

## **EXPLORING NEW DIMENSIONS IN THE ASSESSMENT OF VIRTUAL REALITY INDUCED SIDE EFFECTS**

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### **EXPLORING NEW DIMENSIONS IN THE ASSESSMENT OF VIRTUAL REALITY INDUCED SIDE EFFECTS**

*Stéphane Bouchard, Geneviève Robillard, Patrice Renaud, François Bernier*

**ABSTRACT.** Two issues are increasingly of interests in the scientific literature regarding virtual reality induced unwanted side effects: (a) the latent structure of the Simulator Sickness Questionnaire (SSQ), and (b) the overlap between anxiety symptoms and unwanted side effects. Study 1 was conducted with a sample of 517 participants. A confirmatory factor analysis clearly supported a two-factor model composed of nausea and oculomotor symptoms. To tease-out symptoms of anxiety from negative side effects of immersion, Study 2 was conducted with 47 participants who were stressed without being immersed in virtual reality. Five of the 16 side effects correlated significantly with anxiety. In a third study conducted with 72 participants, the post-immersion scores of the SSQ and the State Anxiety scale were subjected to a factor analysis to detect items side effects that would load on the anxiety factor. The results converged with those of Study 2 and revealed that general discomfort and difficulty concentrating loaded significantly on the anxiety factor. The overall results support the notion that side effects consists mostly of a nausea and an oculomotor latent structure and that (only) a few items may reflect anxiety more than unwanted negative side effects.

## **INTRODUCTION**

Negative side effects induced by an immersion in virtual reality (VR) are not uncommon. Cobb et al. (1999) and Wilson (1997) summarized the results of a comprehensive research program conducted on 148 civilians and 75 non-civilians using a variety of virtual environments, tasks and equipment, and immersions that varied between 20 to 120 minutes. They found that 20% of their civilian participants did not notice any side effects. Among the remaining participants, only a few (5% of the total sample) experienced side effects severe enough that they had to stop the immersion. The other participants reported side effects that, usually, were mild, occurred within the first 15 minutes of the immersion and subsided within 10 minutes after the immersion. In reviewing the literature on the topic, Lawson et al. (2002) reported that between 50% to 100% of users immersed in virtual reality experience some dizziness and from 20% to 60% of users experience some abdominal symptoms. The frequency of other symptoms appeared less documented but included

oculomotor problems. Overall, Lawson et al. (2002) conclusion was consistent with Cobb et al. (1999), Nichol and Patel (2002) and Stanney and Kennedy (2009) that about 5% of users immersed in virtual reality will report symptoms that are significant enough to warrant stopping the immersion, about 5% will not experience any symptoms at all and the remaining users (between 70 % to 90%) may experience some mild symptoms caused by the immersion in VR.

Given the increasing use of virtual reality in mental health applications, Bouchard et al. (2009) studied virtual reality induced side effects in a clinical sample of 157 adults diagnosed with an anxiety disorder. They found that 80% of their participants reported no or only a few light symptoms. Interestingly, many symptoms usually associated with immersions in VR were already present before the immersion, and 24 hours post-immersion very few participants reported symptoms of side effects. The methodology used did not allow assessing if the symptoms reported on the day following the immersion were lasting effects of

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the immersion or if they were related to other events or conditions that occurred since the immersion. Also, the authors could not discriminate whether the symptoms were caused by anxiety experienced during the immersions or specific to VR.

Looking at factors inducing unwanted side effects, Sharples et al. (2008) confirmed that intensity of negative side effects is affected by the technology used to create the immersion and the extent to which user controls movements during the immersion. They also insisted on the importance of individual differences in the susceptibility to side effects.

