공학석사학위논문

An investigation on the relationship between motion sickness susceptibility and visuospatial ability factors

멀미 취약성과 시각공간능력 인자간 관계에 관한 연구

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Abstract

An Investigation on the Relationship Between Motion Sickness Susceptibility and Visuospatial Ability Factors

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In this thesis, we investigate the relationship between motion sickness susceptibility and different factors of visuospatial ability. Human visuospatial ability is conceptualized as consisting of multiple sub-components or elements. Such aspects of visuospatial ability include Visualization (VZ), Spatial Relations (SR), Closure Speed (CS), Flexibility of Closure (CF), and Perceptual Speed (P). Some research studies have identified associations/correlations between motion sickness and visuospatial ability suggesting some links between the two constructs. However, neither previous studies have explored the possible relation between motion/ visually induced motion sickness susceptibility and visuospatial ability. Therefore, it can be understood in more detail by revealing a possible relationship between motion sickness susceptibility and components of visuospatial ability. Understanding how the different sub-dimensions of visuospatial information processing ability impact motion/visually induced motion sickness susceptibility will significantly improve the current knowledge on motion sickness susceptibility. However, the relationship between motion sickness and visuospatial ability still remains unclear. In particular, the relationships between motion sickness and individual factors of visuospatial ability have not been investigated sufficiently. Discovering possible relationships between visuospatial ability test scores and motion sickness susceptibility would help reduce dropouts in simulator-based human factors studies - the occurrence of dropouts has been identified as a severe problem for simulator-based human factors studies. If significant relationships exist, they could be utilized to develop proper screening guidelines. The objective of the current study was to empirically investigate the relationships between visuospatial ability factors and motion sickness susceptibility.

Keywords: Motion sickness, Visually induced motion sickness, Visuospatial ability, Human information processing, Visualization, Spatial Relations, Closure Speed, Flexibility of Closure, Perceptual Speed
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Chapter 1

Introduction

1.1 Research Background

Motion sickness is a common condition characterized by a feeling of unwellness brought on by certain kinds of movement (Koch et al., 2018). Reported symptoms of motion sickness include sweats, dizziness, fatigue, headache, disorientation, and vomiting, amongst others (Lackner, 2014). About 1 in 3 people are considered highly susceptible to motion sickness, and most of them will become motion sick if exposed to intense motion (National Library of Medicine, 2019). With the dramatic improvement of visual device technologies over the last decade (Keshavarz et al., 2021), visually induced motion sickness has become a common user problem that must be overcome (Keshavarz, 2016). Visually induced motion sickness is a phenomenon similar to traditional motion sickness (Keshavarz et al., 2021). However, in contrast to traditional motion sickness, VIMS is typically induced by watching motion images or dynamic displays. Vection, the perception of illusory self-motion resulting from stimulation of the visual system, is considered a typical reason for VIMS. Symptoms of VIMS are very similar to traditional motion sickness, as reported symptoms of VIMS are primarily caused by stimulation of the visual system (Hemmerich et al., 2020), with oculomotor issues, eyestrain, and blurred vision being more common in VIMS. Depending on the visual device, various terms have been used in the literature to describe specific types of VIMS (e.g., cybersickness, video sickness, virtual reality sickness, simulator sickness).

There are many advantages of newly developed technologies in various fields of medicine, entertainment, and industry. However, motion sickness has been argued comprehensively that it is one of the critical challenges to adopting the latest technology as it can negatively impact human performance (e.g., visual performance, physical performance, cognitive performance, and physical-visual performance) (Smyth et al., 2019). In the areas of AR/VR (Tian et al., 2022; Palmisano et al., 2020; Stanney et al., 2020; Stauffert et al., 2020; Carvalho et al., 2017) and Autonomous Vehicles (Diels & Bos, 2016; Diels & Bos, 2015) motion sickness is considered to be a severe problem, as motion sickness will lead to different levels of discomfort, affect one functional ability, and eventually prevent one from working due to motion sickness (Koch et al., 2018).

Motion sickness is thought to occur when the eyes do not see the same movement that the body experiences or vice versa (Zhang et al., 2016). Sensory conflicts are the most current explanation of motion sickness/visually induced motion sickness and one leading underlying theory that suggests the causes of motion sickness (Ahn et al., 2020; Bertolini & Straumann, 2016). These conflicts arise when information from different sensory channels contradicts or disagrees with expectations/experience (Koch et al., 2018; Warwick et al., 1998). The sensory conflict theory explains that motion sickness is caused by mismatches between the visual, vestibular, and somatosensory input which means that if the mismatch occurs between movement sensed in the inner ear and motion seen by the eye, there is a sense, and motion sickness prevails. In addition, based on sensory conflict theory, motion sickness is strongly related to the information processing ability as the human has to process information from different sensory channels (Park et al., 2021).

Concerning motion sickness (including visually induced motion sickness), large inter-individual variability in motion sickness susceptibility has been observed (Takov & Tadi., 2019; Zhang et al., 2016); as an effort to discover the possible personal factors (predicting factors), previous research studies have investigated the relationships between motion sickness susceptibility/occurrences of motion sicknesses and different personal factors such as demographic variables (such as age, gender, habituation, education level, and BMI), physiological variables (such as vestibular ocular reflex time constant, postural instability, ethnicity), and psychological variables (such as field dependency, mental rotation ability, autokinesis, state or trait anxiety) (Mittelstaedt, 2020; Takov & Tadi., 2019; Zhang et al., 2016). Especially, some psychological variables, such as visuospatial ability, which measures mental rotation ability and field dependency, have been examined as possible predicting factors and seem to correlate significantly with motion sickness (Smyth et al., 2021; Levin & Stern, 2002; Parker & Harm, 1992; Bick, 1983; Barret & Thronton, 1970; Barret & Thronton, 1968).

1.2 Literature Review

Previous research studies examined individuals' visuospatial ability as possible factors that may influence the occurrence/susceptibility of motion sickness. Some examples are: Barret & Thronton (1968, 1970), Bick (1983), Parker & Harm (1992), Levin & Stern (2002), Smyth et al (2021).

Barret & Thronton (1968, 1970) and Bick (1983) investigated the relationship between motion sickness and field dependency. Field dependency is regarded as a type of visuospatial ability Flexibility of Closure (Rittschof, 2010). The flexibility of Closure is the ability to identify a visual figure or pattern embedded in a complex distracting or disguised visual pattern or array when one knows in advance what the pattern is (Schneider & McGrew, 2012). (Note: Flexibility of Closure appears to be related to the cognitive style called "Field independence" (French et al. 1969; Witkin et al. 1971), and both were measured with the Hidden Figure test). Barret & Thronton (1968) reported that motion sickness is positively correlated with field dependency (measured in terms of the Rod and Frame test and embedded pattern test). However, in Barret & Thronton (1970) and Bick (1983), no significant correlation between motion sickness and field dependency (measured in terms of Embedded pattern test/Hidden figure test) was observed. That is, Barret & Thronton's (1968) and (1970) studies even showed contradictory results; in Barret & Thronton's (1970), one with the highest motion sickness had the lowest visuospatial ability score.

