Individual differences and personality correlates of navigational performance in the virtual route learning task

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Abstract

Research on the mechanisms and processes underlying navigation has traditionally been limited by the practical problems of setting up and controlling navigation in a real-world setting. Thanks to advances in technology, a growing number of researchers are making use of computer-based virtual environments to draw inferences about real-world navigation. However, little research has been done on factors affecting human-computer interactions in navigation tasks. In this study female students completed a virtual route learning task and filled out a battery of questionnaires, which determined levels of computer experience, wayfinding anxiety, neuroticism, extraversion, psychoticism and immersive tendencies as well as their preference for a route or survey strategy. Scores on personality traits and individual differences were then correlated with the time taken to complete the navigation task, the length of path travelled, the velocity of the virtual walk and the number of errors.

Navigation performance was significantly influenced by wayfinding anxiety, psychoticism, involvement and overall immersive tendencies and was improved in those participants who adopted a survey strategy. In other words, navigation in virtual environments is effected not only by navigational strategy, but also an individual's personality, and other factors such as their level of experience with computers. An understanding of these differences is crucial before performance in virtual environments can be generalised to real-world navigational performance.

Keywords
wayfinding; personality traits; virtual environments; psychoticism; spatial cognition; anxiety

1. Introduction

Real world navigational performance has traditionally been explored indirectly using either two-dimensional pen-and-paper tasks or seated laboratory experiments (Galea & Kimura, 1993; Moffat et al., 1998). Experiments looking at real-world navigation are very difficult to control and execute, and have only been attempted on very rare occasions (Lawton et al., 1996; Malinowski & Gillespie, 2001). Advances in the development of 3D virtual environments (VEs) have provided researchers with an important tool to investigate how people navigate and what wayfinding strategies they adopt in unfamiliar places. The application of these methods enables the exploration of the underlying processes which mediate acquisition and integration of spatial knowledge in a more controlled manner. However, before the findings from virtual environments can be generalised to real-world navigation, individual differences that might be mediating performance in virtual environments uniquely need to be explored. Although age and gender have previously been examined, it remains unclear how personality constructs and other individual differences might impact on wayfinding within a virtual environment. This study explores how major personality traits (e.g., neuroticism, extraversion), wayfinding anxiety and other individual differences such as computer experience, state anxiety and immersive tendencies interact to impact on navigation within a simple virtual environment. We begin by reviewing existing literature in the field of navigational performance, with particular emphasis on personality and individual differences and the generalisability of studies using virtual and real-world environments.

1.1 Measuring wayfinding strategy

The origins of research on wayfinding derive from a paper published by Trowbridge (1913), who was the first to distinguish between two separate strategies used in human navigation. It is now generally accepted that wayfinding strategies can be defined in terms of route and survey knowledge, in other words, the degree to which individuals orient themselves using local or global landmarks, respectively

(Maguire et al., 1998; O'Keefe & Nadel, 1978; Siegel & White, 1975). As route knowledge makes use of the self-centred (*i.e.* egocentric) viewpoint and perspective of the subject, it consists of information about the environment that is readily available to the person and therefore involves a set of instructions on how to get from one point to another with the use of local cues and landmarks. In contrast, the survey representation benefits from all the information that is potentially accessible by the subject and thus implies the formation of a cognitive map (a *"bird's eye view"*), which integrates all possible routes in a given environment and employs cardinal directions to assist the wayfinding process (Lawton, 1994).

Some authors (Dabbs et al., 1998) also argue that the preference for either route or survey strategy may be culturally and evolutionary determined. For evidence, they point to the hunter-gatherer theory (Silverman & Eals, 1992) as a source of development of cognitive skills and neural mechanisms required to fulfill specific roles within a family and a larger community by primitive hunters (usually males) and gatherers (predominantly females; Choi & Silverman, 1996; Silverman et al., 2000). As the survey strategy makes use of global cues such as position of the sun and Euclidean co-ordinates (North, South, East and West) it benefits individuals involved in hunting by providing them with a much higher level of space constancy (Bisiach et al., 1997). On the other hand, applying a route strategy would be more suitable for gatherers as it greatly depends on the availability of local landmarks and features of the most immediate environments.