According to Kennedy et al. (1993), the temporary side effects associated with immersion in VR include general discomfort, difficulty focusing, increased salivation, sweating, fullness of head, stomach awareness and burping and are classified into three clusters of symptoms: (1) *oculomotor problems* (i.e., eyestrain, blurred vision, headaches), (2) *disorientation* (i.e., vertigo, imbalance) and (3) *nausea* (i.e., vomiting, dizziness). The ocular problems are probably related to the wear of the head mounted display (HMD) (e.g., a HMD that is too heavy or too tightly strapped to the head) or related to the eyestrain of looking for a long period of time at computer monitors that are located at a fixed distance within a few inches from the eyes. The nausea and the disorientation problems are temporary and are often associated with motion sickness symptoms. The most-often reported explanation for these symptoms would be a conflict between information provided by the otolith organs (providing information about linear acceleration of the head), the semicircular canals (providing information about angular acceleration of the head), the visual system (providing information about the position and orientation of the body with respect to the visual environment) and the kinesthetic system (providing information about limb and body position) (Reason & Brand, 1975; Harm, 2002). The sensory conflict theory is not without its critics (e.g., Riccio & Stoffregen, 1991) and other theories may

also explain some of the nausea and disorientation symptoms, such as the difficulties maintaining postural stability in virtual environments (Bonnet et al., 2006; Riccio & Stoffregen, 1991). Lawson et al. (2002) mentioned a fourth cluster of symptoms described as the Sopite syndrome. Sopite syndrome is a form of motion sickness manifesting itself solely by signs of fatigue (drowsiness, difficulty concentrating and apathy). It is possible that this syndrome involves the vestibular system. To this day, factors associated with Sopite syndrome after an immersion in virtual reality remain poorly understood (Lawson et al., 2002; Kennedy et al., 2010).

In order to measure virtual reality induced side effects, the Pensacola *Motion Sickness Questionnaire* (Kennedy et al. 1965) is one of the earliest measure available and was designed for the assessment of motion sickness. It consists of a list of more than 20 signs or symptoms initially presented by Hardacre and Kennedy (1963). A shorter version was published by Wood et al. (1966) using seven criteria, including the cardinal signs of vomiting and retching. Over the years, research on motion sickness progressed and four symptoms became considered as key signs of motion sickness: nausea, vomiting, pallor and cold sweating.

According to the review by Lawson et al. (2002), several versions of the Miller and Graybiel questionnaire (referred to under different names such as the *Pensacola Diagnostic Index*, the *Pensacola Diagnostic Criteria* and the *Graybiel Scale*) have been routinely used in different research and training establishments, particularly in the field of Marine, of aviation and of technology. Their questionnaire was modified several times since the seventies, which after a series of factorial analyses eventually led to the 16-item *Simulator Sickness Questionnaire (SSQ)*. As noted by Kennedy et al. (2010), Lane and Kennedy's (1988) intent was to include on the form distributed to participants the original 27 items from the Pensacola *Motion Sickness Questionnaire* and to score only the

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16 items retained in the SSQ. Their intention of leaving the “irrelevant” items on the form was based on the desire to preserve the psychometrics of the scale (Kennedy et al., 2010), but the large majority of scientists and clinicians have adopted the form listing only the 16 items that are scored. Other instruments have also been developed over the years, such as the *Nausea Profile* (Muth et al., 1996) or the *Virtual Reality Symptom Questionnaire* (Ames et al., 2005), but they remain far less popular than the SSQ. The history of the SSQ might explain the wide dissemination of this questionnaire.

The SSQ was developed because symptoms experienced in a flight simulator are similar to sickness symptoms caused by traveling (“kinetosis or naupathia”), but have a tendency to be less severe, to have a lower incidence, and to be more associated to the visual system and the atypical interaction of the visual, vestibular and proprioceptive systems. Thus, certain symptoms of the *Motion Sickness Questionnaire* have never been reported by people who use simulators. Sixteen symptoms are listed and their severity is rated from “0” (none) to “3” (severe). It was conceived for immersions in various simulators, including those frequently used in virtual reality such as head mounted displays (HMD) and CAVE systems. The factor structure of the SSQ is based on Lane and Kennedy (1988) and Kennedy et al.’s (1993) study on a sample of 1 119 military participants who were immersed in a variety of Navy simulator training exercises. The researchers wanted to determine which symptoms demonstrated systematic changes before and after virtual immersion, thus the SSQ was administered before and after the immersions. After performing a principal factor analysis with varimax rotations and comparing factor solutions with three to six factors, a three-factor solution was identified: (a) the *oculomotor symptoms* (i.e., eyestrain, difficulty concentrating, etc.), (b) *disorientation* (i.e., dizziness, vertigo, etc.) and (c) *nausea* (i.e., nausea, burping, increased salivation, etc.). This factor structure of the SSQ has been widely

used since then (e.g., Kennedy et al., 2010; Lawson et al., 2002).