Parker & Harm (1992) and Levin & Stern (2002) investigated the relationship between motion sickness and visuospatial ability (mental rotation ability). Parker & Harm (1992) directly suggested a negative correlation between motion sickness and visuospatial ability (mental rotation). The study interviewed the astronauts' spatial orientation type and motion sickness susceptibility. This research has discovered that individuals who lack mental rotation ability are much more likely to experience simulator sickness. Levin and Stern (2002) reported that motion sickness susceptibility is negatively correlated with Spatial Visualization (measured in terms of mental rotation) and Spatial Relation (measured with water level tests). In this research study, a motion sickness susceptibility questionnaire (Reason & Bran, 1975) was adopted, and to measure visuospatial ability, Water-level test (Piaget & Inhelder, 1956) and Mental Rotation test (Thurstone, 1948) were adopted. The authors have discovered a negative correlation between visuospatial ability and motion sickness susceptibility.

Smyth et al. (2018a) observed an interesting relationship between driving simulator use, visuospatial ability, and motion sickness. To observe the impact of motion sickness on human cognitive performance, Smyth et al. (2018a) measured six categories (including physical, cognitive, visual, and the intersections of each) of cognitive task performance before and after a driving simulator exposure. It was observed that after driving simulator exposure, the average motion sickness score improved, average visuospatial ability test scores (Mental Rotation Test (Vandenberg & Kuse, 1978)) increased, and the average time taken to complete the task decreased.

Smyth et al. (2021) further investigated the training effects on visuospatial ability and motion sickness. Participants were trained for 14 days with different kinds of visuospatial ability tests (i.e., Spatial Visualization, Spatial Relation, Flexibility of Closure, and other tests). Throughout the study, Smyth et al. (2021) showed that visuospatial ability (measured with Mental Rotation Test) can be improved through 14-day pen and paper visuospatial ability training. Such improvement might have led to the reduction of motion sickness during actual and simulated driving situations.

Other research studies examined individuals' vestibular functions as possible factors. Some examples are Bigelow & Agrawal (2015) and Fowler et al. (2020). Fowler et al. (2020) revealed that motion sickness susceptibility was significantly and positively correlated with caloric slow-phase velocity. In this study, motion sickness susceptibility was evaluated with the Motion Sickness Susceptibility Questionnaire-Short (Golding, 2006), and vestibular function was measured by the caloric response of VGN. In addition, Bigelow & Agrawal (2015) revealed the relationship between vestibular function and visuospatial ability through a literature review. This study suggests that vestibular dysfunction was significantly associated with lower visuospatial ability, including spatial memory, navigation, mental rotation, and mental representation of three-dimensional space. These studies might imply a relationship between visuospatial ability, motion sickness susceptibility, and vestibular function.

1.3 Research Motivation

Despite past research on personal factors, many research gaps exist. One possible area of further research pertains to the relationships between human visuospatial information processing capabilities and motion sickness susceptibility. Although some research studies, such as Barret & Thronton (1970), Parker & Harm (1992), Levin and Stern (2002), and Smyth et al. (2018a, 2021) reported/suggested that visuospatial ability is negatively correlated with motion sickness susceptibility, they are limited in that: 1) the different sub-dimensions of visuospatial information processing abilities were not fully considered, and 2) motion sickness susceptibility and visually induced motion sickness susceptibility were not considered together.

According to the previous studies above, motion sickness is caused by unfamiliar stimulus patterns incompatible with prior experiences and/or sensory conflicts. Internal information processing (information manipulation) ability may be used to correct these incompatible stimuli internally (Park et al., 2021; Smyth et al., 2021). In addition, a previous study suggests that visuospatial ability can be improved through training, and training can reduce a person's experience of motion sickness. Then, it is possible to hypothesize that an individual's general ability to manipulate internally (visual/vestibular/proprioceptive) information, measured in the absence of training, would have a relationship with that person's susceptibility to motion sickness. In contrast, it is also possible that a person's internal information processing/manipulation abilities do not have any significant relationship with their motion sickness susceptibility. The most widely accepted theory, sensory conflict theory, states that cause motion sickness is caused by the conflict between the current pattern of sensory inputs about self-movement and the pattern that is expected based on previous experience; in other words, the cause of motion sickness is a mismatch between the input information from the visual and vestibular systems (Warwick et al., 1998; Schmäl & Stoll, 2000). According to sensory conflict theory, the possibility of predicting motion sickness susceptibility using visual or vestibular information processing ability alone seems unclear. In addition, the relationship between visuospatial information processing ability and motion sickness susceptibility suggested by previous research is even doubtful. Despite much research on motion sickness, currently, little knowledge is available regarding possible relationships (or lack thereof) between internal information processing/manipulation abilities and motion sickness susceptibility. Empirically testing if any relationships exist or not would contribute to the current body of knowledge on motion sickness susceptibility.

The most comprehensive review of factor analytic studies of visuospatial ability was conducted by John Carroll and identified five major factors of visuospatial ability (Hegarty & Waller, 2005). These are Spatial Visualization, Spatial Relations, Closure Speed, Flexibility of Closure, and Perceptual speed. These five factors visuospatial ability is not a single undifferentiated construct but instead composed of several somewhat separate abilities (Hegarty, 2010). Understanding how the different sub-dimensions of visuospatial information processing abilities impact motion/visually induced motion sickness susceptibility will significantly improve the current knowledge on motion/visually induced motion sickness.

Discovering possible relationships between visuospatial ability test scores and motion sickness susceptibility would also have a practical application –it could be utilized to develop helpful screening or worker allocation guidelines if a significant relationship exists between the two; motion sickness is one of the critical challenges to adopting the latest technology in industries as it can negatively impact human performance. In specific, it can help to reduce dropouts in motion sickness related human factors studies; the occurrence of dropouts has been identified as a severe problem for simulator-based human factors studies.

1.4 Research Objective

To address the problem described above and thereby contribute to the current body of knowledge on motion sickness susceptibility and visuospatial ability, the objective of the current study is to investigate the relationship between motion sickness/visually induced motion sickness susceptibility and five major factors of visuospatial ability. In an effort towards understanding the relationship, the current study adopted two-motion sickness susceptibility questionnaires and six visuospatial ability tests. In the method section, measures of both visuospatial ability and motion sickness susceptibility will be explained more. The Visuospatial ability was determined by adopting the ETS Kit of Cognitive test 1968 and the revised Purdue Spatial visualization test of Spatial Relation (Yoon, 2011). Motion sickness was susceptibility measured by adopting the Motion Sickness Susceptibility Questionnaire short (MSSQ-short) (Golding, 2006) and Visually Induced Motion Sickness Susceptibility Questionnaire (VIMSSQ) (Keshavarz et al., 2021).

Chapter 2

Method

2.1 Participants

Prior to entering the study, a 15-min face-to-face briefing and consent form were given to participants in the classroom, and participants signed an informed consent approved by the institutional review board of Seoul National University. As there is a considerable possibility that individuals with vision or vestibular problems would possibly affect the result of the study, participants without vestibular or vision problems were recruited. Fifty young adults aged between 21 – 37, with a mean age of 26.17 years (SD = 4.102), were recruited from the university community and local community without regard to their susceptibility to motion sickness. The group comprised 25 men with a mean age of 27.36 years (SD=4.222) and 25 women with a mean age of 25.72 years (SD=3.348).