The distinction between route and survey strategies receives further support from the field of neurobiology. Gron et al. (2000) found that participants showing stronger preference for route strategy exhibited greater activation of their right parietal and prefrontal areas such as Brodmann's area 9/46, which are thought to be responsible for integrating visual information about landmarks and local cues into working memory (Goldman-Rakic, 1995). As for the individuals who employed survey strategy, they were more likely to engage their left hippocampal areas associated with more general, wider *"bird's eye-view"* mapping of an environment and geometric or Euclidean cues. The degree to which an individual shows preference for one wayfinding strategy over another can be measured by the International Wayfinding Strategy Scale (Lawton & Kallai, 2002). This scale has been successfully applied in studies investigating gender differences in navigational performance and hence it will also be implemented in the current experiment.

1.2 Individual differences in navigation

The vast majority of research on individual difference in virtual environments has focused on participants sex. Castelli et al. (2008) found that men are generally faster and make fewer errors than women when performing a task requiring the adoption of a survey strategy. These findings confirmed earlier results from studies carried out by Moffat et al. (1998), Tlauka et al. (2005) and Waller (2000), who all provided substantial evidence for superior male performance in survey-based navigational tasks. Hegarty et al. (2006), have also demonstrated that men generally outperform women on a number of spatial ability measures such as mental rotation and sense of direction.

Lin et al. (2012) recently proposed a number of explanations for these sex differences in navigational tasks. They found that female participants took more time to locate specific targets, whereas males were more likely to travel greater distances and they moved faster than women in both local and global landmark tasks. Lin et al. made the important observation that these differences between genders in performance measures in virtual wayfinding tasks could be caused by higher computer experience and increased exposure of male participants to virtual environments and video games, which make them more familiar than females with the computer interfaces. Nevertheless, up till now, no research has explored how computer experience and other individual differences might constrain our measurement of performance in virtual tasks. The present study provides an opportunity for testing Lin et al.'s hypothesis within a single-sex sample of participants.

1.3 Personality differences in wayfinding

The currently favoured model of navigation in virtual environments developed by Chen & Stanney (1999) also does not include any reference to personality traits neither as primary or secondary components influencing the wayfinding processes in VE. Nevertheless, it has been hypothesized that factors such as extraversion, neuroticism, openness to experience, anxiety or empathy would play an important role in how people navigate within a virtual or natural environment (Sas, 2004; Sjöllinder, 1998). Lawton (1994) was the first to link spatial anxiety in women to their navigational performance and preference for a route-based wayfinding strategy (Lawton, 1994, 1996). Lawton and colleagues argue that wayfinding anxiety, as measured by the Spatial Anxiety Scale (Lawton, 1994, 1996) or Wayfinding Anxiety Scale (Lawton & Kallai, 2002) are situation-specific personality traits. The relationship between wayfinding anxiety and more general anxiety is still unclear. We therefore also measured state anxiety, via the State-Trait Anxiety Inventory (Marteau & Bekker, 1992), which reflects the current level of anxiety experienced by participants. Castelli et al. (2008), building on earlier research carried out by Saucier & Green (2002) and Schmitz (1997) tested the hypothesis that the level of spatial anxiety might be correlated with measures of navigation performance. The analysis of post-task questionnaires revealed that female participants reported having experienced a much higher level of spatial anxiety in navigation tests than males. Nevertheless, sex differences remained substantial even when spatial anxiety scores were used as a covariate.

