Personal Navigation:

The Influence of Personality and Spatial Anxiety on active spatial navigation in a Virtual Reality and Real World environment.

Keywords: Spatial navigation, personality, route knowledge, survey knowledge, virtual reality, real world, spatial anxiety

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Abstract

Introduction: Navigation is a fundamental cognitive function in daily life, influenced by several separate mechanisms. However, the influence of personality traits on objectively measured navigation performances has hardly been investigated. Therefore, current research has focused on the influence of the Big-Five personality traits and spatial anxiety on actual navigation performances in a virtual reality and a real world environment.

Methods: Actual navigation performances have objectively been measured by tracking the number of errors and hesitations of the participants, while they were completing four routes in virtual reality and real world environments. Route and survey knowledge tasks were executed after completion of the routes to verify potential moderation of these cognitive mechanisms on the influence of personality on navigation performances. Personality and spatial anxiety have been measured using the IPIP-100 questionnaire and Lawton's spatial anxiety scale.

Results: Results have indicated that spatial anxiety is a significant negative predictor for navigation performances. A combination of a high level of conscientiousness and survey knowledge has been a significant predictor for improved navigation performances. No significant differences in performances between a virtual reality and a real world environment has been indicated.

Discussion: Current research has been an explorative study which has given indications to a negative influence of anxiety mechanisms on navigation abilities due to impaired attentional disengagement to environmental features in the route. Moreover, the beneficial effect of the combination of conscientiousness and survey knowledge have given directions that mental structuring and working memory modulation might enhance path integration while navigating. These results have given a unique contribution to an integrated model predicting enhanced navigation performances.

Introduction

The ability to navigate through the environment is a fundamental cognitive function allowing people to move to well-known (e.g. home or supermarket) and unknown locations. Spatial orientation is defined as the tuning between the subject and its internal representations of the external world (Peer, Salomon, Goldberg, Blanke & Arzy, 2015). While animals use these skills to survive, humans mainly use it to find their way in complex environments and to plan routes to remote locations (Wolbers & Hegarty, 2010).

Navigation has been associated with a variety of cognitive functions, such as processing of visual and spatial information, auditory, kinesthetic, proprioceptive, olfactory and somatosensory functioning, working memory, mental imagery, attention and executive functioning (Bosco, Longoni & Vecchi, 2004; Burgess, Maguire & O'Keefe, 2002; Wolbers & Hegarty, 2010). The information about the surrounding area is processed by internal (e.g. somatosensory, proprioceptive) and external (e.g. visual and auditory) representations of the environment (Arleo & Gerstner, 2000; Gramann, Müller, Schönebeck & Debus, 2006). Because of the variety of cognitive functions involved and the daily use of spatial orientation, navigation ability is an important part of daily life functioning. Therefore, research into the process of spatial orientation in humans is necessary.

Up to now, navigation has primarily been investigated from a cognitive perspective. In this line of research a distinction has been made between an allothetic and an ideothetic representation of the environment. An allothetic representation is mainly based on visual external stimuli about the environment whereas an ideothetic representation is based on internal movement related stimuli such as proprioceptive and vestibular functions and metric features of the route (Arleo & Gerstner, 2000; Foster, Morris & Dayan, 2000; Gramann et al., 2006; Jacobs, Thomas, Laurance & Nadel, 1998). This distinction has led to the implementation of two separate cognitive mechanisms during spatial orientation. The first mechanism is route knowledge, which is knowledge based on distinct features of the environment, called landmarks, mainly based on an allothetic representation of the environment. The second mechanism is survey knowledge, which is knowledge based on spatial relations and map-like representations of the environment such as cardinal directions and distance estimation, which is mainly based on an ideothetic representation of the environment (Claessen, Van der Ham, Jagersma & Visser-Meily, 2015; Glück & Fitting, 2003; Walkowiak, Foulsham & Eardly, 2015). Although both cognitive mechanisms are necessary for spatial orientation, survey knowledge has been associated with a more flexible view of the environment and leads to a better and faster spatial orientation (Glück & Fitting, 2003; Walkowiak et al., 2015; Wolbers & Hegarty, 2010).

While most of the studies have focused on the role of cognitive skills applied during navigation, only a few studies have investigated the influence of personal factors, such as the degree of anxiety about performing spatial tasks (spatial anxiety) and personality characteristics on navigation. Research into the influence of spatial anxiety on spatial abilities has pointed out that a high level of spatial anxiety impairs the ability to memorize spatial locations and leads to a reduced performance on the Mental Rotation Task (measuring visuospatial performances). Furthermore, research has indicated that people with a high level of spatial anxiety navigate slower than people with lower levels of spatial anxiety (Coluccia & Louse, 2004; Cooke-Simpson & Voyer, 2007; Ramirez, Gunderson, Levine & Beilock, 2012). These impairments in spatial abilities due to a higher level of spatial anxiety could be explained by an attentional bias, expressed in inadequate shifting between distinct features of the route (attentional disengagement). More specifically, previous research has indicated that a higher level of anxiety is associated with an increased tendency to hold attention to the threatening stimulus, leading to an attentional deficiency to other relevant landmarks in the route (Clarke, MacLeod & Guastella, 2013). This impairment in disengagement leads to deficits in visuospatial, orientation and allocation tasks (Fox, Russo, Bowles & Dutton, 2001; Mogg, Holmes, Garner & Bradley, 2008; Salemink, Van der Hout & Kindt, 2007).