Two themes of discussions are emerging in the literature regarding side effects induced by immersions in virtual reality and their assessment with the SSQ: the factorial structure of the SSQ and the potential confound with anxiety symptoms

As Kennedy et al. (1993) noted, many items of the SSQ loaded significantly on more than one factor. Therefore, some items are scored on two different subscales and, following Kennedy et al.’s (1993) scoring procedure, are scored twice in the calculation of the total score. The items “general discomfort” and “difficulty concentrating” were assigned to both the nausea and oculomotor subscales, the items “difficulty focusing” and “blurred vision” were assigned to both the oculomotor and disorientation subscales, and “nausea” was assigned to both the nausea and the disorientation subscale. Given the slightly blurred factor structure of the SSQ, Bouchard et al. (2007) suggested that a two-factor solution was probably more adequate than the three-factor solution reported by Kennedy et al. (1993). The difference in factor structure may be due to differences in the type of simulations (i.e., flight simulators used to train pilots versus HMD used in the treatment of phobias), or the populations for which the SSQ was originally developed (i.e., physically fit military personnel versus general public).

Bruck and Watters (2011) also questioned the factor structure of the SSQ when used in a VR application with volunteers from the general population. With a sample of 28 participants, they performed a factor analysis using items of the SSQ plus the total score from an anxiety questionnaire and two physiological measures of anxiety (heart rate and respiration rate). They concluded that negative side effects of immersions in VR are spread into four latent components. They reported that the two measures of anxiety loaded on their “cybersickness” factor with

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several other items of the SSQ, and that respiration may be a latent structure underpinning the side effects.

The importance of overlap between symptoms of anxiety and side effects of immersion has been also noted by Bouchard et al. (2009). When using VR with clinical populations, or when inducing anxiety in VR in order to confront feared stimuli, symptoms such as sweating, discomfort or fatigue may be better explained by anxiety than by being immersed in a virtual environment. In order to clarify this question, it would be required to induce anxiety and assess its relationship with the intensity of the symptoms measured by the SSQ.

The current article reports on three studies exploring new dimensions in the assessment of negative side effects of VR immersions using the SSQ: (a) testing the adequacy of the proposed two-factor structure for the SSQ, and (b) documenting the potential confound of symptoms caused by anxiety.

### **STUDY 1**

#### ***Method***

Two research questions were addressed about the factors structure of the SSQ: (a) can the four-factor structure found by Bruck and Watters (2011) be replicated in a larger sample?, and (b) would a factor analysis confirm the adequacy of a two-factor solution? To this end, a French-Canadian translation of the 16-item SSQ was used. The entire translation process from English to French was carried out more than a decade ago by the team at the Cyberpsychology Lab of UQO in Gatineau, Québec (Canada). Five fully bilingual researchers who were actively working in the field of virtual reality systematically reviewed a preliminary translation. Their task consisted of indicating, for each item and the instructions, if they considered the translation “good”, “mediocre”, or

“bad”, taking into account the content, the meaning, the shape and the clarity of the statements. Following their recommendations, some minor modifications were carried out on a few items so that 100 % of the translations were considered “good”.

#### ***Participants***

The sample consisted of 517 adults (316 females) recruited in the general population either for research on anxiety disorders (n = 162 received a DSM-IV diagnosis based on a structured clinical interview) or for experiments with “normal controls” (n = 355 screened for the absence of anxiety disorders based on a structured clinical interview). The mean age was 33.93 (s.d. = 12.55, range from 18 to 68). Among the 162 anxious participants, the most frequent diagnosis was specific phobia, followed by social phobia, generalized anxiety disorder, panic disorder with agoraphobia, post-traumatic stress disorder and obsessive-compulsive disorder.

