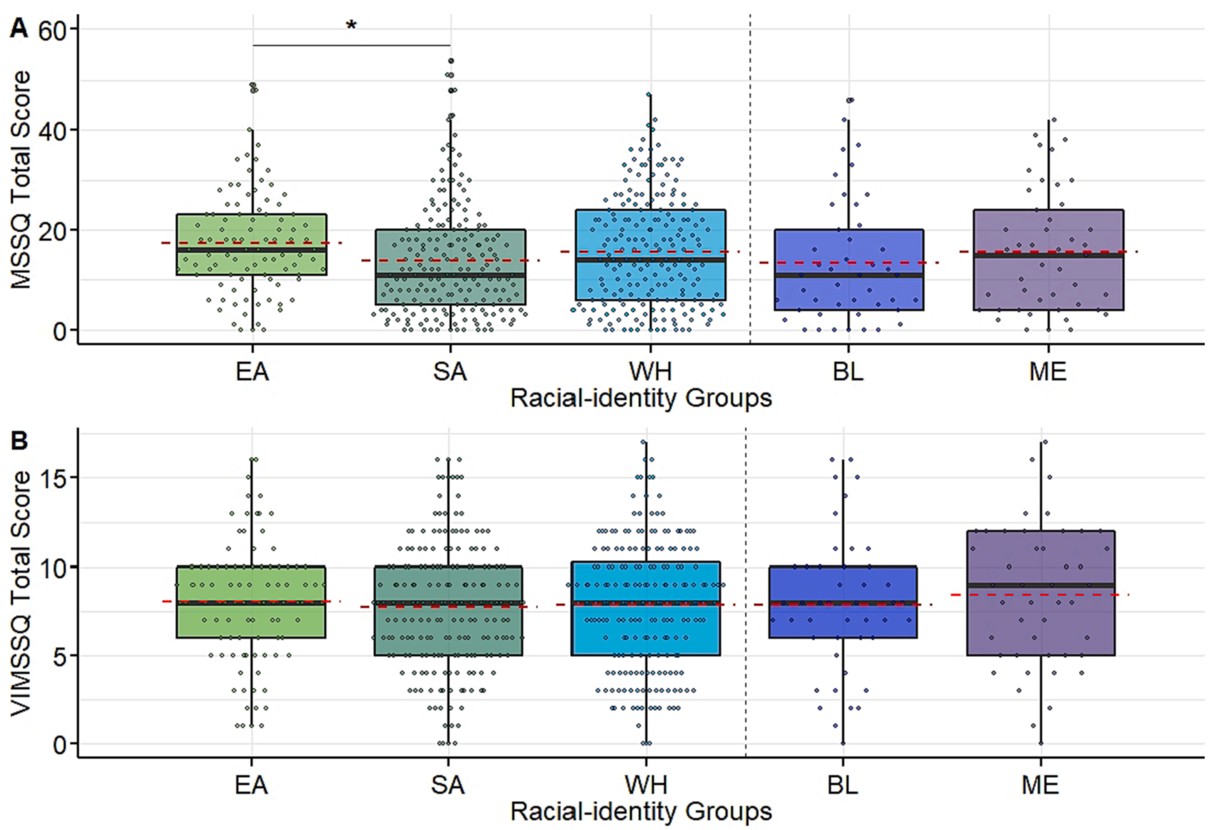

Fig. 4. Boxplots showing the distribution of MSSQ (Panel A) and VIMSSQ (Panel B) scores separated by racial-identity groups. *Note:* Circles represent individual data points, and the red dashed lines illustrate the mean. The black dashed line separates the groups that were compared with each other in statistical tests (EA vs. SA vs. WH and BL vs. ME). EA = East Asian (n = 94), SA = South Asian (n = 193), WH = White (n = 200), BL = Black (n = 45), ME = Middle Eastern (n = 45), MSSQ = Motion Sickness Susceptibility Questionnaire, VIMSSQ = Visually Induced Motion Sickness Susceptibility Questionnaire. $^{*}p$ <.05. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

17.34, *SD* = 10.28) reported significantly higher MSSQ scores compared to South Asians (*M* = 13.75, *SD* = 11.19; *p* =.03) but not compared to Whites (*M* = 15.61, *SD* = 11.10). No significant effect was found for VIMSSQ scores. No significant difference was found between Black and Middle Eastern participants for the MSSQ or VIMSSQ scores.