Apart from the influence of spatial anxiety on spatial performances, a few studies have also investigated the influence of the Big-Five personality characteristics (McCrae & John, 1992) on navigation abilities. These studies have shown that a high level of neuroticism, a personality trait associated with frequently experiencing negative emotions, such as anxiety, anger, and self-consciousness (Burles et al., 2014), is associated with a reduced ability of cognitive map formation, ineffective coping strategies during navigation and a reduced level of self reported sense of direction (Burles et al., 2014; Condon et al., 2015; Walkowiak et al., 2015). In contrast, higher levels of extraversion, openness and conscientiousness have been related to a higher level of self reported sense of direction (Condon et al., 2015; Walkowiak et al., 2015). In extraversion (energy, enthusiasm, approach behavior) this beneficial effect might be explained by the fact that this trait promotes active engagement with the environment (Condon et al., 2015). In openness (curiosity, ingenuity, adventurousness) this might be explained by its association with increased achievement motivation and ability to maintain environmental impulses simultaneously (Bussato, Prins, Elshout & Hamaker, 1999; McCrae & Costa, 1997). In conscientiousness (attention to detail, organization, diligence) this beneficial effect might be explained by an increased perseverance and commitment to goal-directed behavior and a more accurate decision making process (Le Pine, Colquitt & Erez, 2000).

The lack of research into the influence of personality traits on navigation skills could be considered as remarkable. Given the fact that a decent number of studies has already demonstrated the influence of personality characteristics on a variety of cognitive and daily life skills, such as academic achievement (Bussato et al., 1999), work behavior (Barrick, Stewart, Neubert & Mount, 1998) and working memory (Dima, Friston, Stephan & Frangou, 2015), personality could also affect navigation performances which makes it a relevant issue for research. Although personality characteristics seem to affect spatial abilities according to a few studies, one of the main weaknesses of these studies is that these findings have mainly been based on self report measures, measuring the way people rate their own navigation skills. Hardly any study has investigated the influence of personality characteristics on objectively measured actual navigation, by moving actively through an environment. That is striking, as that skill is generally used in everyday life and is a more objective measurement of navigation abilities than self reported ratings of navigation skills. This makes more research about the influence of personality characteristics on objectively measured navigation abilities, instead of self report measures of navigation abilities, necessary. Therefore, the current study is mainly focused on the influence of personality characteristics and spatial anxiety on objectively measured navigation abilities by actively moving through an environment.

These active spatial abilities could be measured in two ways: by moving through a Virtual Reality (VR) environment or by moving through a Real World (RW) environment. Both methods have their strengths and weaknesses. One of the strengths of a VR environment, is the fact that it takes place in a fixed and controlled environment. This characteristic is not applicable for the RW environment, because this type of environment could be affected by environmental changes. However, one of the weaknesses of a VR environment is the fact that it is primarily a visual device, moving solely by controlling a joystick, which is an unnatural way of moving. In this way other important factors during navigation, such as proprioceptive and kinesthetic functions, are ignored, while these functions are generally used in RW conditions. Furthermore, the visual field in VR environment is restricted compared with RW environments (Allahyar & Hunt, 2003; Maguire, Burgess & O'Keefe, 1999; Witmer, Bailey & Knerr, 1996). This restriction could result in a distorted metric representation of the environment in the VR condition, which might affect the development of survey knowledge while navigating (Witmer et al., 1996). Because both methods have their strengths and weaknesses, the current study has measured spatial abilities both in a VR and RW environment.

To summarize, the current study is focused on the influence of personal factors, such as personality and spatial anxiety, on objectively measured active navigation abilities in a virtual reality and real world environment. These effects might be moderated by route and survey knowledge. This leads to the following hypotheses: 1a. A high level of neuroticism and spatial anxiety is associated with more mistakes during navigation partly due to a below average survey knowledge; 1b. A high level of extraversion, openness and conscientiousness is associated with less mistakes during navigation partly due to a high level of survey knowledge; 2. A real world environment leads to better navigation performances compared with a virtual reality environment.

Methods

Participants

65 Participants (38 (59.5%) female; 27 (41.5%) male), aged 18 to 35 years old (M=22.55; SD = 2,80), were included in current study. Requirements for inclusion were a medium or high education level (scale 5, 6 or 7) according to the system of Verhage (Verhage, 1964; see table 2), no past with brain damage and no recent diagnosis of a psychiatric disorder at the moment of testing. Furthermore, they also never visited the city of Tübingen (target VR environment) and reported no detailed knowledge of the district of Rijnsweerd in Utrecht (target RW environment) before testing.

Procedure

Before the participants were tested, they were briefed about the overall content of the study. Participants were tested in a windowless room in the social sciences building on the campus of Utrecht University.

First the participants were asked to fill out an informed consent form in which they give compliance to participate in the study. Subsequently they had to complete questionnaires about the level of spatial anxiety, the level of immersion in virtual reality tasks, video game experience and personality. Participants were also asked to provide some demographic data. After completing the questionnaires, participants had to pass through four routes: two in a virtual reality and two in a real world condition. The order of route following was counterbalanced across participants, whereby participants started at different virtual reality and real world routes. After each route the participant was asked to perform two tasks. These tasks were designed to asses both route and survey knowledge of the followed route.

