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Defining Spatial Anxiety – A Concept of State Rather Than Trait Anxiety

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Abstract

Performing spatial tasks, such as navigating through a city, often bring along feelings of intense stress. This spatial anxiety has been the subject of many studies over the past few decades, but has not been investigated in detail and remains a rather abstract concept. This study aims to explore the relation between general state/trait anxiety and specific spatial anxiety, in hopes of defining the concept more clearly. A total of 53 participants completed measures of trait-, state-, and spatial anxiety, as well as two spatial ability assessments: the self-report Wayfinding Questionnaire and an extensive objective measure, which includes 9 navigation tasks based on the previously learned Virtual Tübingen route. Contrary to previous literature, no relation between participants' spatial ability and their spatial anxiety was found. Results suggest that the effect of trait anxiety on spatial anxiety is moderated by state anxiety: individuals experience higher anxiety surrounding spatial navigation when they tend to appraise situations/stimuli as negatively demanding or harmful (state), but independent of their general predisposition to appraise many situations/stimuli as threatening (trait). Spatial anxiety was found to be more closely related to state- than trait anxiety, suggesting that it is a temporary negative emotional response that is only induced by the situational factors of navigation, and can thereby be classified with performance anxieties such as math anxiety.

Defining Spatial Anxiety – A Concept of State Rather Than Trait Anxiety

In order to successfully complete daily tasks, such as commuting to work or running errands, humans must acquire a spatial sense of their environment. Being able to find the way from one destination to another is a necessity for mobility and independence. This spatial ability is defined as "the ability to generate, retain, retrieve, and transform structured visual images" (Ramirez, Gunderson, Levine, & Beilock, 2012). While such navigation may often seem effortless on a behavioral level, it is a complex cognitive ability that varies widely between individuals (Hegarty et al., 2002; Lawton, 1996). Interestingly, performing spatial tasks, such as deciding where to go when exiting a bus, often bring along feelings of intense stress (Chang, 2013; Gabriel, Hong, Chandra, Lonborg, & Barkley, 2011; Phillips, Walford, Hockey, Foreman, & Lewis, 2013). This spatial anxiety (SA) has been defined as "anxiety experienced when navigating on one's own" (Van der Ham, Kant, Postma, & Visser-Meily, 2013), such as the anxiety of taking an unknown shortcut.

While SA has been the subject of many clinical and non-clinical studies over the past few decades (Claessen et al., 2017; Gabriel et al., 2011; Lawton, 1996), it has generally been discussed as a possible explanation of group differences (e.g. gender differences in spatial ability; Lawton, 1994), but has not been investigated in detail regarding its relation to other types of anxiety. This research aims to explore the relationship between SA and aspects of general anxiety on navigation performance in a virtual environment (VE) task.

Spatial Anxiety & Ability

Spatial ability has been studied using various methodologies, such as by having participants navigate through a virtual environment and testing their memory of the order of depicted landmarks (Van der Ham, de Zeeuw, & Braspenning, 2017). Other studies have focused on wayfinding strategies, including the use of global reference points rather than route information (Lawton & Kallai, 2002), or the effects of acute stress (e.g. physiological stress induced by cold-water hand immersion) on one's spatial abilities (Gabriel et al., 2011).

A differentiation can be made between direct measures of spatial ability and self-reported measures: While both types of assessments show significant overlap (De Rooij et al., 2017), self-report measures tend to reflect one's subjective evaluation of spatial abilities, which previous studies have found to be misleading for certain populations. For example, de Rooij and colleagues (2017) concluded that older individuals tend to overestimate their spatial abilities, reporting that their performance just as favorably as younger individuals. It is therefore important to weigh self-reported spatial ability measures in comparison with direct measures for an accurate assessment of performance and self-evaluation.

Many studies have found a relationship between navigation task performance and reported levels of anxiety (Gabriel et al., 2011; Hund & Minarik, 2006; Nowak, Murali, & Driscoll, 2015; Sari, 2016; Schoenfeld, Foreman, & Leplow, 2014). Anxiety has been found to be negatively correlated with navigation performance (Pazzaglia, Meneghetti, & Ronconi, 2018), whereby those who score higher on measures of anxiety make significantly more errors than individuals with lower levels of anxiety (Walkowiak, Foulsham, & Eardley, 2015). However, these correlational findings lack analysis of causality. It has been speculated that a third variable may influence this relationship (Hund & Minarik, 2006), such as trait or state anxiety (Walkowiak et al., 2015).

Related Constructs: Trait & State Anxiety

Anxiety is broadly categorized into state and trait anxiety: state anxiety (A-state) is a negative emotional response as a result of negatively demanding or harmful situations or stimuli, while trait anxiety (A-trait) refers to individual differences, a general predisposition to appraise many situations/stimuli as threatening (Hodges & Spielberger, 1969; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). A negative relationship has been found between both anxiety types and cognitive task performance (Ng & Lee, 2015), whereby as A-trait and A-state levels increase, cognitive task performance decreases. This mechanism is widely studied (Eysenck, Derakshan, Santos, & Calvo, 2007; Ng & Lee, 2015; Walkenhorst & Crowe, 2009) and identified in the Processing Efficiency Theory by Eysenck and colleagues (2007): Anxiety drains working memory capacity through additional cognitive tasks, including worry, threat detection and monitoring, among other responses caused by the fight or flight response. By allocating mental resources towards the anxiety, a smaller functional capacity is left for the cognitive task at hand, leading to a decrease in performance.