#### ***Procedures***

The participants completed the SSQ before and immediately after immersions in virtual reality (note that only post-immersion questionnaires were used in the current study). The participants were immersed in different virtual environments created for the treatment of phobias. One strength of this sample is that participants were immersed in virtual reality with different technologies (HMD, CAVE-like), had to perform different tasks (i.e., exposure to feared stimuli, exploration, attention) and were immersed for different durations (immersions lasted between 5 to 60 minutes). Such variety in procedures favors generalization of the results. The project was approved by the Research Ethics Board and participants had to remain in the waiting room 15 minutes after the immersion before leaving the laboratory. While in the waiting room, they received a handout describing what is “cybersickness” and contact information in the event they experienced

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after-effects or prolonged side effects after the study.

**Other measure**

*Structured Clinical Interview for DSM-IV* (First et al, 2000). This is a semi-structured interview used for screening every participant and diagnosing mental disorders according to DSM-IV criteria (APA, 2000).

**Results**

The Kaiser-Meyer-Olkin measure of sampling adequacy was .87, Bartlett’s test of sphericity was significant [ $\chi^2_{(120)} = 2584.36, p < .001$ ] and the ratio of participants per variable was 32 to 1, confirming the sample meets basic assumptions and criteria to perform a factor analysis. There was no missing data.

A four factor solution was tested with a principal component analysis (see Table 1 for results of the Varimax rotation) and, to be consistent with Bruck and Watters (2011), factors loadings as low as .30 were considered. The eigenvalue of the fourth factor was below 1 and the observed factor structure was not optimal, with many cross-loadings, some factors with few items, and some items would not load on any factor if more conservative thresholds (e.g.,  $> .40$ ) we considered. The items also load on different factors than the solution reported by Bruck and Watters (2011). To put to the test the 4-factor structure as proposed by Bruck and Watters (2011), a confirmatory factor analysis was performed using AMOS 16.0 (Arbuckle, 2007). Maximum likelihood estimation was used and modification indices as well as the following traditional indexes and their critical values were used, as suggested by Byrne (1994), Tabachnick and Fidell (1996) and Arbuckle (2007): CFI ( $>0.90$ ), PCFI ( $> .75$ ) and RMSEA ( $< 0.07$ ). Actually, three versions of the model were tested based on results from Bruck and Watters (2011), one with only the items that loaded above  $+ .40$  ( $\chi^2_{(97)} = 510.64, p < .001, GFI = .88, AIC = 588, BIC = 754$ ), one with all positive loadings and cross-loading above

$.30$  ( $\chi^2_{(90)} = 385.97, p < .001, GFI = .91, AIC = 477, BIC = 673$ ) and one with all loadings and cross-loadings above  $\pm .30$  ( $\chi^2_{(81)} = 344.13, p < .001, GFI = .92, AIC = 454, BIC = 687$ ). The statistical significance of the chi-square should not be a matter of concern given the known limitation of this index with large samples (Byrne, 1994; Tabachnick & Fidell, 1996), but all three models were deemed inadequate based on the modification and fit indices.

Table 1. Factor loadings for a tentative four-factor structure of the *SSQ*

Items	Factor 1	Factor 2	Factor 3	Factor 4
Item 1 - General discomfort	.34	.53		
Item 2 - Fatigue		.76		
Item 3 - Headache	.31	.65		
Item 4 - Eyestrain		.39	.66	
Item 5 - Difficulty focusing			.80	
Item 6 - Increased salivation				.79
Item 7 - Sweating	.37			.57
Item 8 - Nausea	.60			
Item 9 - Difficulty concentrating		.51	.31	
Item 10 - Fullness of head	.35	.61	.36	
Item 11 - Blurred vision			.84	
Item 12 - Dizzy (eyes open)	.73			
Item 13 - Dizzy (eyes closed)	.68			
Item 14 - Vertigo	.67			
Item 15 - Stomach awareness	.38	.36		.45
Item 16 - Burping	.30	.35		