2.2 Questionnaires

2.2.1 Motion Sickness Susceptibility Questionnaires

Prior to entering the study all participants completed motion sickness susceptibility questionnaire and visually induced motion sickness susceptibility questionnaires, which measures person's susceptibility to motion sickness by asking history of motion sickness when one use certain types of transportation/entertainment/visual display.

2.2.1.1 Motion Sickness Susceptibility

The MSSQ, which was introduced by Golding (1998), is one of the most well-known questionnaires to evaluate motion sickness susceptibility. The MSSQ was revised as an MSSQ-Short form, and its validity was assessed and verified by Golding (2006). Participants filled out the MSSQ-S, which concerns susceptibility to motion sickness and the types of transportation/entertainment motion that are most effective in causing the motion sickness symptoms. Individuals rated their frequency of motion sickness for different types of transportation/entertainment motion in childhood and within the last ten years (e.g., amusement park rides, trains, cars, boats, aircraft). MSSQ scores were determined for motion sickness symptoms in childhood (MSSQ-S A) and adulthood (MSSQ-S B), and the total scores were the addition of these two parts. Most commonly, researchers use the Motion Sickness Susceptibility Questionnaire (MSSQ; Golding, 2006) to estimate the motion sickness susceptibility (Fowler et al., 2020).

2.2.1.2 Visually Induced Motion Sickness Susceptibility

The VIMSSQ was firstly introduced by Keshavarz et al. (2019) as a tool to evaluate the visually induced motion sickness susceptibility. The validity of VIMSSQ was assessed and verified by Keshavarz et al. (2021), which concerns susceptibility to visually induced motion sickness and the types of display most influential in causing the visually induced motion sickness symptoms. Individuals rated their frequency of nausea, headache, fatigue, dizziness, and eyestrain for 11 different types of displays (e.g., 2D movie theatre or cinema, 3D movie theatre or cinema, IMAX theatre, smartphones, tablets, TV, HMD, and video games). Raw scores were determined for symptoms of nausea, headache, fatigue, dizziness eyestrain and the total scores were the addition of these five parts.

2.2.2 Visuospatial ability

All participants completed five measures of visuospatial ability using the six tests; the participants' visuospatial ability was evaluated using the paper-pencil test. From the ETS kit of Factor-reference Cognitive test, the Paper folding (2D Spatial Visualization), Card

Rotations (Spatial Relation), Gestalt completion (Closure Speed), Hidden figure (Flexibility of Closure), and number comparison (Perceptual Speed) were adopted in our study to compare these factors with motion sickness/ visually induced motion sickness susceptibility. Also, a prominently well-known test, the Revised Purdue Spatial Visualization Test of rotation (revised PSVT: R), was adopted to compare 3D Spatial Visualization with motion sickness/ visually induced motion sickness susceptibility.

2.2.2.1 Spatial Visualization

Spatial Visualization is the ability to perceive complex patterns and mentally simulate how the object might look when transformed (Schneider & McGrew, 2012). To evaluate the 2D Spatial Visualization, the Paper Folding test was adopted. Thurstone’s Punch Holes suggested the Paper Folding Test. The Paper Folding Test consists of two parts of 10 items on which the participants are shown a drawing of an irregularly folded piece of paper, with all requisite folds marked. The participants are told to imagine a single hole being punched through the paper at an indicated point. Then participants are asked to choose between five possible responses as to what the paper would look like when the paper is fully reopened. Participants have 3 min to complete each part of the test set. The final score on this test is the number of correct items minus incorrect items (maximum score of 20), which is considered a 2D Spatial Visualization test.

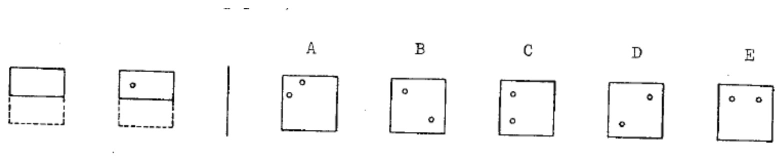

Figure 2.1. Test of 2D Spatial Visualization, Paper Folding Test

To evaluate the 3D Spatial Visualization, the Revised Purdue Spatial Visualization Test of Rotation (revised PSVT: R) was adopted. The PSVT: R was initially suggested by Guay (1977), and its revised form was suggested by Yoon (2011). The revised PSVT: R consists of 30 items on which the participants are shown a picture of an irregularly rotated block piece. The participants are told to imagine that the object shown in the middle line is rotated in the same manner as shown in the top line of the question. The participants are asked to choose between five possible responses as to what the block would look like when rotated similarly. Participants have 20 min to complete the test set. The final score on this test is the number of correct items (maximum score of 30), which is considered a 3D Spatial Visualization test.

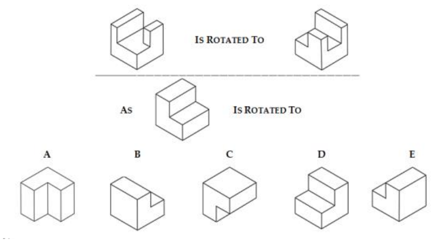

Figure 2.2. Test of 3D Spatial Visualization, the revised Purdue Spatial Visualization Test (revised PSVT:R)

2.2.2.2 Spatial Relation

Spatial relation is the ability to quickly solve the problem of simple image rotation (Schneider & McGrew, 2012). To evaluate the Spatial Relation, the Card Rotation Test was adopted. Thurstone's Card suggested it. The Card Rotation test consists of two parts of 10 items on which the participants are asked to mark whether each of the eight possible options represents either a rotation or a mirror image of a given shape. Scores were only given if participants marked all eight items correctly. Participants have 3 min to complete each part of the test set. The final score on this test is the number of correct items minus incorrect items (maximum score of 20), which is considered a Spatial Relation test.

Figure 2.3. Test of Spatial Relation, the Card Rotation Test

2.2.2.3 Closure Speed

Closure Speed is the ability to quickly identify a familiar and meaningful visual object from incomplete visual stimuli (e.g., vague, partially obscured, disconnected) (Schneider & McGrew, 2012). To evaluate the Closure Speed, the Gestalt Completion Test was adopted. The Street Gestalt completion test suggested it. The Gestalt completion test consists of two parts of 10 items. The participants are shown a picture of an incomplete drawing and asked to use imagination to fill the missing parts and write down the answer correctly. Participants have 2 min to complete each part of the test set. The final score on this test is the number of correct items (maximum score of 20), which is considered a Closure Speed test.