This mechanism has been studied for many higher-order cognitive processes, such as those underpinning math ability, where statistics performance is negatively impacted by anxiety (Macher et al., 2013). Moreover, Macher and colleagues (2013) found A-trait to be a strong predictor of statistics anxiety, meaning that one’s general proneness to experience anxiety acts as a predisposition to highly situation-specific anxieties, such as statistics anxiety. They also found that statistics anxiety is directly positively related to A-state, entailing that while a part of the variance of statistics anxiety is explained by a general proneness to anxiety (A-trait), the effect of A-trait on A-state is mediated by statistics anxiety (Macher et al., 2013). Similar relationships between anxiety and spatial performance are to be expected, considering that spatial tasks require similar cognitive functions such as episodic memory, executive functioning, and mental working speed (De Rooij et al., 2017). Similarities between mathematical anxiety and spatial anxiety have been mentioned previously, such as a negative relationship between sense-of-direction and math-, and spatial anxiety (Ferguson, Maloney, Fugelsang, & Risko, 2015).

Though the relationship between both A-state and A-trait with the cognitive process of spatial navigation have been demonstrated (Ferguson et al., 2015) it is unclear as to which type of anxiety is more closely related to SA. Furthermore, findings that include specific SA remain puzzling: While previous research tends to agree that SA is related to "general anxiety," the type and conceptual status of it is often ambiguous. The failure in most investigations of SA to distinguish between A-state and A-trait has made the literature in this area difficult to interpret. Drawing on the similarities between mathematical ability and spatial ability mentioned above, the findings on statistical anxiety could be applied to SA: A-state may be induced through exposure to a SA-invoking situation, such as going to an appointment in an unfamiliar area. However, the navigational challenges would be more likely to be appraised as being threatening in those who were more predisposed to state anxiety. Therefore, it could be hypothesized that some of the variance of SA can be explained by a general anxiety proneness (A-trait), but that SA has a unique contribution to A-state.

Feeling of Presence in Virtual Environments

A feeling of ‘presence’ in virtual environments (VE) was found to have a significant impact on the validity of human-technology interaction research (Kronqvist, Jokinen, & Rousi, 2016). Presence is defined as “a perceptual illusion of non-mediation” (Lessiter, Freeman, & Davidoff, 2001), implying that one incorrectly perceives the VE to be unmediated and authentic. Increased feelings of presence are thought of as the key feature for effective VE applications, especially those designed for measures of cognitive performance, as it plays a causal role in human information processing (Tussyadiah, Wang, Jung, & Dieck, 2018). The level of perceived authenticity of a VE can be measured by the level of immersion and presence one experiences during the VE interaction (Kronqvist et al., 2016), and has been found to improve one’s performance on VE tasks (Witmer & Singer, 1998). Additionally, significant correlations between self-reported presence and anxiety during VE exposure have been reported (Ling, Nefs, Morina, Heynderickx, & Brinkman, 2014; Malbos, Rapee, & Kavakli, 2013).

Current Research

Clearly, there is a need to investigate the relationship between SA and both A-state and A-trait (as also mentioned by e.g. Thorensen et al., 2016; Walkowiak et al., 2015). Therefore, the aim of this study is to explore the relation between general A-trait/-state and specific SA, in hopes of defining the concept of SA more clearly.

First, we hypothesized that individuals who are worse at navigating show higher SA than those who are better at navigating (hypothesis 1). Second, by recording general A-trait and A-state and SA in one study, the extent of autonomy and overlap of the contributions of general anxiety proneness and situational specific SA can be quantified, to explore whether SA is a concept of A-state or A-trait (hypothesis 2). Two possible alternative outcomes were explored: If SA was found to be more closely related to A-state than A-trait, it can be assumed that SA is a type of anxiety that is only induced by the situational factors of navigation. On the other hand, SA could be conceptualized as a general predisposition, if it was found to be more closely related to A-trait. However, if SA was the only type of anxiety that correlates with spatial performance, it could be suggested that spatial performance elicits a specific form of anxiety, one that is not subsumed under either A-state or A-trait.

Methods

Participants

58 participants were recruited on a voluntary basis, in exchange for course credits (3 ECTS). The recruitment was done through flyers, email, and the program “SONA Systems”, which is an experiment system accessible by students from the Social Sciences Faculty at Leiden University. Informed consent was obtained from all participants before completing the battery of online questionnaire and prior to the laboratory testing. Those who did not complete both parts of the study (five participants; 8.6%) were excluded from analysis. A total of 53 participants (M*age* = 21.32 years, *SD* = 3.53), comprised the final sample for the analyses, including 28 females (52.8%; M*age*=20.82 years, *SD*=3.53) and 25 males (47.2%; M*age*=21.88 years, *SD*=3.52).

Inclusion Criteria

Since the language used throughout the study was English, and the VE was presented on a computer screen, the inclusion criteria entailed fluency in English and no visual impairments (unless corrected for, e.g. by contact lenses). Additionally, the virtual environment had to be novel, therefore participants who have visited the German city Tübingen were also excluded from the study. Participants also had to be between ages 18 and 30, since navigation ability is shown to be vulnerable to the aging process (Moffat, 2009) and lastly, no diagnosed neurological or psychiatric condition could have been present at time of participation to ensure a homogenous sample.

Materials & Measuring Instruments

Navigation ability. Participants' navigation ability was measured by use of the English version of the 22 item self-report Wayfinding Questionnaire (Claessen, Visser-Meily, de Rooij, Postma, & Van der Ham, 2016; De Rooij et al., 2017) and through the Virtual Tübingen test, based on the study by Van der Ham and colleagues (2010). While the Wayfinding Questionnaire is mainly used in clinical settings to establish whether assessment of navigation ability is advisable (navigation complaints), the Virtual Tübingen test is a more extensive overview of an individual's strengths and weaknesses within navigation ability (De Rooij et al., 2017).