Note. Principal component analysis with Varimax

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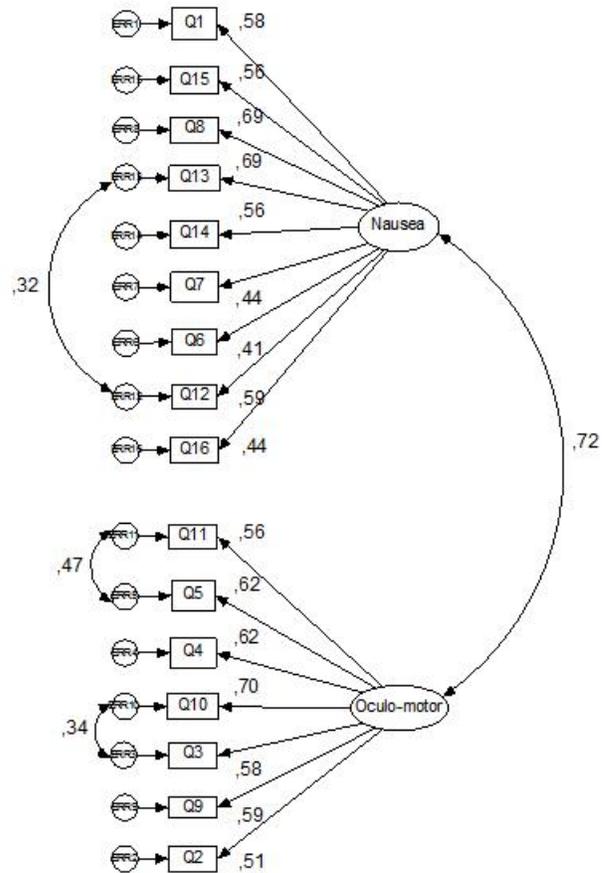
rotated solution. Loadings below .30 are not reported.

To test the adequacy of the two-factor model, a confirmatory factor analysis was performed. Based on Bouchard et al. (2007), the hypothesized model assumed a two-factor solution reflecting nausea and oculomotor factors. Items 1, 6, 7, 8, 12, 13, 14, 15 and 16 served as indicators of the Nausea factor and the remaining seven items served as indicators of the Oculomotor factors (Table 2). Maximum likelihood estimation was used. The final structural equation model is presented in Figure 1, where circles represent latent variable and rectangles represent measured variables (Q stands for Question #; ERR stands for error).

The plausibility of the two-factor solution was confirmed by the fit indexes respecting the critical values (CFI = .91, PCFI = .76, RMSEA = .065), the examination of the modification indices, the low value of the RMR (.017) and a strong percentage of variance explained (GFI = .93). The chi-square was significant ( $\chi^2_{(99)} = 316.34, p < .001$ ). A comparison between the two- and the original three-factor solutions confirmed that the two-factor solution was more parsimonious, based on the AIC (388 vs 565) and the BIC (541 vs 735) criteria. The AIC and BIC criteria also favors the two-factor solution over the four-factor solution tested above.

The total *SSQ* score (not weighted with Kennedy et al.'s formula) in the current sample was 4.32 (s.d. = 5.02, range between 0 and 42). The subscale scores were 1.81 (s.d. = 2.87) for the Nausea factor and 2.51 (s.d. = 2.83) for the Oculomotor factor. The Cronbach Alpha's for the entire scale was .86.

Fig.1. Confirmatory factor analysis of the *SSQ* with two factors.



**STUDY 2**

*Method*

In order to study the association between anxiety symptoms and symptoms measured with the *SSQ*, participants were subjected to an anxiety provoking task and the correlations between anxiety and *SSQ* items examined. Anxiety was elicited with a validated standardized stressful procedure that did not involve virtual reality at all.

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**Participants**

The sample consisted of 43 soldiers who participated in a study designed to test the impact of stressful immersions (Bouchard et al., In press). The mean age of the participants was 25.9 (SD = 5.2) and all were males. Participants were screened for the presence of schizophrenia, psychotic disorder or PTSD with the non-patient version of the *Structured Clinical Interview for DSM-IV* (First et al., 2000). None of the potential participant showed signs of these disorders.