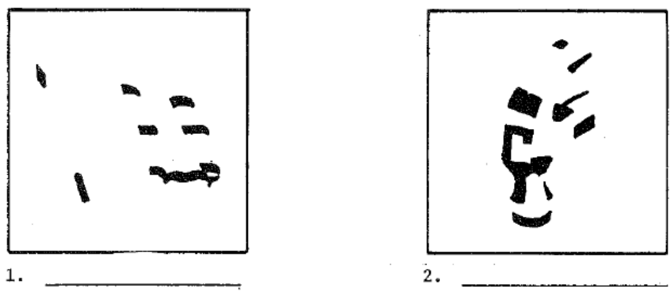

Figure 2.4. Test pf closure speed, the Gestalt Completion test

2.2.2.4 Flexibility of Closure

The flexibility of Closure is the ability to identify a visual figure or pattern embedded in a complex distracting or disguised visual pattern or array when one knows in advance what the pattern is (Schneider & McGrew, 2012). To evaluate the Flexibility of Closure, the Hidden Figure Test was adopted. This test was initially developed in connection with a project designed to study field dependency and used in some studies to measure field dependency (Barret & Thronton, 1970; Ekstrom et al., 1976). The Hidden Figure Test consists of two parts of 16 items on which the participants are given five geometrical figures. The participants are told to find the right side up and precisely the same size as one of the given figures in a more complex pattern. Participants have 12 min to complete each part of the test set. The final score on this test is the number of correct items (maximum score of 32), which is considered a Flexibility of Closure test.

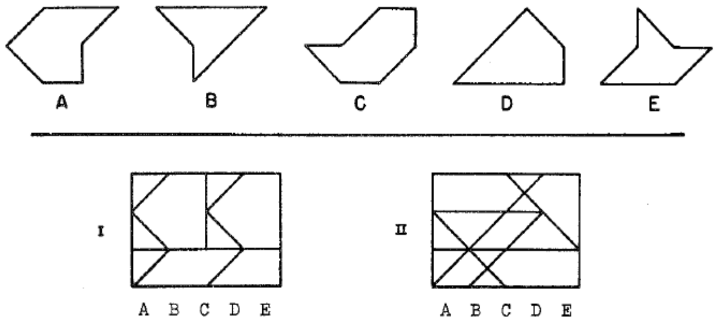

Figure 2.5. Test of flexibility of closure, the Hidden Figure test

2.2.2.5 Perceptual Speed

Perceptual speed is the ability to compare letters, numbers, objects, pictures, or patterns wholly and accurately (Foulds et al., 2020). To evaluate the Perceptual Speed, the Number Comparison Test was adopted. The Minnesota Vocation Test suggested it for Clerical Workers (Andrew, 1937). The Number Comparison Test consists of two parts of 48 items on which the participants are given two numbers to compare. First, the participants are told to decide whether the numbers are the same. Then, if the numbers are the same, go on to the next pair and mark X when it is not. Participants have 1.5 min to complete each part of the test set. The final score on this test is the number of correct items minus incorrect items (maximum score of 96), which is considered a Perceptual Speed test.

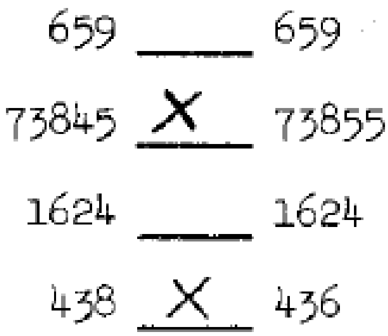

Figure 2.6. Test of perceptual speed, the Number Comparison Test

2.3 Procedure

Participants were tested in a group of 1 to 4 per session. Participants were seated at desks as individuals and asked not to copy each other's answers. First, the experimenter explained that the participants would be asked to complete a series of tests. Then, the experimenter explained the research objects and each test procedure. The visuospatial ability tests were administered in an order that was intended to minimize order effects. Prior to the visuospatial ability test sessions, each participant evaluated their motion sickness susceptibility. To evaluate the subjects motion sickness susceptibility, the Motion Sickness Susceptibility Questionnaire-Short Form (MSSQ-S), Visually Induced Motion Sickness Susceptibility Questionnaire (VIMSSQ), and demographic questionnaire were employed. Then participants' visuospatial ability was tested using the paper-pencil test; all the tests were explained and practiced right before each test set. The ETS kit of Factor-referenced Cognitive tests (1976 Edition) and the revised Purdue Spatial Visualization Test (revised PSVT: R) was used to test an individual's visuospatial ability. It evaluates an individual's visuospatial ability in its five major components: Spatial Visualization (VZ-2D/3D), Spatial Relations (SR), Closure Speed (CS), Flexibility of Closure (CF), Perceptual Speed (P). Sufficient break time was given between each visuospatial ability test to prevent mental fatigue and when participants requested it. The entire session lasted between 100 and 120 min, including break time.

2.4 Data Analyses

In order to perform statistical analyses of data, those subjects whose tests were incomplete or outliers were removed from each analysis. Outliers were screened for each Visuospatial ability test, and the number of subjects' data differed for each test. The mean and standard deviation of each test was obtained, and since the number of data is more than 50, a normal distribution was assumed. In case each visuospatial ability test score is outside the range of 95% ($\pm 1.96\sigma$), regarded as an outlier who is not interested in or effort with the tests, was removed from the data. Also, the total raw scores from the MSSQ-S & MSSQ-S B were transformed into percentage scores using an equation and chart generated by Golding (2006). A number of Visuospatial ability tests & motion sickness/ visually induced motion sickness susceptibility data used in analyses are shown in Tables 2.1, 2.2., 2.3, 2.4. Also, as the study was intended to focus on the current susceptibility of motion sickness/visually induced motion sickness, the MSSQ-A(childhood) score was omitted from the analyses.

Table 2.1. Number of Visuospatial ability test score data used in analyses

Visuospatial ability test	N(=50)	Male	Female
VZ_score	47	22	24
VZ_3D_score	47	24	23
SR_score	48	25	23
CS_score	49	24	25
CF_score	45	22	23
P_score	47	22	25

Table 2.2. Number of motion sickness susceptibility adult score data used in analyses

MSSQ-B	N(=50)	Male	Female
Cars	50	25	25
Buses or Coaches	50	25	25
Trains	49	25	24
Aircraft	50	25	25
Small boats	39	23	16
Ships	41	23	18
Swings	40	21	19
Roundabouts in playgrounds	32	18	14
Big dippers	43	23	20

Table 2.3. Number of visually induced motion sickness susceptibility data used in analyses

VIMSSQ	N(=50)	Male	Female
movie_2d	50	25	25
movie_3d	49	25	24
Imax	42	23	19
Smartphones	50	25	25
Tablets	47	24	23
Television	50	25	25
HMD/VR	44	23	21
Video Games	43	24	19
Static Simulators	47	25	22
Dynamic Simulators	44	22	22
Large Public Moving Display Advertising	49	24	25

Table 2.4. Number of participants in each Motion sickness susceptibility Group used in two-way ANOVA

Motion Sickness Susceptibility Group	None/ (0-25%)	Rarely/ (25-50%)	Sometimes/ (50-75%)	Frequently/ (75-100%)
self-reporting motion sickness Susceptibility	**6**	**21**	**18**	**5**
male	6	11	8	0
female	0	10	10	5
MSSQ-S Percentile	**11**	**11**	**12**	**16**
male	7	7	8	3
female	4	4	4	13
MSSQ-B percentile	**7**	**10**	**15**	**18**
male	7	5	9	3
female	0	5	6	15

2.4.1 Correlation Analysis

The statistical analysis was conducted using SPSS statistics 25 (IBM Corp., Armonk, USA). Correlation analysis was conducted to investigate the relationship between motion sickness susceptibility and visuospatial ability. For correlation analysis, the visuospatial ability test score and the total motion sickness susceptibility scores and their sub-scores were used. The motion sickness susceptibility was derived using each section of MSSQ-S (MSSQ-S adult & total) and VIMSSQ (nausea, headache, fatigue, dizziness, eyestrain).