The *Wayfinding Questionnaire* (*WQ*; Claessen et al., 2016; De Rooij et al., 2017) measures self-reported navigation-related abilities through three subscales: 'navigation and orientation', (NO; ten items), 'distance estimation' (DE; four items), and 'spatial anxiety' (SA; eight items). 19 items are rated on a scale from 1 (*not at all applicable to me*) to 7 (*fully applicable to me*), with sample items including: "In an unknown city I can easily see where I need to go when I read a map on an information board." and "I can usually recall a new route after I have walked it once." Three items are also scored from 1-7, but their options range from "*not uncomfortable at all*" to "*very uncomfortable*", for example "How uncomfortable are you in the following situation: Deciding where to go when you are just exiting a train, bus, or subway station.". The NO and DE scales represent the cognitive aspects of "navigation ability", and are therefore combined into one mean score (resulting in an overall score between 1 and 7), while the subscale SA was investigated separately as a measure of spatial anxiety specifically (see below). In this study, therefore, WQ data refers to the cognitive subscales only, while the SA subscale is investigated separately. Reliability of all three WQ subscales are found to be very high (Cronbach's $\alpha = .95$ for NO; Cronbach's $\alpha = .83$ for DE; Cronbach's $\alpha = .92$ for SA), and they show high internal validity and consistency (Claessen et al., 2016). Z-scores were calculated by use of a large sample of 1147 healthy adults between 18 and 30 (van der Ham et al., in preparation) as a reference group for the interpretation of the scores per scale.

The *Virtual Tübingen (VT) test* is an extensive navigation test developed by Van der Ham and colleagues (2010) to measure human navigation behavior. The VT includes a learning phase, in which a photorealistic route through the center of the German town Tübingen is explored in first person perspective, and a test phase consisting of nine tasks that assess navigation ability. For this study, the instructions on each of the nine tasks were translated to English (from the original Dutch version). Two different routes were used and counter-balanced across participants to ensure generality across settings and counteract a narrow stimulus sampling threat to external and construct validity (Kazdin, 2016). The routes were similar in duration (approximately 4.5 minutes), distance (equivalent to about 400m) and speed (slightly faster than walking speed) to guarantee comparability, as recently employed by Claessen and colleagues (2017). During the learning phase, the participant watched a video of the route twice and was instructed to remember as much as possible without being informed of the types of tasks that will follow. The tasks were administered using E-Prime Version 2.0 (Psychology Software Tools, Pittsburgh, PA).

The latest update of the VT test was used. In the first task, "*Landmark Recognition*", the participant was shown a screenshot and was instructed to indicate whether they had encountered it on the previously shown route or not. The task included 16 trials and answers were scored as 1 (correct) or 0 (incorrect), resulting in a total score ranging from 0 to 16. The cut-off for healthy populations lies at 12, whereby a score below 12 indicated impairment.

In the second task, the participant was asked to indicate whether the route continued straight ahead, right or left at each of the eight intersections (*"Route Sequence"*). The answer was recorded as 1 (correct) or 0 (incorrect) for each intersection, meaning that the overall score ranged from 0 to 8, with a score below two indicating impairment.

Figure 2a. Visual presentation of the Virtual Tübingen task 3 "Route Continuation".

Third, a screenshot of the previously learned route was presented, and the participant indicated which direction the route continued – straight ahead, left or right (*"Route Continuation"*). In a similar manner to the second task, eight trials were completed, resulting in a total score between 0 and 8. A score below 4 was the cutoff for healthy populations (Figure 2a).

Fourth, the task *"Route Order"* entailed indicating which order eight screenshots were presented in the video. A maximum score of three could be obtained for each screenshot: Three points were awarded if the screenshot was assigned to its correct position in the sequence; two points if it was assigned one position too late or too early; one point if it was two positions away from correct placement; zero points if it was placed more than two positions away from the correct placement. Scores on all eight trials were added up to an overall score of 0 to 24, with a score below 11 indicating impairment in this domain.

In the fifth task, the participant was shown a screenshot and asked to point towards the start of the route with a 360-degree rotatable arrow (*"Point to Start"*). For each of the eight trials, a deviation score between 0 and 180 was calculated. The deviation of all trials was averaged per subject, resulting in a final score ranging from 0 to 180, with a score of <77 indicating impairment in healthy populations.

Figure 2b. Visual presentation of the Virtual Tübingen task 6 "Distance Estimation".

Sixth, a screenshot was shown at the top of the screen, and the task was to indicate which of the two other screenshots shown in the lower half of the screen lay closer to the first one (Figure 2b) as the crow flies (*"Distance Estimation"*). The response options included yellow (for the screenshot with a yellow border) and blue (for the screenshot with a blue border). Answers were recorded as 1 (correct) or 0 (incorrect) for each of the eight trials. An overall score between 0 and 8 can be obtained, with any score below three indicating impairment.

The seventh task, *"Direction Estimation"*, presented three screenshots from the route placed across the screen, and participants were instructed to indicate whether these three points lay in the correct relative location to each other. The task includes 8 trials and response options are limited to "yes" and "no". Answers are scored as 1 (correct) or 0 (incorrect), resulting in a total score ranging from 0 to 8. The cutoff for healthy populations lies at three, with a score below three indicating impairment (Figure 2c).

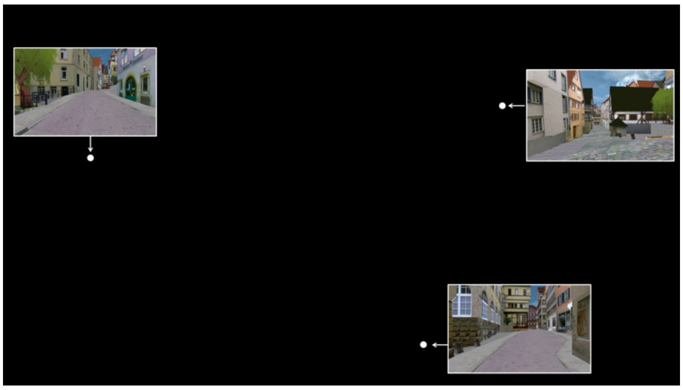

Figure 2c. Visual presentation of the Virtual Tübingen task 7 "Direction Estimation".

Eighth, four different routes were drawn on a map and the task was to indicate which route corresponded to the route previously seen in the learning phase (*"Map Recognition"*). This task was only done once, with four response options (each of the four routes shown), resulting in a score of 1 (correct) or 0 (incorrect). A score of 0 indicated impairment in healthy populations.