The experiment was completed when all four routes were followed and all associated route and survey knowledge tasks were performed. The total duration of the experiment was about 120 minutes.

Materials

Immersiveness and video game experience

Because some studies have indicated that the level of presence and immersion (profound attentional involvement) in virtual reality tasks might influence navigation performance in a virtual reality condition (e.g. Walkowiak et al., 2015; Witmer & Singer, 1998), these constructs were measured in current research. The level of presence and immersiveness was measured by the Immersive Tendencies Questionnaire (ITQ; Witmer & Singer, 1998). This questionnaire measures the amount of presence and immersiveness as well as the level of involvement, focus and video game play tendency on a 7-point Likert scale. The reliability (α = 0.75) and construct validity of the ITQ were found to be sufficient (Witmer & Singer, 1998). Apart from the ITQ, several questions about the level of experience in video games with virtual reality and tests with virtual reality were asked.

Personality

To measure the Big Five personality traits, the IPIP-100 (Goldberg, 1992) was used. This questionnaire consists of a pool of questions derived from well-known personality questionnaires such as the NEO PI-R, Hogan Personality Inventory and the MMPI (Goldberg, 1992; Goldberg, 1999). It contains 100 questions about the Big Five personality traits on a 5-

point Likert scale, evenly divided into the five dimensions of personality (extraversion, agreeableness, openness, neuroticism and conscientiousness). The IPIP-100 shows a good reliability and a satisfactory external validity (Goldberg, 1999).

Spatial Anxiety

Spatial Anxiety was measured using the spatial anxiety scale published in Lawton (1994). In this questionnaire the level of anxiety is rated in eight situations, in which navigation and spatial abilities are presumed to be used (Lawton, 1994). This questionnaire uses a five-point Likert scale with the two end-points labeled *not at all* and *very much*. This questionnaire had a good reliability (α = 0.80) and a satisfactory construct validity (Lawton, 1994).

Virtual Reality and Real World Navigation Tasks

First a video of the route, which should be completed, was shown. After showing the video the participant was instructed to follow the route as fluently and flawlessly as possible and to watch the features of the route while passing it. Each route had to be completed three times, each route completion was called a ‘trial’. While traversing the route, the number of errors (voluntarily going into a wrong direction) and hesitations (stopping and looking into at least two different directions before continuation) were noted by the experimenter.

During the experiment participants had to complete two routes in a virtual reality and two routes in a real world environment. The Virtual Tübingen environment (Van Veen, Distler, Braun & Bülthoff, 1998) was used for the virtual reality tasks. In this environment two separate routes were followed after each other: route 1 and route 2. These routes differed in their level of difficulty: route 1 had two more intersections (decision points) than route 2 (see table 1). In both real world routes, participants had to navigate through the district of Rijnsweerd in Utrecht. The virtual reality and real world routes were matched in terms of decision points and turns (see table 1).

Despite the fact that virtual reality and real world routes were equal in the number of decision points and turns, the distance and appearance was different comparing those two types of routes. While the virtual reality routes were characterized by short and narrow streets with typical houses and squares, the environment of the real world routes was characterized by a variety of longer streets with similar looking houses and small overgrown garden paths (see figure 1).

Videos of the virtual reality route were made with the screen capture program litecam HD (http://www.litecam.net/en/product/litecam-hd), real world route videos were manually made with an eight megapixel camera. All videos were edited with Windows Movie Maker 12 (Microsoft, 2012) and Camtasio studio 8 (TechSmith, 2015).

Table 1.

Features of the routes

Route	Decision points	Turns right	Turns left	Stay straight on	Distance
Real world route 1	10	2	2	6	350 m
Real world route 2	8	3	1	4	475 m
Virtual Reality route 1	10	2	2	6	256 m
Virtual Reality route 2	8	3	1	4	270 m