2.4.2 Two-way ANOVA

Demographic data (gender, self-reporting MS susceptibility) and MSSQ-S were used as independent variables to divide participants into different groups. All the motion sickness susceptibility (self-reporting motion sickness susceptibility, MSSQ total percentile, MSSQ adult percentile) were divided into four-level (None/Rarely/Sometimes/Frequently) and two-level (None & Rarely/Sometimes & Frequently) as shown in Table 2.4. For the dependent variables, all the normalized visuospatial ability test scores were employed. For each motion sickness susceptibility questionnaire and visuospatial ability test, 2-way ANOVA was conducted to investigate the relationship between motion sickness susceptibility and visuospatial ability test score. Levene’s test was performed to test the homogeneity of variance.

Chapter 3

Results

3.1 Correlation analysis

Sub-component of MSSQ& VIMSSQ and visuospatial ability factors were analyzed through correlation analysis and the results are shown in Table 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, .3.8, 3.9.

Overall, the linear correlation between the sub-component of MSSQ & VIMSSQ and visuospatial ability factors are inconsistent and not significant. However, some positive/negative correlations among the participants were observed between aircraft sickness and Flexibility of Closure test score, Imax movie and Spatial Visualization test score. Among the male, aircraft sickness and Flexibility of Closure test scores, ship sickness and Perceptual Speed test scores, the Imax movie and Spatial relation test scores were positively correlated. In contrast, the Television and Flexibility of Closure test scores were negatively correlated. Among females, a significant negative correlation was observed between Roundabouts in playgrounds and the Spatial Relation test score.

Table 3.1. Correlations between motion sickness sub-score and visuospatial ability test score (whole participant)

All	VZ_score	VZ_3D_score	SR_score	CS_score	CF_score	P_score
MSSQ_RAW	-0.049	0.028	-0.125	-0.010	0.098	0.115
MSSQ_B	-0.031	0.065	0.003	0.066	0.014	0.128
MSSQ_percent	-0.051	0.006	-0.129	-0.025	0.045	0.073
VIMSSQ_RAW	-0.135	-0.017	0.057	-0.049	-0.096	-0.086
VIMSSQ_nausea	-0.085	0.032	-0.033	-0.018	0.043	-0.022
VIMSSQ_fatigue	-0.178	0.032	0.026	-0.075	-0.115	-0.096
VIMSSQ_dizz	-0.047	-0.087	-0.019	0.015	-0.059	-0.120
VIMSSQ_eyestrain	-0.167	-0.080	0.117	-0.033	-0.158	-0.029
VIMSSQ_headache	-0.047	0.060	0.110	-0.088	-0.064	-0.110

(*: p<0.05, **: p<0.01, ***: p<0.001)

Table 3.2. Correlations between motion sickness sub-score and visuospatial ability test score (male participants)

Male	VZ_score	VZ_3D_score	SR_score	CS_score	CF_score	P_score
MSSQ_RAW	0.108	0.185	-0.004	0.144	0.269	-0.023
MSSQ_B	0.236	0.285	0.091	0.244	0.256	0.052
MSSQ_percent	0.133	0.142	-0.020	0.107	0.195	-0.024
VIMSSQ_RAW	-0.137	0.067	0.183	-0.212	0.000	-0.117
VIMSSQ_nausea	-0.303	0.047	-0.102	-0.235	0.202	0.078
VIMSSQ_fatigue	-0.231	0.110	-0.079	-0.232	0.011	-0.121
VIMSSQ_dizz	-0.139	0.028	0.087	-0.021	0.248	0.199
VIMSSQ_eyestrain	-0.045	-0.024	0.296	-0.108	-0.150	-0.093
VIMSSQ_headache	0.125	0.128	0.133	-0.146	-0.021	-0.284

(*: p<0.05, **: p<0.01, ***: p<0.001)

Table 3.3. Correlations between motion sickness sub-score and visuospatial ability test score (female participants)

Female	VZ_score	VZ_3D_score	SR_score	CS_score	CF_score	P_score
MSSQ_RAW	-0.041	0.178	-0.182	-0.181	0.250	0.275
MSSQ_B	-0.122	0.195	0.000	-0.115	0.065	0.235
MSSQ_percent	-0.061	0.193	-0.174	-0.178	0.225	0.197
VIMSSQ_RAW	0.003	0.220	0.091	0.034	-0.058	-0.078
VIMSSQ_nausea	0.113	0.252	0.037	0.102	0.213	-0.042
VIMSSQ_fatigue	-0.041	0.263	0.134	-0.002	-0.191	-0.089
VIMSSQ_dizz	0.196	0.156	0.018	0.072	-0.037	-0.240
VIMSSQ_eyestrain	-0.153	0.067	0.040	0.054	-0.231	0.030
VIMSSQ_headache	0.007	0.275	0.168	-0.057	0.149	-0.042

(*: p<0.05, **: p<0.01, ***: p<0.001)

Table 3.4. Correlations between motion sickness sub-component score and visuospatial ability test score (whole participants)

MSSQ_All	VZ_score	VZ_3D_score	SR_score	CS_score	CF_score	P_score
Cars	0.040	-0.038	-0.164	-0.050	-0.106	-0.035
Buses or Coaches	0.058	-0.024	0.089	-0.024	-0.070	-0.205
Trains	-0.085	0.018	-0.035	0.067	0.127	0.100
Aircraft	0.064	0.014	0.142	0.149	**0.298***	0.130
Small_boats	-0.119	-0.007	-0.093	0.037	-0.020	0.098
Ships	-0.102	0.044	-0.139	0.055	0.072	0.258
Swings	-0.148	0.090	0.037	-0.018	-0.072	0.085
Roundabouts in playgrounds	-0.232	-0.069	-0.263	-0.135	-0.063	0.161
Big Dippers	-0.120	-0.026	0.161	-0.008	-0.144	0.165

(*: p<0.05, **: p<0.01, ***: p<0.001)

Table 3.5. Correlations between motion sickness sub-component score and visuospatial ability test score (male participants)

MSSQ_Male	VZ_score	VZ_3D_score	SR_score	CS_score	CF_score	P_score
Cars	0.015	0.118	-0.259	-0.084	0.045	-0.312
Buses or Coaches	0.335	0.067	0.018	0.026	0.047	-0.349
Trains	0.284	0.268	0.047	0.147	0.340	-0.053
Aircraft	0.155	0.176	0.274	0.212	**0.430***	0.245
Small_boats	0.019	0.062	-0.238	0.018	0.303	0.270
Ships	0.123	0.343	-0.006	0.169	0.333	**0.473***
Swings	-0.043	-0.055	0.235	0.092	0.233	0.060
Roundabouts in playgrounds	0.078	0.172	0.180	-0.064	0.117	0.104
Big Dippers	-0.007	0.060	0.068	-0.096	0.102	0.193

(*: p<0.05, **: p<0.01, ***: p<0.001)