Lastly, the participant was shown a map with a marker indicating the start- and end-points of the route previously seen in the learning phase, and a screenshot from said route. The task was to point out where on the map the screenshot was taken (*"Locations Map"*). A deviation score was calculated by means of the Pythagorean Theorem on the basis of a Cartesian coordinate system: The distance d between the indicated point (x_1, y_1) and the point of the correct answer (x_2, y_2) was calculated through the formula: $d = \sqrt{((x_1-x_2) + (y_1-y_2))}$, with points being scored in pixels. This task includes eight trials, and the distance deviation of all eight trials was averaged to compute a final score (Figure 2d).

Figure 2d. Visual presentation of the Virtual Tübingen task 9 "Locations Map".

Trials within each task were counterbalanced, however, the nine tasks themselves were always completed in the same order to ensure that an earlier task did not provide information that would be useful for a later task. Each of the nine total scores were converted into a z-score based on the current sample (see table 1 for Means and SD for each task). All nine z-scores were combined to an overall indication of spatial performance in the form of a mean z-score. The VT task has previously shown high convergent validity as an alternative to real-world navigation measures (Claessen et al., 2016).

Spatial anxiety. The concept of SA was instrumentalized through two self-report measures. The *Spatial Anxiety Scale (SAS)* by Lawton (1994) measures the level of self-reported anxiety experienced while engaged in common navigation tasks. All eight items were rated on a 5-point scale from 1 (*not at all anxious*) to 5 (*very much anxious*). Sample items include: "Leaving a store that you have been to for the first time and deciding which way to turn to get to a destination" and "Finding your way back to a familiar area after realizing you have made a wrong turn and become lost while driving". An overall sum score was calculated, ranging from 8 to 40, whereby higher scores indicated greater anxiety in navigation situations. The SAS items have been found to possess relatively high internal consistency (Cronbach's α = .80; Lawton, 1994).

The subscale *'spatial anxiety'* from the above mentioned WQ (*WQSA*; Van der Ham et al., 2013) acted as a second measure of self-reported SA. The 8-item subscale includes items such as "I am afraid to get lost in an unknown city", which are measured on a 1 (*not at all applicable to me*) to 7 (*fully applicable to me*) scale. Mean scores were calculated, resulting in an overall score between 1 and 7. For this mean of the subscale, none of the items were reversed, so that higher scores reflected greater self-reported navigation anxiety. Z-scores were calculated based on the same large sample as used for the WQ z-scores.

Trait- and State Anxiety. The commonly used self-report *Trait-State Anxiety Inventory* (*STAI*; Spielberger et al., 1983) was administered to measure participants' current symptoms of anxiety (state) and generalized propensity towards anxiousness (trait). Form Y was used, which includes 20 items measuring state anxiety (STAI-S) by asking how the participant feels 'right now' (e.g. "I am worried"). The remaining 20 items measure trait anxiety (STAI-T) by asking how anxious the participant generally feels (e.g. "I feel inadequate"). All 40 items are rated on a 4-point scale from 1 (*almost never*) to 4 (*almost always),* with the subscales being administered separately. After reversing all anxiety-absent items (ten in STAI-S, nine in STAI-T), total sum scores were calculated, which varied between 20 and 80 for both subscales, with higher scores indicating greater anxiety. On the STAI-S, a normative sample of college students had a mean score of 36.47 (*SD*=10.02; Cronbach's α = .91) for males and a mean score of 38.76 (*SD*=11.95; Cronbach's α = .93) for females (Spielberger et al., 1983). Their score on the STAI-T was 38.30 (*SD*=10.02; Cronbach's α = .90) for males and 40.40 (*SD*=10.15; Cronbach's α = .91) for females (Spielberger et al., 1983). The STAI has been extensively used in psychological research to investigate effects of anxiety on other concepts, such as social anxiety (Bourne & Vladeanu, 2011) and working memory (Walkenhorst & Crowe, 2009).

Presence. As mentioned, the participant's level of perceived authenticity of the VE can have a statistically significant effect on whether anxiety is elicited (Ling et al., 2014; Malbos et al., 2013). An adapted version of the widely used *Presence Questionnaire* (*PQ*; Witmer & Singer, 1998) was administered to measure intensity of feelings of presence in the VE (Cronbach's α = .91). The original PQ contains 29 items, which is considered too long and detailed to be administered between the learning and the testing phase of the VT test: longer questionnaires it could induce fatigue in participants and also impede their memory of the route (Kronqvist et al., 2016). Therefore, the adapted version by Kronqvist (2016) was used, which operationalizes presence in two subscales of 'immersion' and 'feeling of control'. Previous studies measured presence in a variety of different ways, depending on the VE used (e.g. presence as authenticity, presence as involvement, etc.; Tussyadiah et al., 2018). Since in this study participants did not navigate through the VE autonomously, the second subscale of 'feeling in control' (e.g. "I could control what happened in the environment") was found to be irrelevant to this study and only the subscale 'immersion' was administered. All four items (e.g. "the visual elements of the environment felt natural") were rated on a scale of 1 (*very much disagree*) to 5 (*very much agree*), and answers were averaged into an overall mean score ranging from 1 and 5, whereby higher scores indicated a greater immersion into the VE. The PQ has shown sufficient reliability (with Cronbach's α = .78; Kronqvist et al., 2016), as well as high content and construct validity (Witmer & Singer, 1998).

Design

The within-subjects experimental design included an online self-report questionnaire battery as well as laboratory assessment, during which spatial ability in a virtual environment (VE) was measured.