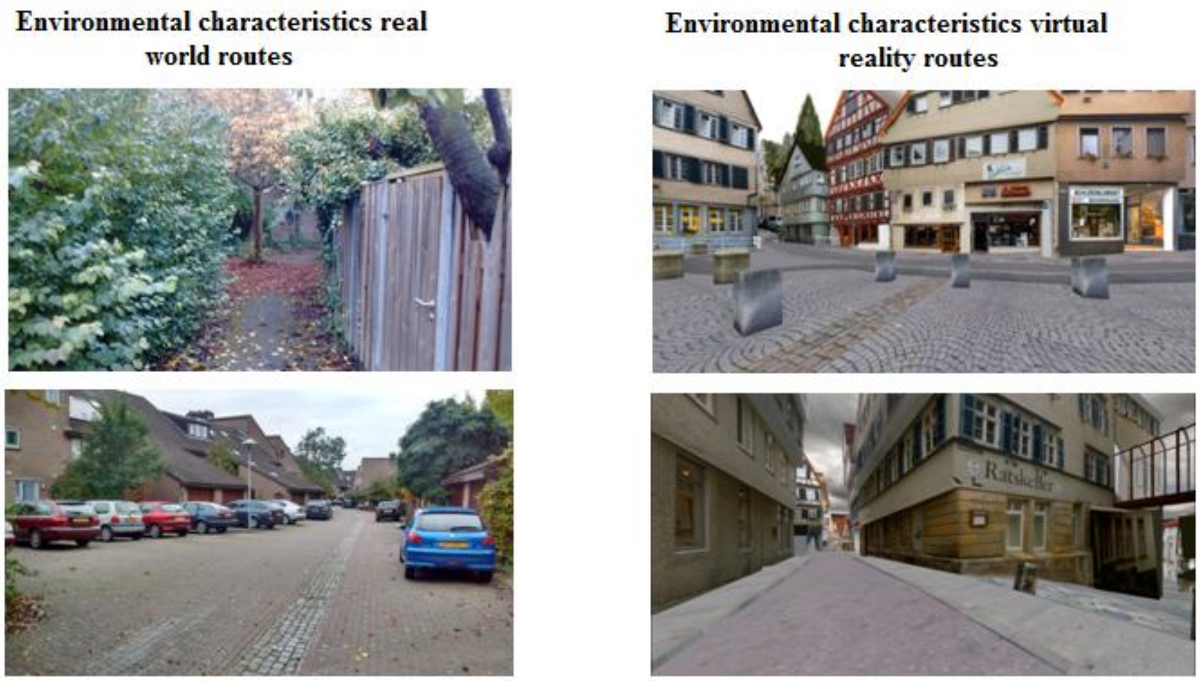

Figure 1. *Environmental characteristics virtual reality and real world routes*

For each participant the average number of errors and hesitations per trial were calculated. Also the amount of route learning (improvement score) was calculated based on the Learning Index Score by Kessels, Nys, Brands, Van den Berg & Van Zandvoort (2006) by calculating the relative difference in errors and hesitations by the following formula:

$$\frac{(A-B)/A + (B-C)/B + (A-C)/A}{3}$$

Each letter in the upper section of the formula represents the trial number in the route (A=trial 1; B=trial 2; C=trial 3). The total score has been divided by 3. When both compared trials (i.e. trial 1 vs. trial 2, trial 2 vs. trial 3 and trial 1 vs. trial 3) were completed without any errors, this subsection in the formula is counted as 1 instead of 0. This adaptation was administered in the formula to prevent underestimation of the improvement score for participants with a small number of errors. Eventually a total score has been calculated ranging between 0 (minimum score) and 1 (maximum score). Finally the number of errors and hesitations had also been merged into one compound variable measuring overall task performance. Because an error is considered as a heavier (more significant) mistake during navigation than a hesitation, the number of errors was counted twice and summed with the number of hesitations creating one compound variable.

Route and Survey Knowledge

Route knowledge was measured using a route ordering task (e.g. Van der Ham et al., 2010). In this task eight pictures of locations within the route were shown, which had to be put in the right order in accordance with the order in which these locations were encountered during the route. Each picture put in the right place yielded two points, while one point was earned when the picture was placed right next to the correct place, making a total of 16 points to be earned when every picture was put correctly.

Survey knowledge was measured using a triadic comparison task (e.g. Schinazi, Nardi, Newcombe, Shipley & Epstein, 2013) in which the shortest and the longest straight-line distance between three landmarks within the route had to be registered in six trials. Each correct answer was awarded with one point, which leads to a maximum of 12 points per route.

Analysis

The influence of personality, spatial anxiety, route knowledge and survey knowledge on navigation performances was analyzed using a moderation analysis by executing a multiple linear regression analysis. This was executed hierarchically by including variables stepwise in three models: in model 1 only the personality traits (IV) were analyzed, while in model 2 the amount of survey knowledge and the interaction between the IV and survey knowledge were added. In model 3 route knowledge and the interaction with the IV had also been added to enable analysis of the influence of both route and survey knowledge. Potential mediation was also analyzed following Baron & Kenny's (1986) three steps for mediation: first the independent variable should significantly predict the dependent variable, second, the independent variable should be a significant predictor for the mediator variable and third, the independent variable should be a lower (or non-) significant predictor for the dependent variable when the mediator variable has been added in the regression model. When the analysis met all three steps, a mediation could be indicated.

Differences between virtual reality and real world environments were measured using a one-way ANOVA, in which differences between each separate route had been analyzed using a post hoc test. Furthermore, differences explained by the degree of immersiveness were checked using a Pearson correlation and a regression analysis measuring the association between the degree of (subscales of) immersiveness and the performances on the navigation task. All analysis were executed in SPSS statistics 22 (IBM Corp. released, 2013).

Results

Demographics

Demographic variables are presented in table 2. Participants have little virtual reality experience and limited virtual reality game experience. Furthermore, participants have declared only few and global knowledge of the real world environment and no participant has ever visited the virtual reality environment (Tübingen). This indicates that results are unlikely to be explained by extensive familiarity with the real world or virtual reality environment. Finally, participants made on average less than one error or hesitation per trial during the navigation experiment with a low standard deviation (see table 2). This indicates that participants have shown strong task performances during the experiment with a low variance between the participants.

Table 2.