**Procedures**

As in Study 1, the project was approved by a Research Ethics Board, participants provided their informed consent and the SSQ was administered both before and after the experimental procedure.

Participants were exposed to the Trier Stress Social Test (TSST; Kirschbaum et al., 1993). The TSST is essentially a social performance where participants are called in front of an interview panel and must give a speech on a topic outside their comfort zone. The three members of the interview panel are introduced as being especially trained to monitor non-verbal behavior and that a voice frequency analysis of non-verbal behaviors would be performed on the video recording. Panel members are instructed not to look empathetic to the presenter, to put pressure on his performance and to ask challenging questions.

**Other measure**

Post TSST, in addition to the French version of the SSQ, participants also completed the French version (Gauthier & Bouchard, 1993) of the state anxiety subscale from the State-Trait Anxiety Inventory (Spielberger, 1983). The State Anxiety scale of the *State-Trait Anxiety Inventory* consists of 20 items, each assessing how the participant feels right now on a scale from 1 to 4. After reverse scoring of the relevant items, all items are sum-up and a higher total score expresses more anxiety.

**Results**

Scores of the participants on State Anxiety scale increased significantly after performing the TSST [ $t_{(42)} = -6.52, p < .001$ ], from an average of 29.77 (s.d. = 6.82) to 38.14 (s.d. = 10.12), indicating that the procedure successfully induced anxiety. Post TSST, the number of symptoms assessed by the SSQ was low, with an average unweighted total score of 3.56 (s.d., 2.58). Four items of the SSQ were scored “0” by every participant and most items had extremely low scores. Therefore, the correlation with the State Anxiety scale was performed using Spearman’s correlation and no correlations were calculated for four items which had zero variance.

Table 2. Correlation of SSQ items with the State Anxiety scale.

Items	State anxiety after the TSST
Item 1 - General discomfort	.65***
Item 2 - Fatigue	.15
Item 3 - Headache	-
Item 4 - Eyestrain	.18
Item 5 - Difficulty focusing	.3*
Item 6 - Increased salivation	.35*
Item 7 - Sweating	.48**
Item 8 - Nausea	-
Item 9 - Difficulty concentrating	.41**
Item 10 - Fullness of head	.07
Item 11 - Blurred vision	.15
Item 12 - Dizzy (eyes open)	.20
Item 13 - Dizzy (eyes closed)	-
Item 14 - Vertigo	.24
Item 15 - Stomach awareness	-.05
Item 16 - Burping	-

Note. \*  $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$ . – is reported when no correlation could be computed due to lack of variance in SSQ items.

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Results are reported in Table 2 and revealed that eleven SSQ items did not correlate with anxiety. Only four symptoms were clearly not experienced by the participants after a stressful task that did not involve any VR. The five items that significantly correlated with anxiety were evenly distributed between the nausea (# 1, 6 and 7) and oculomotor (# 5 and 9) factors.

### STUDY 3

#### *Method*

Another approach to determine the overlap between anxiety and virtual reality induced side effects is to test if after an immersion items of the SSQ would load on a factor describing anxiety instead of loading on their own SSQ factor. This approach complements the analysis performed after the TSST and converging information would point toward SSQ items that may be biased by anxiety.

#### *Participants and procedures*

The sample consists of 72 adults (75% females) aged between 19 and 63 (Mean = 35.96, sd = 12.16) recruited from the general community. As in Study 2, the project was approved by a Research Ethics Board, participants provided their informed consent and the SSQ and the State Anxiety scale were administered both pre and post-immersion.