Procedure

Online questionnaire battery. After signing-up for the study, participants were contacted via email and asked to complete a questionnaire battery, lasting approximately 10 minutes, at least one day before the scheduled laboratory session. The battery was administered through the online survey research platform Qualtrics Software (2018 Version; Qualtrics, Provo, UT), and included an informed consent form, the SAS, STAI-S and STAI-T and questions regarding demographic data. In order to link both phases, participants received a three-digit code to be entered during both assessments. A reminder e-mail was sent out approximately 30 hours before the scheduled laboratory session to ensure that the participants completed the online questionnaire battery on time. The interval of at least one day between the online questionnaire battery and the lab assessment was chosen to control for a possible pretest sensitization effect (Kazdin, 2016).

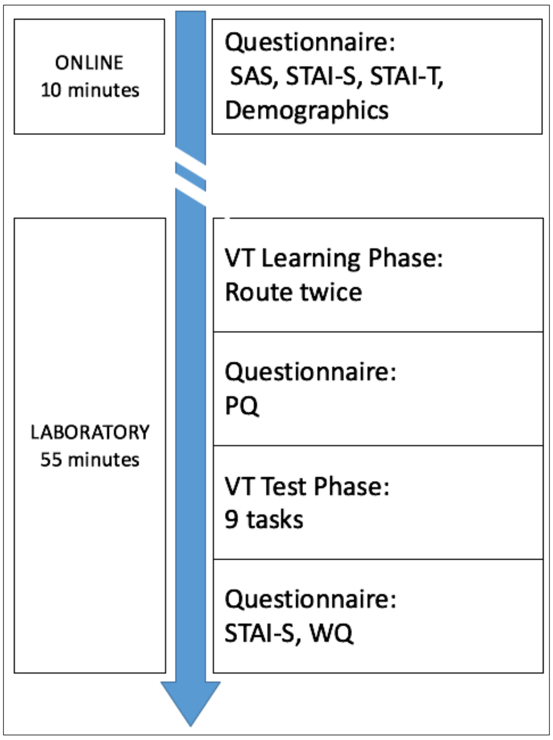

Figure 3. Procedure timeline.

Laboratory assessment. During the laboratory session, the participant was first asked to sign the informed consent form. The VT test was presented on a 75.4cm computer screen. The participant was instructed to watch the video of the route twice and asked to remember the route to the best of their ability (learning phase). Following the VT learning phase, the PQ was administered and the VT test phase commenced. Each task was explained with standardized verbal and on-screen instructions. Once all tasks were completed, the participant immediately completed the STAI-S (post-test) to ensure that the measure was assessing state anxiety induced by VT test. The question items were presented in a different order than during the first assessment (random order) to diminish noise due to the effects of repeated testing. No breaks were allowed during this phase to ensure similar time spans between learning the virtual route, completing the testing, and reporting feelings of state anxiety. Lastly, the WQ was administered and once completed, the participant obtained the compensatory course credit. This second phase of the study took approximately 55 minutes, resulting in an overall duration of 65 minutes per participant (see figure 3). Variability in the procedures was minimized through strict protocol, which decreased variations in how all facets of the study were implemented among participants, thereby diminishing a threat to data evaluation validity (Kazdin, 2016).

Planned Statistical Analyses

All data was analyzed using the IBM predictive analytics software Statistical Package for the Social Sciences (SPSS) Version 21. An alpha of .05 was employed as criteria for significance, and transformations were made if necessary. The normality and reliability of all measures were tested prior to analyses. Outliers were removed if necessary.

Supporting analyses. To ensure the current study's VE elicited a feeling of presence, the frequency distribution of PQ scores was visually inspected. To test the assumption that the VT test elicited state anxiety, the pre- and post-test STAI-S scores were investigated by means of a paired samples t-test. Additionally, the two measures of spatial ability, VT (direct) and WQ (self-report), were correlated (Pearson) with the three anxiety measures of SA, A-state and A-trait.

Main analyses. By use of simple linear regression, the relation between SA and spatial ability (hypotheses 1) was tested, with SA as the dependent variable and spatial ability as the independent variable. To test the relations of A-trait and A-state to SA (hypothesis 2), the unique contributions of A-trait and A-state (independent variables) in the explanation of SA (dependent variable) were examined using a multiple hierarchical regression analysis, while controlling for spatial ability. Assumptions of normality, linearity, homoscedasticity and outliers were tested beforehand and post hoc analyses were performed where applicable.

Results

Mean performance scores of all 53 participants are provided in table 1, including standard deviation (*SD*) and Range. All variables were inspected for outliers by use of boxplots. Only SAS and VT showed one value each which was greater than 3 SD from the mean and therefore classified as an outlier. The VT outlier was due to missing data on the task "*Route Sequence*" and was excluded from only those analyses involving the specific task. By inspection of the Kolmogorov-Smirnov goodness of fit test for all variables, it was found that only the PQ ($D(53) = .15$ and $p = .005$) and STAI-S pre-test ($D(53) = .15$, $p = .003$) did not exhibit normality. Since an adapted version of the PQ was used, the scores were also inspected for reliability, which was found to be low, with Cronbach's $\alpha = .39$. Since the WQSA scores exhibited to be normally distributed (Kolmogorov-Smirnov $D(53) = .92$, $p = .200$), contained no outliers, and were more reliable (Cronbach's α = .88) than the SAS ($D(53) = .18$, $p < .001$; Cronbach's α = .82), the WQSA was used in the further analyses as the measure of SA.

Table 1. *Performance of all participants on the questionnaire and experimental measures.*

Questionnaire/Measure	Mean	SD	Minimum	Maximum
STAI-S (pre)	35.62	11.56	21.00	70.00
STAI-S (post)	35.26	9.58	20.00	54.00
STAI-T	38.34	10.10	22.00	64.00
PQ	3.31	.79	1.00	4.50
SAS	14.23	4.56	8.00	29.00
WQ (NO & DE)[a]	.03	.70	-1.63	1.21
WQSA[a]	-.02	.72	-1.25	1.47
VT				
Landmark Recognition	14.23	1.489	10	16
Route Sequence	5.29	2.099	1	8
Route Continuation	6.98	1.248	2	8
Route Order	20.25	3.817	8	24
Point to Start	50.30	32.94	4.25	148.88
Distance Estimation	6.30	1.501	2	8
Direction Estimation	5.23	1.382	2	8
Map Recognition	.77	.423	0	1
Locations Map	90.36	82.60	7.88	388.13

Note. $N = 53$ for all analyses; [a]Z-score based on an age, gender, and education level matched sample of 1147 participants (van der Ham et al., in preparation).