Table 3.6. Correlations between motion sickness sub-component score and visuospatial ability test score (female participants)

MSSQ_Female	VZ_score	VZ_3D_score	SR_score	CS_score	CF_score	P_score
Cars	0.254	0.095	-0.021	-0.011	-0.084	0.282
Buses or Coaches	0.063	0.273	0.251	-0.092	0.007	-0.099
Trains	-0.126	0.201	-0.003	0.050	0.247	0.209
Aircraft	0.057	0.030	0.090	0.117	0.267	0.082
Small_boats	-0.138	0.161	0.164	0.055	-0.103	-0.047
Ships	-0.210	0.089	-0.319	-0.142	0.066	0.068
Swings	-0.118	0.309	-0.010	-0.161	-0.091	0.183
Roundabouts in playgrounds	-0.502	-0.075	**-0.656***	-0.212	0.036	0.343
Big Dippers	-0.208	-0.032	0.288	0.107	-0.294	0.153

(*: p<0.05, **: p<0.01, ***: p<0.001)

Table 3.7. Correlations between visually induced motion sickness sub-component score and visuospatial ability test (whole participants)

VIMSSQ_All	VZ_score	VZ_3D_score	SR_score	CS_score	CF_score	P_score
movie_2d	0.070	0.096	0.146	0.015	-0.126	-0.117
movie_3d	-0.211	-0.154	-0.016	-0.062	-0.116	0.001
imax	**-0.338***	-0.307	0.062	-0.006	-0.023	0.140
Smartphones	-0.115	0.059	0.049	-0.168	-0.115	-0.055
Tablets	-0.148	0.048	0.228	-0.171	-0.097	-0.031
Television	-0.244	0.034	0.067	-0.157	-0.229	-0.013
HMD/VR	-0.239	-0.011	-0.055	-0.076	-0.120	-0.033
Video Games	0.028	0.086	0.007	0.049	0.078	-0.118
Static Simulators	-0.046	0.026	0.078	0.041	-0.203	-0.059
Dynamic Simulators	0.028	-0.060	-0.053	0.034	-0.067	-0.050
Large Public Moving Display Advertising	-0.203	-0.196	0.078	-0.045	-0.211	0.123

(*: p<0.05, **: p<0.01, ***: p<0.001)

Table 3.8. Correlations between visually induced motion sickness sub-component score and visuospatial ability test (male participants)

VIMSSQ_Male	VZ_score	VZ_3D_score	SR_score	CS_score	CF_score	P_score
movie_2d	0.169	0.110	0.157	-0.041	-0.257	-0.210
movie_3d	-0.088	0.000	0.010	-0.175	0.078	0.202
imax	-0.051	-0.012	**0.415***	0.233	0.408	0.084
Smartphones	-0.029	0.008	0.106	-0.225	-0.003	-0.140
Tablets	0.053	-0.104	0.225	-0.196	-0.068	-0.051
Television	-0.111	0.024	-0.086	-0.323	**-0.550****	-0.172
HMD/VR	-0.215	0.017	0.105	0.042	0.038	-0.139
Video Games	-0.039	0.173	-0.003	0.052	0.142	-0.428
Static Simulators	-0.066	0.140	0.202	-0.121	-0.103	-0.049
Dynamic Simulators	-0.020	0.128	0.123	-0.201	0.055	-0.076
Large Public Moving Display Advertising	-0.331	-0.199	-0.202	-0.397	-0.231	0.343

(*: p<0.05, **: p<0.01, ***: p<0.001

Table 3.9. Correlations between visually induced motion sickness sub-component score and visuospatial ability test (female participants)

VIMSSQ_Female	VZ_score	VZ_3D_score	SR_score	CS_score	CF_score	P_score
movie_2d	0.153	0.281	0.188	0.064	0.012	-0.050
movie_3d	-0.166	0.028	0.066	-0.012	-0.059	-0.068
imax	-0.409	-0.275	-0.142	-0.188	-0.075	0.273
Smartphones	-0.016	0.345	0.069	-0.169	-0.058	0.015
Tablets	-0.167	0.307	0.332	-0.254	-0.030	0.009
Television	-0.254	0.225	0.200	-0.055	0.001	0.103
HMD/VR	-0.116	0.263	-0.152	-0.210	-0.082	0.112
Video Games	0.225	0.277	0.106	0.031	0.174	0.214
Static Simulators	0.131	0.280	0.099	0.205	-0.136	-0.048
Dynamic Simulators	0.242	0.124	-0.102	0.263	0.029	0.031
Large Public Moving Display Advertising	-0.073	-0.047	0.256	0.175	-0.154	0.062

(*: p<0.05, **: p<0.01, ***: p<0.001)

3.2 Two-way ANOVA

Two-way ANOVA revealed that there is no interaction effect between gender and motion sickness susceptibility group. However, there was a significant difference in 2D Spatial Visualization and 3D Spatial Visualization test score between gender and motion sickness susceptibility groups. 2-way ANOVA with four-level self-reporting motion sickness susceptibility result revealed male outperform 2D Spatial Visualization test than females, $F = 8.376$, $p < .05$, $\eta_p^2 = .166$ and lower motion sickness susceptibility group tend to score low in 2D Spatial Visualization test, $F = 3.197$, $p < .05$, $\eta_p^2 = .186$. however, Bonferroni post-hoc test results show no significant difference between the motion sickness susceptibility group.

Table 3.10. Bonferroni post hoc result

Visuospatial ability	motion sickness susceptibility		Mean difference	SD	*p*
2D Spatial Visualization	None	Rarely	-18.5	8.7	0.241
	None	Sometimes	-16.7	8.9	0.403
	None	Frequently	-16.2	10.6	0.803
	Rarely	Sometimes	1.8	5.8	1.000
	Rarely	Frequently	2.3	8.1	1.000
	Sometimes	Frequently	0.5	8.3	1.000

Two-way ANOVA with two level self-reporting motion sickness susceptivity result revealed male outperform 3D Spatial Visualization test than females, F = 12.183, p < .005, η_p^2 = .221 and lower motion sickness susceptibility group tend to score low in 3D Spatial Visualization test, F= 7.288, p < .05, η_p^2 = .145.