#### *Results*

The reasoning behind the statistical analysis was that items of the State Anxiety scale and the SSQ should be orthogonal and load on two distinct factors. Items of the SSQ significantly loading on the anxiety factor would show that these symptoms were biased by anxiety. The Kaiser-Meyer-Olkin measure of sampling adequacy was .73, Bartlett's test of

sphericity was significant [ $\chi^2_{(630)} = 1895.04, p < .001$ ], suggesting that it was appropriate to conduct a factor analysis on this dataset. The ratio of participants per variable was low (2 participant per variable), which lead to the decision to be conservative and consider only loadings higher than .50 as significant. The mean of the State Anxiety scale post-immersion was 31.73 (sd = 10.08) and the mean SSQ non weighted score was 2.69 (sd = 3.3). The correlation between the State Anxiety scale and the total score of the SSQ was significant ( $r = .46, p < .001$ ), as well as for the nausea ( $r = .37, p < .01$ ) and the oculomotor ( $r = .41, p < .001$ ) factors. Note that tentatively removing some items from the SSQ to perform again these correlations slightly reduced the coefficients but they remained significant.

The principal component factor analysis was followed by a Varimax rotation of all items of the State Anxiety scale and the SSQ. The number of factors to extract was forced to two, with the expectation that items of each questionnaire would load on their respective factors, with minimal cross loadings. The eigenvalue of the second factor was 4.1, followed by several other potential factors with eigenvalues higher than one and accounting for a significant portion of unique variance. This information suggested that more elaborated factor structures could be examined, if the goal was to find the best solution describing the complex latent structures and the sample size was larger.

Examination of the rotated loading matrix revealed that only two items of the SSQ loaded above .40 on the State Anxiety factor: items #1 – General discomfort (cross loading = .55) and item #9 – Difficulty concentrating (cross loading = .54). These loadings were stronger on the anxiety factor than on the SSQ factor and were evenly distributed between the nausea and oculomotor factor reported in Study 1.

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### CONCLUSIONS

Immersion in virtual reality can lead to unwanted side effects and, as the application of this technology grows, the need to monitor their symptoms is significant. The most popular self-administered tool to assess virtual reality induced side effects is the SSQ (Kennedy et al., 1993). This tool has a very strong track record and is practical for professionals using VR for mental health applications, among others. However, using the SSQ with immersion in VR, as opposed to flight simulators, and with users from the general population has raised a few questions in the recent years. Two of them are whether the symptoms measured by the SSQ measure two latent dimensions (a nausea and an oculomotor factor; Bouchard et al., 2007) or additional dimensions such as disorientation (Kennedy et al., 1993), or vision, fatigue, arousal and general “cybersickness” (Bruck & Watters, 2011). Also, applications in the treatment of anxiety disorders raised the concern that symptoms measured by the SSQ may be contaminated by anxiety induced by the immersion. If it was the case, some of the unwanted side effects of the immersion should not be considered as a limitation of VR but as a normal consequence of therapeutic *in virtuo* exposure (Bouchard et al., 2006).

Results of exploratory and confirmatory factor analyses clearly revealed that, with our sample, the SSQ essentially measures two latent dimensions, nausea symptoms and oculomotor symptoms. What are the implications of this finding? First, it has practical implications for scoring the SSQ. According to Kennedy et al. (1993), the total score is calculated after adding the score of the items from each factor, summing the total of the three factors, and multiplying the result by a constant. Since five items (#1, 5, 8, 9, 11) load on more than one factor, these items have twice the weight on the total score than the others. Dropping the Disorientation subscale would

further complicate the situation if researchers and clinicians want to remain consistent with the traditional weighting procedure. As mentioned in Bouchard et al. (2007, 2009), most researchers do not report if they followed or not Kennedy et al.’s (1993) procedure to calculate the total score of the SSQ and we urge researchers to state which method they followed. Based on our findings, the raw (not weighted to obtain a standard deviation of 15) total score should be simply obtained by calculating the sum of each item (only once per item).