Supporting analyses

Presence. Based on previous research, the participant's level of perceived authenticity of the VT test was examined by investigation of the presence (PQ), and it was found that 64.9% of participants scored the PQ at 3 or higher.

State anxiety. The pre- and post-test measures of the STAI-S were analyzed by paired sample t-test to test the assumption that completing the VT test induced a significant amount of state anxiety, as compared to the baseline measure. Participants' report of A-state did not differ significantly between pre-test (*M* = 35.62, *SD* = 11.56) and post-test (*M* = 35.26, *SD* = 9.58), with $t(52) = .31$, $p = .762$.

Spatial ability and anxiety. A Pearson's correlation was conducted to analyze the relationship between self-reported and direct spatial ability measures (WQ and VT), STAI-S, STAI-T and WQSA (tables 2 and 3).

Table 2. *Pearson's Correlation for Self-Reported Spatial Ability, Direct Spatial Ability, State Anxiety, Trait Anxiety and Spatial Anxiety.*

	WQ (NO & DE)[a]	VT[b]	STAI-S	STAI-T	WQSA[a]
WQ (NO & DE)[a]	-				
VT[b]	.26	-			
STAI-S	-.38**	-.37**	-		
STAI-T	-.40**	-.13	.64**	-	
WQSA[a]	-.49**	-.10	.52**	.48**	-

Note. **p* < .05, ***p* < .01, ****p* < .001. *N* = 53 for all analyses; [a]Z-score based on an age, gender, and education level matched sample of 1147 participants (van der Ham et al., in preparation); [b]Z-scores based on current study sample.

Table 3. *Pearson's Correlation for Self-Reported Spatial Ability, Direct Spatial Ability (Separated by Task), State Anxiety, Trait Anxiety and Spatial Anxiety.*

	WQ (NO & DE)[a]	WQSA[a]	STAI-S	STAI-T
Landmark Recognition[b]	.00	.07	-.02	-.02
Route Sequence[b]	.35*	-.17	-.30*	-.25
Route Continuation[b]	-.02	.03	-.09	.18
Route Order[b]	.10	-.01	-.27*	.03
Point to Start[b]	.15	-.05	-.11	-.19
Distance Estimation[b]	.17	.03	-.24	.05
Direction Estimation[b]	.25	-.10	-.23	-.09
Map Recognition[b]	.19	-.13	-.42**	-.28*
Locations Map[b]	.30*	-.20	-.33	-.19

Note. **p* < .05, ***p* < .01, ****p* < .001. *N* = 53 for all analyses except VT 2, where *N* = 52; [b]Z-score based on current study sample.

To investigate these relations in spatially anxious participants specifically, a similar Pearson's correlation was conducted for the quartile with the highest WQSA scores only: WQ, VT, STAI-S, STAI-T and WQSA scores of these thirteen participants were correlated, and found that in this subsample only WQ and VT correlate significantly ($r = .65$; $p = .015$; see tables 4 and 5).

Table 4. *Pearson's Correlation for Self-Reported Spatial Ability, Direct Spatial Ability, State Anxiety, Trait Anxiety and Spatial Anxiety for the 25% most spatially anxious participants.*

	WQ (NO & DE)[a]	VT[b]	STAI-S	STAI-T	WQSA[a]
WQ (NO & DE)[a]	-				
VT[b]	.65*	-			
STAI-S	-.32	-.40	-		
STAI-T	-.20	.12	.26	-	
WQSA[a]	.11	.06	-.06	.28	-

Note. *p < .05, **p < .01, ***p < .001. N = 13 for all analyses; [a]Z-score based on an age, gender, and education level matched sample of 1147 participants (van der Ham et al., in preparation); [b]Z-scores based on current study sample.

Table 5. *Pearson's Correlation for Self-Reported Spatial Ability, Direct Spatial Ability (Separated by Task), State Anxiety, Trait Anxiety and Spatial Anxiety for the 25% most spatially anxious participants.*

	WQ (NO & DE)[a]	WQSA[a]	STAI-S	STAI-T
Landmark Recognition[b]	.29	.18	-.14	-.23
Route Sequence[b]	.54	-.16	-.30	-.20
Route Continuation[b]	.32	.58*	-.12	.23
Route Order[b]	.49	.34	-.25	.39
Point to Start[b]	.32	-.21	.16	-.03
Distance Estimation[b]	.39	-.08	-.40	-.21
Direction Estimation[b]	.11	-.21	-.12	.39
Map Recognition[b]	.40	-.07	-.56*	.19
Locations Map[b]	.63*	-.10	-.32	.18

Note. *p < .05, **p < .01, ***p < .001. N = 13 for all analyses; [a]Z-score based on an age, gender, and education level matched sample of 1147 participants (van der Ham et al., in preparation); [b]Z-score based on current study sample.

Hypothesis 1. To test the first hypothesis a simple linear regression was calculated to predict WQSA based on VT scores for each task. A non-significant regression equation was found (F(9, 42) = .76, p = .654), with an R^2 of .14. For eight VT tasks non-significant regression equations were found, while the VT task "*Locations Map*" showed a significant regression with t(53) = -2.04, p = .047 (see appendix table A for details).

Because this finding contradicts the majority of previous research, it was followed up with further investigations. Since gender has been a strong influencer in spatial tasks in previous research (e.g. Hund & Minarik, 2006; Lawton, 1994; Lawton & Kallai, 2002), it was investigated as a possible explanation of this surprising result: A post-hoc one-way ANOVA was conducted to compare the effect of gender on WQSA and VT. The analysis of variance showed that the effect of gender on WQSA was non-significant ($F(1, 51) = 1.66$, p =.203). The effect of gender on VT, however, was significant ($F(1, 51) = 14.80$, $p < .001$), with men (M = .30, SD = .404) scoring significantly higher than women (M = -.27, SD = .631; table 6).