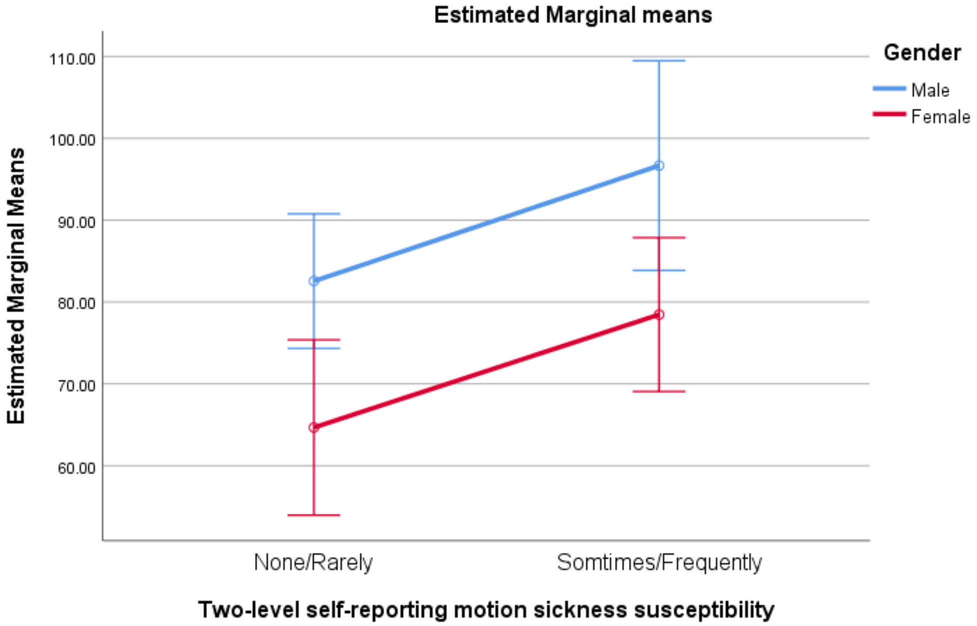

Figure 3.1. estimated marginal means for 3D Spatial Visualization score by gender and Two-level self-reporting motion sickness susceptibility error bars: 95% CI.

Chapter 4

Discussion

4.1 Discussion

Surprisingly the results revealed either there is no relationship, or a weak relationship exists between sub-dimensions of visuospatial ability and motion/visually induced motion sickness susceptibility. In addition, these results were inconsistent with previous research (Barret & Thronton, 1968; Levin & Stern, 2002; Smyth et al., 2021)

A significant relationship between motion sickness and visuospatial ability was found in previous research (Levin & Stern, 2002; Smyth et al., 2021). However, our finding does not support other studies showing that one with poorer visuospatial ability may be more susceptible to motion sickness. It is entirely unclear why there were no relationships between an individual's visuospatial information processing ability and motion sickness susceptibility. Even though five significant visuospatial ability factors were considered, including mental imagery and rotation ability, our study obtained different results from Levine & Stern (2002). While the Visuospatial ability (measured with Paper Folding, the Revised Purdue Spatial Visualization, Card Rotation, Gestalt Completion, Hidden Figure, and Number Comparison) test scores quantify an individual's visual information processing capability, they do not provide any information as to an individual's abilities for vestibular/somatosensory information processing. This case may be accounted for based on the sensory conflict theory – motion sickness is associated with the visual system (visual information processing) and the inner ear's functional vestibular system (vestibular function).

Further, visuospatial ability dimensions do not represent the ability to re-code the multimodal information, to resolve perceived mismatches or transfer newly experienced (novel) multimodal information to the long-term memory. Note that: the sensory conflict theory seems to imply the involvement of long-term memory in the occurrence of motion sickness. If a multimodal information pattern is to be judged 'unusual' or 'not right,' some references for 'usual' or 'right' patterns must be pre-stored in the memory system. It is thought that motion sickness susceptibility is related to many factors besides 'visual information processing.

We hypothesized that an individual's internal information processing (information manipulation) ability, measured in the absence of training, would have a relationship with that person's susceptibility to motion sickness. However, the results showed that a person's internal visual information processing/manipulation abilities do not have significant relationships with the person's motion sickness susceptibility. Our result contradicts Levine & Stern (2002) but not with Smyth et al. (2021)

Smyth et al. (2021) study reported that visuospatial ability could be improved through training and leads to a reduction in motion sickness. Then, it may be possible to assume a causal relationship exists between visuospatial ability and motion sickness. However, the direct link between visuospatial ability and motion sickness seems to be doubtful as it has not been clarified whether visuospatial ability training leads to reduced motion sickness or high visuospatial information processing ability itself resulted in lower motion sickness susceptibility. The result of this study suggests that there might be a strong habituation effect, whereby repeat exposures to unusual visual stimuli, a motion sickness-inducing task, or a spatially difficult task might reduce motion sickness (Smyth et al., 2021; Palmisano & Constable, 2022).

Although our study did not show any relationship between visuospatial ability test score and motion sickness susceptibility questionnaires' score (MSSQ/VIMSSQ), this does not contradict Smyth et al.'s (2021). Smyth et al. (2021) only confirmed the effect of visuospatial information processing ability by using FMS (Fast Motion Sickness Scale) and SSQ (Simulator Sickness Questionnaire). While FMS and SSQ were motion sickness questionnaires designed to specifically measure VIMS (the nausea aspect, stomach awareness, and general discomfort) within a specific time and specific task, MSSQ and VIMSSQ were motion sickness questionnaires designed to measure one's motion sickness experience in a different kind of transportation/visual display. As our study only measured the individual motion sickness susceptibility and individual innate visuospatial ability, it seems different but similar to Smyth et al.'s (2021) study.

Levine & Stern (2002) measured the motion sickness susceptibility by using MSQ (ref). MSQ is the questionnaire that assesses a person's history of experiences with motion sickness. It includes questions about the experience an individual has had with various forms of transportation such as boats, ships, cars, trains, buses, airplanes, and park amusements, and how often the individual has felt nauseated or vomited while traveling on each form of transportation. The MSQ seems similar to MSSQ in measuring motion sickness susceptibility. In addition, to measure visuospatial ability, Levine & Stern (2002) used the Water-level test and mental rotation tests, which measure Spatial Relation and Spatial Visualization.

Similarly, our study used the card rotation test and revised PSVT: R to measure Spatial Relation and Spatial Visualization, but completely different results were obtained. There is a considerable possibility that repeated exposures to unusual visual stimuli or a motion sickness-inducing task would have reduced motion sickness and increased the visuospatial ability. Due to substantial development in transportation and visual display technologies between 2002 and 2022, people's past and present behaviors in transportation and use of visual display seem to be diversified. People now frequently use visual displays (cell phones, tablets, mounted displays in airplanes or trains) in transportation. Also, it is easy to access different visual displays (such as Imax/3D movies, video games, HMD, or

VR), which might lead people to experience unusual visual stimuli or motion sickness-inducing tasks and result in reduced motion sickness susceptibility and increase the visuospatial ability. This could be explained as playing video games like Halo would increase one's visuospatial ability (Sanchez, 2012) and as unusual visual stimuli or motion sickness-inducing tasks could reduce one's motion sickness (Palmisano & Constable, 2022)

Chapter 5

Conclusion

5.1 Conclusion

This study has investigated the relationship between motion sickness susceptibility and five major factors of visuospatial ability. For motion sickness all of the sub-component of motion sickness susceptibility and visually induced motion sickness questionnaire were considered. For visuospatial ability factor, Spatial Visualization, Spatial Relation, Closure Speed, Flexibility of Closure, and Perceptual Speed were consider. As a result, it has been identified that either there is no relationship between motion sickness and visuospatial ability factors or even if it exist it may not be strong.

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Appendix A. MSSQ-Short

Table A.1: The motion sickness susceptibility questionnaire short used in this study

나이	
성별	
직업	

멀미 민감도			
전혀	적음	중간	심한

3. 어린 시절(만 12 살 이전)에 멀미로 인해 얼마나 자주 **아프거나 속이 울렁거린다고** 느꼈습니까?