Demographic variables

	N	Minimum	Maximum	Mean	SD
Age	65	18	35	22.55	2.80
Education*	65	5	7	6.25	0.50
Virtual Reality Experience**	65	1	10	3.09	2.51
Virtual Reality Game Experience**	65	1	10	4.17	2.89
Familiarity of Real World (RW) environment***	65	1	5	2.42	1.14
Average number of errors per trial made during the experiment	65	0.00	1.833	0.33	0.28
Average number of hesitations per trial made during the experiment	65	0.00	2.333	0.59	0.41

* 5 = Finished secondary school, medium level; 6 = Finished secondary school, high level; 7 = university degree

** 1 = No experience at all; 10 = a lot of experience

*** 1 = No knowledge; 2 = Few knowledge; 3 = Global knowledge; 4 = Above average knowledge; 5 = Detailed knowledge

1. Personality characteristics and spatial anxiety

As previously described, two hypotheses have been formed concerning the predictive value of personality characteristics and spatial anxiety for navigation performances: hypothesis 1a: A high level of neuroticism and spatial anxiety is associated with more mistakes during navigation partly due to a below average survey knowledge; hypothesis 1b: A high level of extraversion, openness and conscientiousness is associated with less mistakes during navigation partly due to a high level of survey knowledge. Results, testing these hypotheses, are described below.

1a. Spatial Anxiety and Neuroticism

According to the results shown in table 3, hypothesis 1a is partially confirmed. As results concerning spatial anxiety are in line with the expected results, no significant effects of neuroticism on the amount of errors and hesitations have been indicated.

Results (see table 3) show that spatial anxiety is a significant predictor for the error score (B = 0,20; $p < 0.05$) of the number of hesitations made during the experiment. This signifies that a higher level of spatial anxiety is associated with more hesitations during the experiment. Also a significant trend ($p < 0.10$) in the same direction for the compound variable has been indicated. This demonstrates that a high level of spatial anxiety could not only be associated with solely hesitations but might be generalized to a composition of both errors and hesitations.

Furthermore, results indicate that when route and survey knowledge are combined with spatial anxiety in the regression model (model 3; see table 3) a significant negative interaction between route knowledge and spatial anxiety has been shown in the error score of the number of errors made during the experiment (B = -0.07; $p < 0.05$) and a significant trend of a negative interaction between spatial anxiety and route knowledge on the compound variable. Also, only a significant trend for spatial anxiety as a predictor for the error score of the number of hesitations has been indicated in model 3. Because the association between spatial anxiety and the number of hesitations is not significant in model 3, route knowledge might be a mediator for this effect. However, spatial anxiety is no significant predictor for route knowledge (step 2 of Baron & Kenny, 1986; B = -0.65; p =0.13). This indicates that route knowledge attenuates the predicting value of spatial anxiety on the amount of hesitations made during navigation. This effect, though, is not explained by a mediation of route knowledge on the association between spatial anxiety and the number of hesitations. In contrast with all these results on the error score, spatial anxiety has not been associated in any manner with the improvement of the number of errors or hesitations.

According to the regression model, neuroticism has, in contrast with hypothesis 1a, no significant predicting value for the number of errors or hesitations made during navigation. Only a significant trend of a negative predictive value of neuroticism on the improvement score, of the number of errors in model 1 and the compound score in model 2, might indicate that neuroticism has a negative influence on route learning.

1b. Extraversion, Agreeableness, Conscientiousness and Openness

According to the results, hypothesis 1b could also partially be confirmed. In accordance with the hypothesis a significant predicting value of conscientiousness on the number of errors and hesitations has been found, when conscientiousness is combined with survey knowledge. However, no significant associations have been indicated between openness, agreeableness and extraversion on the number of errors and hesitations made during navigation.

Results indicate that conscientiousness, as a stand-alone variable (model 1; table 3), does not significantly predict the error score or improvement score of the number of errors and/or hesitations made during the experiment. However, when conscientiousness is combined with survey knowledge (model 2; table 3) results show that conscientiousness is a significant negative predictor for the error score of the number of errors ($B = -0.45$; $p < 0.05$) and the compound variable ($B = -0.75$; $p < 0.05$). Also a significant interaction between survey knowledge and conscientiousness in the error score of the number of errors ($B = 0.06$; $p < 0.05$) and the compound variable ($B = 0.11$; $p < 0.05$) have been indicated. These results demonstrate that survey knowledge has a moderating effect on the predicting value of conscientiousness on the number of errors (alone and combined with hesitations) made during navigation and that the combination of a high level of conscientiousness and a high level of survey knowledge is leading to a significantly smaller amount of errors made during navigation. Furthermore, a significant trend of positive predictive value of conscientiousness on the improvement score of the number of errors in model 2 and model 3 of the regression analysis has been indicated. This might support the beneficial influence of conscientiousness on navigation performance when survey knowledge has been added to the model.

Because conscientiousness shows contradictory results compared with spatial anxiety both variables could possibly have a significant negative correlation. However, results indicate no significant negative correlation between spatial anxiety and conscientiousness ($r = 0.15$; $p = 0.23$). This indicates that the contradictory predictive value of both variables could not be explained by a negative association between both variables and that both predictors are attributable to separate mechanisms.

Table 3.