Table 6. *One-Way Analysis of Variance of Spatial Ability and Spatial Anxiety by Gender*

	Source	df	SS	MS	F	p
WQSA[a]	Between groups	1	.85	.85	1.66	.203
	Within groups	51	26.16	.51		
	Total	52	27.01			
VT[b]	Between groups	1	4.26	4.26	14.80	<.001
	Within groups	51	14.66	.29		
	Total	52	18.92			

Note. N = 53 for all analyses; [a]Z-score based on an age, gender, and education level matched sample of 1147 participants (van der Ham et al., in preparation); [b]Z-score based on current study sample.

Hypothesis 2. In order to test the second hypothesis, a multiple hierarchical regression was conducted to predict WQSA based on STAI-S (post test) and STAI-T, controlling for VT. Alternatively, the specific VT task "*Locations Map*" is controlled for since this task showed a significant relation to the WQSA (see hypothesis 1). STAI-S was entered in model one, STAI-T in model two, and both STAI-S and STAI-T simultaneously in model three. Spatial ability was additionally entered in model four, and alternatively, in model five only the VT task "*Locations Map*" was entered instead.

In model one, STAI-S contributed significantly to the regression model ($F(1, 51) = 18.56$, $p < .001$), and accounted for 26.7% of the variation in WQSA, with ß= .52 and $t(53) = 4.31$ ($p < .001$). A significant regression equation was also found for WQSA based on STAI-T ($F(1, 51) = 14.84$, $p < .001$), with R^2 of 22.5%. Introducing STAI-S together with STAI-T explained 30.3% of variation in WQSA (model three; $F(2, 50) = 10.86$, $p < .001$). In this model, the variance of WQSA explained by STAI-T is not significant, however the variance explained by STAI-S is found to remain significant ($t(53) = 2.36$, $p = .022$; ß = .25). In model four, the addition of VT mean score to the regression model explained an additional 0.5% of the variation in WQSA ($F(3, 49) = 7.28$, $p < .001$). STAI-S still explained a significant amount of variance in WQSA ($t(53) = 2.40$, $p = .020$), however neither STAI-T nor VT were significant predictors of WQSA. Adding only the task "*Locations Map*" instead of the mean VT score concluded in a regression model that explained 30.4% of the variation in WQSA ($F(3, 49) = 7.14$, $p < .001$). Similarly as in model four, STAI-S explained a significant amount of variance in WQSA ($t(53) = 2.17$, $p = .035$), however neither STAI-T nor the "*Locations Map*" task were significant predictors of WQSA (table 7).

Table 7. *Multiple Hierarchical Regression Analysis for Variables Predicting Spatial Anxiety*

	WQSA			
Predictor	B	SE	p	R^2
Model 1				.27***
STAI-S	.04	.01	<.001	
Model 2				.23***
STAI-T	.03	.01	<.001	
Model 3				.30***
STAI-S	.03	.01	.022	
STAI-T	.02	.01	.114	
Model 4				.31***
STAI-S	.03	.01	.020	
STAI-T	.02	.01	.141	
VT[b]	.10	.15	.541	
Model 5				.30***
STAI-S	.03	.01	.035	
STAI-T	.02	.01	.116	
Locations Map[b]	-.03	.09	.767	

Note. *$p < .05$, **$p < .01$, ***$p < .001$. $N = 53$ for all analyses; [b]Z-scores based on current study sample.

Discussion

Overall, while SA has been persistently found as a by-product in previous research, the concept had yet to be investigated in detail. The current study aimed to investigate the relationship between general A-trait/-state and specific SA, in hopes of defining the concept of SA more clearly in terms of stimulus-related- and general anxiety.

Findings

Supporting analyses. Similar to previous research on A-state/-trait and cognitive tasks (e.g. the digit span task; Hodges & Spielberger, 1969), high levels of A-state were related to significant decrements in spatial ability, yet there was no relation between A-trait and spatial ability. This finding is consistent with Trait-State Anxiety Theory (Spielberger, Lushene, &

McAdoo, 1971; as cited in Hodges & Spielberger, 1969), according to which cognitive performance declines are produced by increased levels of A-state rather than differences in A-trait. An alternative explanation for the negative relation between A-state and spatial ability is that individuals who performed more poorly on the VT test experienced an increase in A-state in response to their performance. This interpretation, however, can be excluded: First, the interpretation of cognitive performance influencing reported A-state would entail an increase in A-state levels from pre- to post-test, which was was not found. Additionally, the former interpretation - emphasizing the impact of anxiety on cognitive performance rather than the reverse - is more consistent with the existing literature (e.g. Lawton, 1996; Schoenfeld et al., 2014; Spielberger et al., 1983). For example, Kallai and colleagues (2009) found that experiencing anxiety delays the shift from egocentric to allocentric encoding frames, which slows the process of establishing relationships among distributed spatial cues, such as those needed in the VT tasks. Therefore, it can be assumed that one's performance on cognitive tasks, such as spatial navigation, is negatively influenced by increased levels of A-state. When investigating only the most spatially anxious individuals, this interaction of A-state and spatial ability was found non-significant. It seems that this specific subsample of individuals with high SA exhibits attributes influencing the relationship, however the investigation of such goes beyond the scope and experimental design of the current study.

Hypothesis 1. Contrary to the predicted results, no relation between participants' performance on the VT test and their SA was found. Because the data does not support the anticipated negative relation between one's objectively measured spatial abilities and one's anxiety surrounding such spatial tasks, the current study contradicts previous research on the topic of spatial (e.g. Van der Ham et al., 2013; Walkowiak et al., 2015). The only exception was the VT task "*Locations Map*", which exhibited a significant relationship to SA. This specific task entailed converting the egocentric perspective in which the VE was explored into an accurate allocentric perspective of the route, and placing egocentric screenshot within the allocentric map.