5.4. Fitness types and MS/VIMS

To determine whether the type of fitness impacts VIMSSQ and MSSQ, a non-parametric Kruskal-Wallis test was conducted. For this analysis, comparisons were made to participants who reported to 'often' engage in the different types of exercises. Comparisons were made between non-equipment-based aerobics (n = 157), equipment-based aerobics (n = 104), balance (n = 126), and strengthening (n = 147). No significant differences were noted for VIMSSQ scores (χ2 [3] = 52.72, p = 0.44) or for MSSQ scores (χ2 [3] = 7.36, p = 0.06).

5.5. Videogame types, usage, and VIMS

As seen in Table 4, there was a weak but significant negative correlation (r = -0.12) between VIMSSQ scores and the frequency of video game in years, suggesting that more years of video game experience are linked to lower VIMS susceptibility. To further investigate whether the frequency of video game usage affects VIMS, a one-way ANOVA including the between-subjects factor frequency of video game usage (never, rarely, sometimes, often) was calculated for the VIMSSQ score. No significant effect was revealed, F(3, 709) = 0.62, p =.61, suggesting that the frequency of video game usage does not affect the level of VIMS susceptibility. To investigate whether the type of videogame impacts VIMSSQ scores, a nonparametric Kruskal-Wallis test was conducted. Again, only participants who reported 'often' to playing action/adventure (n = 93), battle royale (n = 68), fighting (n = 38), first-person shooter (n = 71), racing (n = 52), role-play (n = 54), sandbox (n = 65), and sports (n = 44) were compared. No significant differences were noted (χ2 [7] = 9.12, p = 0.24), suggesting that the type of videogame does not affect VIMS susceptibility. Since the correlation between MSSQ scores and video game usage was not significant, no additional analyses were conducted to further investigate this relationship.

6. Discussion

The aim of the present study was to investigate how selected lifestyle factors, biological sex, and racial identity affect one's susceptibility to MS/VIMS. Overall, we found that female participants reported higher MS/VIMS susceptibility than male participants and that East Asians had the highest MS/VIMS susceptibility. However, with regards to lifestyle factors, no meaningful association with MS/VIMS was found; only about 8 % of the variance in the VIMSSQ data were explained by lifestyle factors including specific food groups (legumes, fruits and vegetables, fats) as well as the number of years spent playing videogames. For the variance in the MSSQ scores, only about 3 % of the variance were explained by lifestyle factors such as consumption alcohol, fats, and animal protein. These results suggests that the impact of lifestyle factors on MS/VIMS can be considered minimal. Our study also revealed insights into the general prevalence of VIMS in everyday situations, with eyestrain and headache being the most prominent symptoms when using visual devices. We will discuss these findings in more detail in the following sections.

6.1. MS/VIMS prevalence, sex, and racial identity

It is estimated that approximately two in three individuals experience MS as a passenger in moving vehicles during their life [9]. Here, we found similar results, with only 30 % of participants reporting to never experience MS in cars during adulthood. MS was also common when travelling by bus, small ships, or airplanes, with approximately 25 % of participants experiencing MS at least sometimes. Regarding VIMS, the prevalence in the general population is not very well understood. In the present study, eyestrain was the most common symptom, with 70 % of participants experiencing it at least sometimes when using visual devices. Nausea, on the other hand, was the least prominent symptom; however, still 25 % of participants indicated that they experience at least sometimes nausea when using visual devices, highlighting that VIMS-associated symptoms are indeed a serious concern when using visual devices such as VR headsets, smartphones, or tablets.

A previously mentioned, the role of biological sex for MS/VIMS susceptibility remains controversial [3]. In the present survey, we found further evidence for a sex-related difference for both MS and VIMS susceptibility, with female participants reporting higher MS/VIMS susceptibility compared to male participants across all measures. Sex was also one of the most important predictors of VIMS and MS susceptibility in the multiple regressions. The reason for this sex-related difference is not well understood. It has been suggested that the female hormonal system may contribute to this difference [12,68,69]. Gender-related differences (rather than sex-related differences) might play a role as well; it has been noted that male participants may feel more reluctant to self-report higher levels of MS/VIMS compared to female participants [70], although there is insufficient evidence to support this assumption and it remains speculative. It is also important to note that our sample was predominantly comprised of female participants (in a ratio of 3.5:1), which may contribute to the higher MS/VIMS susceptibility scores in female compared to male participants.