	없음/ 탑승경험 없음	드물게	가끔	자주	항상
자동차					
버스					
기차					
비행기					

작은 배					
배, 유람선					
그네					
놀이터 뱅글돌이					
놀이기구(롤러코스터)					

4. 지난 10 년간 멀미로 인해 얼마나 자주 **아프거나 속이 울렁거린다고** 느꼈습니까?

	없음/ 탑승경험 없음	드물게	가끔	자주	항상
자동차					
버스					
기차					
비행기					
작은 배					
배, 유람선					
그네					
놀이터 뱅글돌이					
놀이기구(롤러코스터)					

Appendix B. VIMSSQ

Table B.1: The visually induced motion sickness susceptibility questionnaire used in this study

1. 아래 기기들을 이용하거나 사용할 때 얼마나 자주 **속이 매스껍다고** 느꼈습니까?	사용경험 없음/ 해당사항 없음	없음	드물게	가끔	자주
2D 영화					
3D 영화					
IMAX 영화					
핸드폰을 사용한 게임 및 영화 감상					
테블릿을 사용한 게임 및 영화 감상					
티비					
HMD/VR Glasses					
비디오 게임(컴퓨터 or 조이스틱) (ex. 플레이스테이션)					
정적 시뮬레이터(자동차, 비행기 등등 놀이동산을 포함하여) 정적 시뮬레이터는 시뮬레이터가 움직이지					

않는 것을 의미함					
동적 시뮬레이터(자동차, 비행기, 놀이동산을 포함하여) 동적 시뮬레이터는 시뮬레이터 자체가 움직이는 것을 의미함					
대형 광고판, 대형 전광판 (3D LED Display 포함, ex) 파도치는 듯한 전광판)					

2. 아래 기기들을 이용하거나 사용할 때 얼마나 자주 **피로감을** 느꼈습니까?	사용경험 없음/ 해당사항 없음	없음	드물게	가끔	자주
2D 영화					
3D 영화					
IMAX 영화					
핸드폰을 사용한 게임 및 영화 감상					
테블릿을 사용한 게임 및 영화 감상					

티비					
HMD/VR Glasses					
비디오 게임(컴퓨터 or 조이스틱) (ex. 플레이스테이션)					
정적 시뮬레이터(자동차, 비행기 등등 놀이동산을 포함하여) 정적 시뮬레이터는 시뮬레이터가 움직이지 않는 것을 의미함					
동적 시뮬레이터(자동차, 비행기, 놀이동산을 포함하여) 동적 시뮬레이터는 시뮬레이터 자체가 움직이는 것을 의미함					
대형 광고판, 대형 전광판 (3D LED Display 포함, ex) 파도치는 듯한 전광판)					

3. 아래 기기들을 이용하거나 사용할 때 얼마나 자주 **어지러움**을 느꼈습니까?	사용경험 없음/ 해당사항 없음	없음	드물게	가끔	자주

2D 영화					
3D 영화					
IMAX 영화					
핸드폰을 사용한 게임 및 영화 감상					
테블릿을 사용한 게임 및 영화 감상					
티비					
HMD/VR Glasses					
비디오 게임(컴퓨터 or 조이스틱) (ex. 플레이스테이션)					
정적 시뮬레이터(자동차, 비행기 등등 놀이동산을 포함하여) 정적 시뮬레이터는 시뮬레이터가 움직이지 않는 것을 의미함					

동적 시뮬레이터(자동차, 비행기, 놀이동산을 포함하여) 동적 시뮬레이터는 시뮬레이터 자체가 움직이는 것을 의미함					
대형 광고판, 대형 전광판 (3D LED Display 포함, ex) 파도치는 듯한 전광판)					

4. 아래 기기들을 이용하거나 사용할 때 얼마나 자주 **눈의 피로감을** 느꼈습니까?	사용경험 없음/ 해당사항 없음	없음	드물게	가끔	자주
2D 영화					
3D 영화					
IMAX 영화					
핸드폰을 사용한 게임 및 영화 감상					
테블릿을 사용한 게임 및 영화 감상					
티비					
HMD/VR Glasses					

비디오 게임(컴퓨터 or 조이스틱) (ex. 플레이스테이션)					
정적 시뮬레이터(자동차, 비행기 등등 놀이동산을 포함하여) 정적 시뮬레이터는 시뮬레이터가 움직이지 않는 것을 의미함					
동적 시뮬레이터(자동차, 비행기, 놀이동산을 포함하여) 동적 시뮬레이터는 시뮬레이터 자체가 움직이는 것을 의미함					
대형 광고판, 대형 전광판 (3D LED Display 포함, ex) 파도치는 듯한 전광판)					

5. 아래 기기들을 이용하거나 사용할 때 얼마나 자주 **두통을** 느꼈습니까?	사용경험 없음/ 해당사항 없음	없음	드물게	가끔	자주
2D 영화					
3D 영화					

IMAX 영화					
핸드폰을 사용한 게임 및 영화 감상					
테블릿을 사용한 게임 및 영화 감상					
티비					
HMD/VR Glasses					
비디오 게임(컴퓨터 or 조이스틱) (ex. 플레이스테이션)					
정적 시뮬레이터(자동차, 비행기 등등 놀이동산을 포함하여) 정적 시뮬레이터는 시뮬레이터가 움직이지 않는 것을 의미함					
동적 시뮬레이터(자동차, 비행기, 놀이동산을 포함하여) 동적 시뮬레이터는 시뮬레이터 자체가 움직이는 것을 의미함					

대형 광고판, 대형 전광판 (3D LED Display 포함, ex) 파도치는 듯한 전광판)						

국문초록

본 논문은 멀미에 대한 이해를 높이고자 멀미 민감도와 시각공간능력 인자간 관계를 더욱 자세하게 살펴보고자 한다. 사람의 시각공간 능력은 여러 하위 요소가 있으며 멀미의 종류도 다양하다. 멀미 민감도는 동적 멀미 민감도와 시각적 멀미 민감도를 평가하고 시각공간능력의 5가지 주요 인자를 평가하여 멀미 민감도와의 관계를 살펴보는 연구를 진행하고자 한다. 연구 결과를 바탕으로 개개인의 멀미 민감도에 영향을 주는 인간의 시각공간 정보 처리 능력 파악함으로써, 어떠한 사람이 멀미를 더 잘 느끼는지 파악할 수 있으며, 멀미를 줄이기 위한 해결 방안을 제시할 수 있을 것으로 기대된다. 시각공간 능력이 뛰어난 개개인이 시각정보처리 능력과 시각정보조작능력이 더 좋기 때문에 일반적으로 멀미를 덜 느낄 것이라 예상된다. 하지만, 기존 시각공간 능력과 멀미가 연관이 있다는 연구와 없다는 연구가 있기 때문에 본 연구를 통해 둘 사이의 관계를 파악함으로써 멀미에 대한 지식을 넓힐 수 있을 것이라 기대한다. 나아가 개개인의 시각공간 능력에 따라 멀미 민감도가 어떻게 달라지는지를 파악함으로써 시각정보처리이나 시각정보조작 능력과 멀미와의 개념도 함께 접목시켜 설명할 수 있을 것이다.

주요어: 멀미 민감도, 시각적 멀미 민감도, 정보처리능력, 시각공간 능력

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