Multiple Regression Analysis Route and Survey Knowledge, Spatial Anxiety and Personality Characteristics

		Model 1***			Model 2***			Model 3***		
Error score	N	Error	Hesitation	Compound	Error	Hesitation	Compound	Error	Hesitation	Compound
Route Knowledge	65	-3.52*	-2.64*	-2.35*						
Survey Knowledge	65	-2.15*	-1.58*	-1.43*						
Spatial Anxiety	65	0.06	0.20*	0.17**	0.17	0.50	0.42	0.29	0.59**	0.59
X Survey Knowledge					-0.02	-0.05	-0.05	0.09	0.07	0.12
X Route Knowledge								-0.07*	-0.08	-0.11**
Neuroticism	64	0.01	0.10	0.06	0.11	-0.11	0.06	0.31	0.08	0.36
X Survey Knowledge					-0.02	0.02	-0.01	0.02	0.06	0.04
X Route Knowledge								0.04	-0.03	-0.05
Extraversion	64	0.04	-0.02	0.03	-0.06	0.13	0.00	-0.09	-0.03	-0.11
X Survey Knowledge					0.01	-0.02	0.00	0.01	-0.05	-0.02
X Route Knowledge								0.01	0.03	0.02
Agreeableness	64	0.02	0.06	0.05	-0.28	-0.32	-0.44	-0.19	-0.36	-0.37
X Survey Knowledge					0.05	0.06	0.08	0.08	0.04	0.10
X Route Knowledge								-0.02	0.01	-0.02
Conscientiousness	64	-0.02	-0.02	-0.03	-0.45*	-0.60**	-0.75*	-0.38	-0.57	-0.67**
X Survey Knowledge					0.06*	0.09**	0.11*	0.08**	0.10	0.13**
X Route Knowledge								-0.02	-0.01	-0.02

Openness	64	0.06	-0.1	0.01	0.25	-0.17	0.17	0.50**	0.1	0.54
X Survey Knowledge					-0.02	0.02	-0.01	0.08	0.11	0.13
X Route Knowledge								-0.08*	-0.07	-0.11**

		Model 1***			Model 2***			Model 3***		
Improvement score	N	Error	Hesitation	Compound	Error	Hesitation	Compound	Error	Hesitation	Compound
Route Knowledge	65	0.01	0.01	0.01						
Survey Knowledge	65	0.02*	0.02**	0.02*						
Spatial Anxiety	65	-0.01	-0.01	0.00	0.10	-0.06	0.05	0.09	-0.04	0.04
X Survey Knowledge					-0.02	0.01	-0.01	0.02	0.02	-0.01
X Route Knowledge								0.00	-0.01	0.00
Neuroticism	64	-0.03**	-0.01	-0.02	-0.15	-0.09	-0.20**	-0.07	-0.11	-0.15
X Survey Knowledge					0.02	0.01	0.03	0.03	0.01	0.02
X Route Knowledge								-0.01	0.00	-0.01
Extraversion	64	0.01	0.01	0.01	0.06	-0.08	0.02	0.08	-0.20	-0.02
X Survey Knowledge					-0.01	0.01	-0.00	-0.00	-0.01	-0.01
X Route Knowledge								-0.00	0.02**	0.01
Agreeableness	64	0.01	-0.02	-0.01	-0.11	-0.10	-0.14	-0.16	0.13	-0.21
X Survey Knowledge					0.02	0.02	0.02	0.00	0.00	-0.00
X Route Knowledge								0.01	0.01	0.02
Conscientiousness	64	0.01	0.01	0.01	0.15**	0.03	0.09	0.21**	0.02	0.09
X Survey Knowledge					-0.02**	-0.00	-0.01	-0.01	-0.01	-0.01

X Route Knowledge								-0.01	0.00	-0.00
Openness	64	0.01	0.04	0.02	0.02	-0.05	-0.08	0.04	-0.10	-0.10
X Survey Knowledge					-0.00	0.01	0.01	0.00	-0.01	0.00
X Route Knowledge								-0.00	0.02	0.01

* significant: $p < 0.05$

** significant trend: $p < 0.10$

*** model 1: route and survey knowledge, spatial anxiety or personality characteristic (IV) alone; model 2: IV, survey knowledge, and IV*survey knowledge; model 3: IV, route knowledge, survey knowledge, IV*route knowledge, IV* survey knowledge

Furthermore, results indicate a significant trend in the predictive value of openness on the number of errors made during navigation while route and survey knowledge have been appended to the model (model 3; table 3). Also a significant negative interaction between openness and route knowledge ($B = -0.08$; $p < 0.05$) has been found indicating an attenuating effect of route knowledge on the predictive value of openness for the number of errors made during navigation.

According to the regression model, agreeableness and extraversion have, in contrast with hypothesis 1b, no significant predicting value for decrease in the number of errors or hesitations made during navigation.

1c. Route and Survey Knowledge

Finally results indicate that both route and survey knowledge are strong significant negative predictors for the number of errors and hesitations made during navigation (see table 3). However, only survey knowledge also appears to be a significant predictor for the improvement score of the number of errors and hesitations. These results demonstrate that a high level of route or survey knowledge will lead to a small amount of errors and hesitations, indicating that both cognitive mechanisms are beneficial during navigation.

2. Virtual Reality versus Real World navigation

Beside the influence of spatial anxiety and personality characteristics on navigation performances, also the difference between virtual reality and real world navigation performances has been measured based on hypothesis 2: A real world environment leads to better navigation performances compared with a virtual reality environment.

According to the results (table 4), hypothesis 2 could not be confirmed. No significant differences are indicated between both navigation conditions in the error score or the improvement score of the amount of errors and hesitations. These results demonstrate that navigation performances are equal between virtual reality and real world environments. Post hoc tests, measuring the four routes (real world route 1, real world route 2, virtual reality route 1 and virtual reality route 2) separately, have indicated that in real world route 1 the error score of the number of errors, hesitations and the compound variable is higher than in all other routes. These differences between real world route 1 and the other routes were also found in the improvement score (see table 4). These results demonstrate that the higher difficulty level of real world route 1, compared with the other routes, could have influenced the differences between the general results of the virtual reality and real world routes.