A second implication of our findings relates to the construct of disorientation. The items pertaining to that subscale are not dropped from the SSQ, preserving the integrity of the scale and the availability of the information about these symptoms. Also, the four items from that subscale that were not affected by cross-loadings load significantly and meaningfully on the oculomotor (fullness of head) and the nausea (dizziness with eyes open, with eyes closed, vertigo) subscales. The difference in factor structure between the original model proposed by Kennedy et al. (1993) and the present one may be explained by differences in applications and populations. The SSQ was meant to be used with training simulators with a population of physically fit military personnel, not for immersion in virtual reality with users from the general population. As pointed-out by Lawson et al. (2002), military personnel may be less likely to experience negative side effects since they are more likely to be frequently involved in challenging vehicle motion, in better physical shape or able to remain immersed in virtual reality longer despite feeling unwanted effects. Stanney et al. (1997) also suggested that negative side effects differ between immersion in VR and in training simulators. For example, differences in disorientation induced by flight simulators and by exploring a virtual street may have more to do with the tasks performed during the immersion and actual movements of the simulator than the immersion itself. The design of the virtual environment and the task

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performed are known to have an impact on the induction of unwanted negative side effects (Lawson et al., 2002, Sharples et al., 2008) and thus the total score of the SSQ. The importance of vertigo and dizziness, which are highlighted when a disorientation subscale is calculated, may disappear because we are comparing extremely different types of immersions. Three types of factors are prone to having an impact on the intensity of cybersickness felt by virtually immersed people (Stanney et al., 1998): 1) the *user characteristics* (i.e., age, gender, health condition, experience with virtual reality, degree of concentration, etc.); 2) the *system characteristics* (i.e., brightness and spatial resolution of the screen, weight of the HMD, temporal delay between the head movements and the corresponding image, etc.); 3) and the *task characteristics* (i.e., degree of control and speed of the movements, quality of visual field, length of immersion, etc.). Tasks characteristics may have an importance on the presence, or disappearance, of a latent disorientation factor. Replication of our findings with different populations and direct comparison between simulators and VR applications for mental health is therefore warranted before reaching a final conclusion about the disorientation subscale.

Our results do not support the four-factor model suggested by Bruck and Watters (2011), in part because of important differences in sample size and their addition of measures of anxiety in their analysis. However, the very strong contribution of anxiety and heart rate to their factor structure raised the interesting issue of the overlap between symptoms of anxiety and unwanted side effects specific to the immersion in VR. Results from two studies described in the current article confirm the strong correlation between scores on the SSQ and anxiety, but most importantly they show a significant association between anxiety and some symptoms associated with immersions in VR. In one manipulation, a significant association was found despite that symptoms were not induced by an immersion in VR. Only four symptoms were not

present post TSST: nausea, dizziness when eyes are closed, headache and burping. If one wants items devoid of anxiety, these four items are the most likely candidate. The following study benefited from a larger sample size and confirmed that at least the assessment of general discomfort and difficulties concentrating may be significantly blurred by anxiety.

Findings about the overlap with some symptoms of anxiety must raise awareness of experimenters, clinicians and users that some post-immersion symptoms should not automatically be attributed to unwanted negative side effects of virtual reality. This could become a matter of great importance if therapeutic interventions using VR are burgeoning and regulatory boards become sensitive to reporting side effects and adverse events, which is common practice in randomized control trials for pharmacological agents. In the meantime, a more definitive answer on the overlap between anxiety and “cybersickness” requires reproducing both Study 2 and Study 3 with larger samples (at least with a ratio of 10 participants per variable) and with a much stronger induction of anxiety in order to maximize the variance on each item.

To guide professionals using virtual reality in mental health applications, a few basic precautions can be proposed in order to reduce the intensity of unwanted side effects during a virtual therapy session (for a more detailed usage protocol, see Stanney et al., 2002). First, unwanted side effect should be systematically monitored before, during and after the immersion. Second, potential users should be educated and prepared prior to the immersion about the possibility of some side effects. If the user experiences important sickness associated with adaptation to the virtual environment, the session should be terminated. The professional should consider including pauses after 20 to 30 minutes of immersion in order to reduce eyestrain, and people suffering from serious medical conditions (i.e., epilepsy, balance disorders) may refrain from being

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immersed in VR. Finally, it is recommended that users do not leave immediately after an immersion and remain on site for a while to make sure there are no important post-immersion symptoms that would preclude driving, including troubled vision or problems with postural equilibrium.

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