Unlike for sex-related differences, the role of racial identity is not well explored in MS/VIMS research. There is some evidence that Chinese individuals might be particularly susceptible to MS/VIMS [9,13,16,24], and that this difference may be partially driven by heritability [23,25]. The results of the present survey supports the assumption that East Asians are more susceptible to MS when compared to South Asians, but not when compared to White, suggesting that East Asians may be a racial group that is specifically susceptibility to MS. Interestingly, no differences with regards to VIMS susceptibility showed, highlighting that, despite their many similarities, different factors may affect MS and VIMS, respectively.

6.2. Lifestyle factors and MS/VIMS susceptibility

In the present survey, a negative significant (albeit low) correlation between years of video gaming experience and VIMS susceptibility showed, suggesting that those who played video games for a longer period of time seem less susceptible to VIMS. However, years of video gaming experience was only a relevant predictor for MS but not for VIMS susceptibility. In addition, the number of hours played per week was not linked to MS/VIMS susceptibility at all. Despite the results from our study, it is still possible that a more extended history of video gaming experience might potentially contribute to a form of habituation or adaptation towards VIMS. This notion aligns with previous reports suggesting that video game usage may potentially reduce the risk of VIMS, though uncertainties remain.[32,35]. It is important to note that almost 70 % of our participants only rarely or never played video games, biasing the sample towards a "non-gamer" population. It may also be possible that some individuals limit themselves form playing video games to avoid VIMS. Regarding fitness habits, our study did not reveal any meaningful association between fitness and MS/VIMS susceptibility, unlike previous experimental studies [37,38,40]. We found no evidence suggesting that a specific type of physical activity related to MS/VIMS susceptibility.

Only very few studies investigated the relationship between diet and MS [41]. Here, we found that only 3 % of the variance in VIMS susceptibility scores were explained by certain food groups (fruits, legumes, fat), suggesting only a minimal impact of diet habits on MS/VIMS susceptibility. Interestingly, though, legumes such as peanuts, soybeans, or chickpeas [71] and foods high in fat [72–74] have been associated with headaches and increased sympathetic nervous system activity, pointing to a potential link between these and MS/VIMS-related symptoms. Additionally, we did not find evidence that the use of alcohol, nicotine, or cannabis was related to MS/VIMS susceptibility, although the use of these substances has been suggested to promote symptoms similar to those caused by MS/VIMS [48,49,51]. However, it is important to note that substance use was overall limited in the current study sample.

7. Limitations and future directions

Naturally, online surveys are prone to several limitations that need to be kept in mind when interpreting the findings [75]. For instance, participants' responses may have been biased by their tendency to respond in a socially acceptable way (social desirability). Additionally, no researcher was present while participants completed the survey, limiting the opportunity for participants to clarify any questions. Furthermore, the environment the participants completed the survey in or their state of mood were not standardized and could not be controlled. All these limitations may affect how participant responded to the survey questions. Another limitation was that the sample was comprised primarily of younger Whites and South Asian female participants, which hampers the generalizability of the results.

Potential next steps could include replicating the study with an equally diverse sample with regards to racial identity, sex/gender, and age (e.g., children, older adults) to establish more robust findings. Additionally, experimental studies may deliver further insights into the relationship between video game exposure, racial identity, general fitness, and MS/VIMS during in-person testing of potentially MS/VIMS-inducing stimulation. Potential significant findings could inform possible countermeasures to reduce sickness as well as help identify selection criteria for research purposes.

8. Conclusion

This online survey study was conducted to identify the relationship between selected lifestyle factors (video game history, fitness, diet and substance use) and MS/VIMS susceptibility as well as to determine how prevalent MS/VIMS are in daily life. Overall, our results suggested the majority of the survey participants experienced MS and VIMS in their daily lives, with female participants reported higher MS/VIMS susceptibility compared to male participants in general. However, lifestyle factors only played a minimal role for predicting MS/VIMS susceptibility and do not seem to be a prominent factor in the occurrence of MS/VIMS.

CRediT authorship contribution statement

Narmada Umatheva: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft preparation. **Frank A. Russo:** Conceptualization, Supervision, Writing – review & editing. **Behrang Keshavarz:** Conceptualization, Formal analysis, Funding acquisition, Methodolody, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.displa.2024.102666.

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