Furthermore, a significant difference in survey knowledge between the virtual reality and the real world environment is found ($F = 7.73$; $p < 0.01$) demonstrating that participants show a better survey knowledge in the virtual reality environment compared with the real world environment. Also a significant trend for differences in route knowledge favoring the virtual reality environment ($F = 3.39$; $p < 0.10$) indicates that participants also tend to show an enhanced route knowledge in the virtual reality environment compared with the real world environment.

Table 4.

Virtual Reality versus Real World

		Virtual Reality			Real World			Comparisons		
		N	M	SD	N	M	SD	Df	F	p
	Error	65	0.31	0.36	65	0.35	0.29	1	0.50	0.48
Error score*	Hesitation	65	0.52	0.50	65	0.65	0.46	1	2.44	0.12
	Compound	65	0.57	0.57	65	0.68	0.48	1	1.33	0.25
Improvement score*	Error	65	0.96	0.10	65	0.95	0.12	1	0.77	0.38
	Hesitation	65	0.92	0.16	65	0.94	0.12	1	0.74	0.39
	Compound	65	0.94	0.12	65	0.93	0.15	1	0.49	0.49
Route Knowledge		65	12.87	2.55	65	12.01	2.78	1	3.39	0.07
Survey Knowledge		65	7.41	1.93	65	6.58	1.44	1	7.73	<0.01

* Post hoc test errorscore: significant mean differences between RW route 1 and all other routes in errors, hesitations and compound score (p <0.05).

Post hoc test improvement score: significant mean differences in errors between RW route 1 and both RW route 2 and VR route 2; significant mean differences in hesitations between RW route 1 and both RW route 2 and VR route 1; significant mean differences in the compound score between RW route 1 and all other routes.

Immersiveness

The reported results might be explained by a high or low level of immersiveness. Therefore, immersiveness has been measured as potential predictor of outcome. Also associations between immersiveness and the predicting or outcome measures have been measured.

The predictive value of immersiveness has been measured using a multiple regression analysis stepwise measuring immersiveness alone and immersiveness combined with the ITQ subscales as a predictor for all outcome measures. Results indicate that immersiveness during navigation through the virtual reality environment is no significant predictor for the number of errors or the compound variable with a trend of significance ($B = 0.14$; $p < 0.10$) for the number of hesitations made during navigation. When all subscales join the model, immersiveness is a significant predictor for the number of errors ($B = 0.47$; $p < 0.05$) and the compound variable ($B = 0.77$; $p < 0.05$), with a significant trend of the number of hesitations ($B = 0.58$; $p < 0.10$).

After measuring correlations of immersiveness with the amount of (improvement in) errors and hesitations made during navigation, personality traits, spatial anxiety and route and survey knowledge, research indicate no significant correlations of immersiveness with any variable with only a significant trend of a positive correlation with the error score of the number of hesitations made during navigation ($r = 0.21$; $p < 0.10$).

These results indicate that immersiveness has no evident association with the outcome measures or the predicting variables. However, when combined with its subscales, immersiveness could be a predictor for impaired navigation performance, indicating that extensive selective and sustained attention is leading to impaired performance on navigation tasks. These results might demonstrate that navigation tasks could be more successful using divided attention systems.

Discussion

In the current study the influence of personality on navigation performances and the differences between virtual reality and real world environments have been investigated. Participants completed two virtual reality routes and two real world routes. After each completion, participants were instructed to execute two spatial tasks, measuring route knowledge and survey knowledge, based on features of the completed route. Expected results have been formed in three hypotheses: hypothesis 1a: A high level of neuroticism and spatial anxiety is associated with more mistakes during navigation partly due to a below average survey knowledge; hypothesis 1b: A high level of extraversion, openness and conscientiousness is associated with less mistakes during navigation partly due to a high level of survey knowledge; hypothesis 2: A real world environment leads to better navigation performances compared with a virtual reality environment. Results based on these hypotheses are evaluated below.

Based on the results, hypothesis 1a was partially confirmed. Results did indicate that a high level of spatial anxiety is a significant predictor for a high number of hesitations made during navigation, with a significant trend to both errors and hesitations. This has been attenuated by a high level of route knowledge, due to a significant negative interaction effect. In contrast with spatial anxiety, neuroticism is only a significant negative predictor for route learning, whereas no significant associations with navigation performances were found. This discrepancy in results between neuroticism and spatial anxiety might indicate that decreased navigation performances are specifically declared by anxiety mechanisms and that neuroticism, as one spectrum, is too broad to indicate decreased navigation performances. The negative predictive value of spatial anxiety might be explained by a disruption in attention shifting during navigation due to impaired spatial disengagement of the threatening stimulus (Clarke et al., 2013). In case of spatial anxiety, the threatening stimulus could be defined as the unfamiliar surrounding area which could lead to potential disorientation. In current experiment participants were forced to navigate through an unfamiliar environment. The impaired performances in this navigation task, as a consequence of a high level of spatial anxiety, is most probably explained by inadequate switching between several landmarks due to attention retaining on one specific environmental feature. This mechanism is supported by the significant negative interaction of spatial anxiety with route knowledge, indicating that an adequate registration of all landmarks in the route will lead to a decrease in the impairment of navigation performances. Also the significant negative predictive value of immersiveness on navigation performances indicate that selective and sustained attention on one or a few marking points during navigation could lead to impaired navigation performances. This combination of results confirm that dividing attention between several landmarks within the route is a successful tool for enhanced navigation performances.