The current results show a significant differentiation between self-reported spatial abilities and directly measured spatial abilities, and their relation to SA: While SA negatively related to self-reported spatial ability, there was no relation between SA and the direct measure of spatial ability, through the VT test. These findings can be interpreted in two ways: Either, the more SA an individual experience, the worse they (falsely) perceive their navigation ability to be; or, on the reversed, the worse an individual perceives their navigation ability to be, the more SA they experience, independent of their actual ability. However, if this interaction is investigated in the previously mentioned isolated subsample of highly spatially-anxious individuals, the originally non-significant relationship between self-reported spatial ability and directly measured spatial ability was found to be significant. It seems that the subset of participants who exhibit a high level of SA more accurately report their spatial ability than less spatially anxious individuals.

Nonetheless, this finding of no-relation between SA and spatial ability contradicts previous literature, where a negative interaction between directly assessed spatial ability and SA has been established (e.g. Van der Ham et al., 2013; Walkowiak et al., 2015) and thereby highlights the need to explore and define the concept of SA further. The post-hoc analyses revealed that the absent relation between spatial ability and SA is not due to gender differences. In fact, in the current study no difference in SA between men and women was found. The issue of gender differences in spatial ability and SA is controversial, with inconsistent findings across experiments. While some studies have found no gender differences as well, it is still unclear why gender differences in SA are inconsistent (Hund & Minarik, 2006; Lawton, 1994, 1996; Lawton & Kallai, 2002), though it may reflect the complexity of the relation between SA and spatial ability (for an extensive review, see Coluccia & Louse, 2004).

Hypothesis 2. By investigating SA further, the data revealed that A-trait and A-state interacted to influence SA. A-trait explained a part of the variance of SA, but did not display an additional direct effect when A-state was added: The significant relation of A-trait and SA was found to be nonsignificant when the influence of A-state was taken into account. SA seems highly and positively related to both A-state and A-trait, yet the data suggests that the effect of A-trait on SA is actually moderated by A-state. The positive interaction of A-trait and SA is only salient when A-state is not taken into account, meaning that individuals experience higher anxiety surrounding spatial navigation when exhibiting increased anxiety as a result of negatively demanding or harmful situations/stimuli, but independent of their general predisposition to appraise many situations/stimuli as threatening.

Because of the close relation to A-state, SA seems to be a situation-specific form of anxiety which may be classed with performance anxieties such as math anxiety. As spatial-anxious individuals experience anxiety when navigating, SA seems to describe a temporary negative emotional response as a result of interpreting spatial tasks as negatively demanding and/or harmful.

Considerations

Contrary to expectations, the pre- and post-test A-state measures were found to not differ significantly. It seems that engaging in spatial navigation tasks within the VT test did not heighten participants' level of A-state. Considering that A-state was found to be the only anxiety related to spatial ability, this finding is surprising and might be due to the self-report nature of the instrument. This indifference should be investigated further in future research, by to supplementing the self-report measure with physiological indices of A-state (e.g. salivary cortisol).

An important strength of the current study can be seen in the extensive spatial ability measure. The VT test covered nine different aspects of spatial navigation and thereby equaled-out certain cognitive domains that have been found to favor certain subsamples (e.g. tasks with metric nature tend to favor males; Van der Ham et al., 2015). However, it should be noted that the nine VT tasks could not be counterbalanced to ensure that an earlier task did not provide information that would be useful for a later task. It therefore cannot be excluded that the VT test results have been affected by order effects and other factors such as fatigue. Nonetheless, the VT test seemed to elicit a great level of feeling of immersion in individuals, according to the current study's measure of presence, which are thought of as the key feature for effective VE applications (Tussyadiah et al., 2018). Additionally, the inclusion of a self-report measure as well as an extensive direct measure of spatial ability pose an important contribution to spatial ability and SA literature: An individual's perceived ability to navigate novel environments showed a different relationship to SA than directly measured spatial abilities, which can solely be investigated by the inclusion of both types of measures.

An important and novel contribution of the current study to the existing literature is the inclusion of both A-trait and A-state, which allowed for a systematical investigation of the independent and joint contributions of both anxiety types on SA. To our knowledge, few studies have attempted to disentangle the effects of A-trait versus A-state and only included either. Through the current design it could be demonstrated that the effect of A-trait on SA is mediated by A-state, which can be utilized to improve the way in which SA is treated in clinical settings: Incorporating variables of SA as a situational anxiety could enhance the effectiveness of spatial anxiety treatment. Additionally, online or offline navigational tools can be augmented by taking SA into account and thereby ultimately improving navigation ability and navigation experience of end-users.

Conclusion

Taken together, the present study extends previous research by offering first evidence for the moderating role of A-state on the relationship between A-trait and SA: A-trait and A-state are both positively related to SA, but it is only A-state which explains a substantial amount of variance in SA, over the control variable spatial ability. Accordingly, this study shows evidence of SA being a temporary, situation-specific type of anxiety, while contradicting previous research with evidence of no relation between SA and spatial ability.

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Appendix

Table A.

Simple Linear Regression Analysis for Spatial Ability Predicting Spatial Anxiety

	WQSA		
Variable	B	SE	ß
Landmark Recognition[b]	.09	.13	.12
Route Sequence[b]	-.00	.15	-.01
Route Continuation[b]	.14	.18	.16
Route Order[b]	.23	.17	.28
Point to Start[b]	-.01	.12	-.01
Distance Estimation[b]	.05	.13	.07
Direction Estimation[b]	-.01	.12	-.02
Map Recognition[b]	.06	.14	.08
Locations Map[b]	-.49	.24	-.58*
R^2		.14	
F for change in R^2		.76	

Note. *p < .05, **p < .01, ***p < .001. N = 53 for all analyses except VT 2, where N = 52; [b]Z-score based on current study sample.