Hypothesis 1b was partially confirmed. Results have indicated no significant predicting effects of extraversion and agreeableness on navigation performances. Conscientiousness has only appeared to be a significant negative predictor for the amount of errors and hesitations when it is combined with survey knowledge. Research has demonstrated that a high level of conscientiousness is leading to improved task and academic performances due to an increased achievement motivation (Busato, Prins, Elshout & Hamaker, 2000; Revelle, Wilt & Rosenthal, 2008). These performances have not been explained by general cognitive abilities but by dependability facets of conscientiousness (order, dutifulness and deliberation; Le Pine et al., 2000). The lack of a direct connection between conscientiousness and general cognitive abilities could explain that conscientiousness, as a stand-alone variable, is no significant predictor for navigation performance in current experiment. However, the combination of conscientiousness with survey knowledge indicates a remarkable specific predictor for enhanced navigation performances. These specific results might be explained by the fact that a higher level of conscientiousness has been associated with a higher level of working memory modulation, frontoparietal mechanisms and increased activation of the prefrontal cortex (Dima et al., 2015; DeYoung, Hirsch, Shane, Papademetris, Rajeevan & Gray, 2010). Working memory, defined as successful maintenance of task-related representations and information over delay periods in the absence of external cues (Barch & Smith, 2008), could enhance cognitive map formation during the survey knowledge tasks. Furthermore, brain research has indicated that the interaction between the hippocampus and medial prefrontal cortex (MPFC) is leading to enhanced path integration (sense of self motion for keeping track of changes in orientation), while the MPFC is activating spatial working memory, allowing transition of hippocampal spatial information to decision making (Jones & Wilson, 2005; Wolbers, Wiener, Mallot & Büchel, 2007). These findings show that conscientiousness is specifically working well on a survey knowledge mechanism during navigation. These beneficial outcomes are probably due to enhanced modulation of working memory mechanisms, which work beneficially for structuring internal representations of the environment and cognitive map formation. Also the prefrontal mechanism, which are accompanied with conscientiousness, could work beneficially for the transition of spatial information into decision making during navigation.

Hypothesis 2 could not be confirmed. Navigation performances are equal between navigation in a virtual reality and real world environment. In contrast with earlier research, survey knowledge performances were significantly better in the virtual reality environment compared with the real world environment. This result is remarkable, considering that in the virtual reality condition participants did not move by themselves because movement was made on the screen by controlling a joystick. This might indicate that the perception of self-motion and the internal representation of the environment was equally triggered between the virtual reality and the real world environment and that the differences between both types of environment might be explained by the higher difficulty of real world route 1 compared with the other routes. Following these results navigation performances could be measured by using both a virtual reality as a real world environment.

Current research has been a unique contribution to the information about spatial navigation, which has been indicated so far, due to the measurement of active navigation performances and its connection with personality characteristics. Also differences between virtual reality and real world environments have, to our knowledge, not been investigated on active navigation performance. Considering these facts current research is making a unique contribution to the existing literature concerning navigation. Current study has also several limitations. First of all spatial anxiety and personality characteristics have been subjective measures indicating that actual personality and spatial anxiety traits could be biased by unreliable responses in the questionnaire. Considering the fact that, to date, no objective personality measurements are developed, this probable bias is insurmountable. Another important limitation is the small amount of errors and hesitations and its low variance made during the experiment. Especially the low variance might underestimate statistical differences in current experiment. Furthermore, the small number of errors and hesitations might explain this low variance due to overachievement of the sample or to a low general difficulty level of the experiment. This overachievement could also have a negative influence on the contribution of route learning, as a small number of errors is automatically leading to a low improvement score. Finally, also an important limitation of current study is the overestimation of errors and hesitation in real world route 1, which could have influenced the differences in navigation performances between the virtual reality and the real world environment. Virtual reality and real world routes have been adapted to each other in number of decision points and turns left and right. Apparently other variables might have provoked the difference. Most probably the high amount of garden paths in the route (see figure 1 for an example), which are limiting the view, might be an important cause for impaired orientation and impaired navigation performance. However, no decisive answer can be given about this matter.

Summarizing the results, navigation performances are influenced by spatial anxiety, which is probably explained by inadequate disengagement of the attention from a fixed landmark and deficits in switching between those landmarks. Furthermore, the combination of conscientiousness and survey knowledge was also a significant predictor for successful navigation performances. Both conscientiousness and survey knowledge have triggered parietal, hippocampal and prefrontal interactions. These neurologic interactions might influence spatial working memory, path integration and spatial decision making. Future directions should be focused on the influence of spatial disengagement on actual active navigation by triggering stress or fear responses. Also the connection of behavioral and cognitive functioning between survey knowledge and conscientiousness should be captured as a predictor of navigation performance. As current study is mainly an explorative study, future research should specify these findings into an integrated model for the enhancement of navigation performances. The main results have anchored important leads for this potential model.

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