It is also widely accepted that personality traits may affect the degree of spatial presence (Laarni et al., 2004; Sacau et al., 2008; Sas, 2004; Sas & O'Hare, 2003). ‘Presence’ describes the feeling of immersion within the virtual environment (Nash et al., 2000), and increased feelings of presence have been shown to positively correlate with navigational performance and spatial ability (Levinthal, 2003; Nash et al., 2000; Witmer & Singer, 1998). Studies carried out by Laarni et al. (2004), Sacau et al. (2008), Sas (2004) and Sas & O’Hare (2003) have shown that extraversion, impulsivity and focus are good predictors of immersion in virtual reality environments. More recently, Weibel et al. (2010) found that neuroticism may also enhance presence, but they did not assess the nature of this correlation and did not provide sufficient evidence to support the hypothesis that neuroticism does in fact affect presence experiences during actual media use. Participants with high level of neuroticism have also been shown to be more likely to experience high presence in a negative environment and low presence with positive stimuli (Weibel et al., 2010, 2011). A relationship between personality traits and the level of immersion in virtual environments has also been suggested by Alsina-Jurnet and colleagues (Alsina-Jurnet and Gutiérrez-Maldonado, 2010; Alsina-Jurnet et al., 2011). They argued that spatial intelligence and introversion influence the sense of presence experienced by students with high test anxiety, who are exposed to anxiety-triggering virtual reality. However, the degree of presence was not found to be related to the level of anxiety in non-stressful environments. Again, as in Weibel et al. (2011), the level of spatial presence seems to be dependent on the emotional context in which personality traits are triggered. In view of this, this research explores how levels of participants' immersive tendencies (as measured by Witmer & Singer's Immersive Tendencies Questionnaire) influence navigation performance and correlate with other personality factors such as neuroticism, extraversion and wayfinding anxiety, which may mediate and trigger the feeling of immersion in a virtual navigational task. If the influence of personality on navigation is largely due to immersion then it places an important constraint on the generalisability of research carried out in virtual environments.

1.4 The current research

Here we describe the first exploration of the direct relationship between personality traits, individual differences and wayfinding in the virtual environment. The design of the experiment is based on Castelli et al. (2008), with some modifications. We examine whether pesonality traits such as, psychoticism, neuroticism, extraversion and wayfinding anxiety as well as as individual differences e.g. general anxiety, immersive tendencies, and computer experience, influence navigation performance indicators e.g. the time to complete a virtual maze, the length of the path taken, the velocity of the virtual walk and the number of errors made. Given the already well documented influence of gender, we use a sample of females only. Our hypothesis was that wayfinding anxiety would negatively impact navigation, resulting in slower performance and a longer path as well as an increased number of errors in participants reporting high wayfinding anxiety scores. On the other hand, higher levels of immersive tendencies should positively correlate with the degree of neuroticism and together will enhance navigational performance (*i.e.* resulting in a shorter time and path with fewer errors in the route task). Other personality traits such as extraversion and psychoticism as well as computer experience will also be investigated in the virtual route learning task.

2. Method

2.1 Participants

Thirty-three female undergraduate or postgraduate students at the University of Westminster participated in this study. The sample size was comparable to other studies, which investigated navigation performance in virtual environments (Driscoll et al., 2005; Witmer, Bailey & Knerr, 1996) and was much bigger than the sizes of female groups in similar experiments run by Castelli et al.'s (n=20) and Lin et al.'s (n=15). The mean age of all participants was 23.03 (*SD* = 3.68) and the age of participants ranged from 19 to 35 years old. All participants, who agreed to take part in the research, entered a raffle to win five £10 Amazon vouchers. Standard British Psychological Society's ethical guidelines were followed and ethical approval was granted by the University of Westminster before the collection of data commenced.

2.2 Apparatus and materials

All 3D virtual environments were designed by the first author in the MazeSuite software package (Ayaz et al., 2011). Three-dimensional models of landmarks were rendered in Blender 3D (version 2.64) software for Mac OS X. A 14-inch Asus laptop, with Microsoft Windows 7 system was connected to the LG digital projector to display the navigation environments on a large (2000 x 1800 mm) wall-mounted projection screen in the cognitive lab at the University of Westminster, where the study took place.

During navigational tasks, participants used a ThrustMaster® USB joystick to move around the mazes and they were all seated 200 cm away from the projection screen to provide the best vision possible and enhance their immersion.

Upon completion of the virtual mazes participants were asked to fill out a pen-and-paper battery of personality and individual differences questionnaires, which included the following measurements:

- Demographic information: age and gender of participant.
- *Computer Experience Questionnaire* (Schuemie, 2003), which was modified for the purpose of this study. Originally, Schuemie used a 5-item scale, but only the first four items were used in this experiment (e.g. *“How often do you use a computer?”*). The fifth, rejected item referred to the experience in using a virtual reality helmet. All items were scored on a 1-5 Likert scale, where 1 denoted 'very bad' or 'never'' and 5 - 'very good' or 'daily', depending on the question.
- *State-Trait Anxiety Inventory* (Marteau & Bekker, 1992), which was originally based on *the Spielberger State-Trait Personality Inventory* (Spielberger, 1979). It includes 6 items (e.g. *“I feel content”*), scored on a 1-4 Likert scale (1 - 'not at all'; 4 - 'very much') and assesses current level of anxiety in the participants – state anxiety.
- *Wayfinding Anxiety Scale* (Lawton & Kallai, 2002) - based on the earlier Lawton's *Spatial Anxiety Scale* (Lawton, 1994) is a measure of trait anxiety. It consists of 8 items (e.g. *“How anxious did I feel when finding my way to an appointment in an unfamiliar area of a city or town?”*) scored on a 1-5 Likert scale (1 - 'not at all anxious'; 5 - 'very anxious') and relates to past personal experiences of the participants when navigating in unfamiliar places.
- *International Wayfinding Strategy Scale* (Lawton & Kallai, 2002). This 17-item questionnaire is based on the original Lawton's *Wayfinding Strategy Scale* and *Indoor Wayfinding Strategy Scale* (Lawton 1994, 1996). The first eleven statements refer to the orientation (*i.e.* survey) strategy used by the participants in their past wayfinding experiences (e.g. *“I thought of my location in the building or complex in terms of north, south, east, and west”*), and the remaining six items relate to the situations, when route strategy is preferred (e.g. “*Clearly labelled room numbers and signs identifying parts of the building or complex were very helpful in finding my way”*). The subjects indicate their agreement with the statements on a 1-5 Likert scale, where 1 denotes 'not true at all', and 5 - 'very true'. Scores for each strategy are added and divided by the number of items on each scale to provide mean scores for each strategy.
- *Eysenck Personality Questionnaire Revised - Short Form* (EPQR-S; Eysenck et al., 1985) - a 48-item questionnaire devised to measure three main personality

dimensions of neuroticism, psychoticism and extraversion, with an additional scale of lie. Participants are asked to provide 'yes' or 'no' answers to agree or disagree with given statements. The scores are assigned according to the scoring key and a maximum score for each scale equals 12, which denotes a high level of certain personality trait.

- *Immersive Tendencies Questionnaire* (Witmer & Singer, 1998) measuring the degree to which a participant can be immersed and feel presence in virtual environments. The questionnaire traditionally consists of 29 items (in this study the nominal item no. 12 was excluded) and grouped into 3 separate subscales related to three distinct tendencies of immersion: involvement in activities, focus on current activities, and tendency to play video games. All items are scored on a 7-point scale based on the principle of semantic differential (Dyer et al., 1976) with a midpoint value as a modification to the original principle.

2.3 Procedures and design

2.3.1 Training phase

During the training phase, all participants were encouraged to freely explore a practice maze with perpendicular turns for 3 minutes. This part was designed to allow the subjects to familiarise themselves with the specific virtual environment. During this stage, the researcher explained how to use the joystick, through which participants controlled the direction of movement.

The practice maze was similar to the ones used in the experimental route learning task. All graphical elements such as patterns and textures for walls and floors were identical to those used in subsequent stages. The speed of movement was set to constant as it was the case in the route learning maze. The training labyrinth also included a number of local landmarks placed in different regions of the maze to facilitate the process of training and make this phase more enjoyable for the participants. During this preliminary practice phase no data was collected and participants' performance was not analysed. After 3 minutes of the training, the practice phase was terminated automatically.

2.3.2 *Route learning task*

The route learning experiment was divided into two separate phases. In the first part, the route learning stage, the task was to follow red, three-dimensional arrows within the maze from the starting point up until the end point of the maze. No backward movement was allowed in this phase in order to motivate the participants to walk through the virtual labyrinth as quickly as possible. Other manoeuvres such as forward, side and diagonal-forward movements as well as turns were allowed. The labyrinth consisted of perpendicular turns only and there were seven local landmarks positioned along the path of the walk. They functioned as points of reference for the participants to assist their navigation in the second part of the experiment. These landmarks were three-dimensional natural or artificial objects such as a tree, table, vase, TV, etc. The end point of the maze was indicated by a black exit (*i.e.* a large, black hole) in the wall of the maze. Time taken to reach the end point, the length of the path, velocity and the number of errors made (*i.e.* a number of detours taken by the participants) were recorded.

Figure 1 presents a 2D map of the route maze and a sample image of the virtual environment used in this condition.

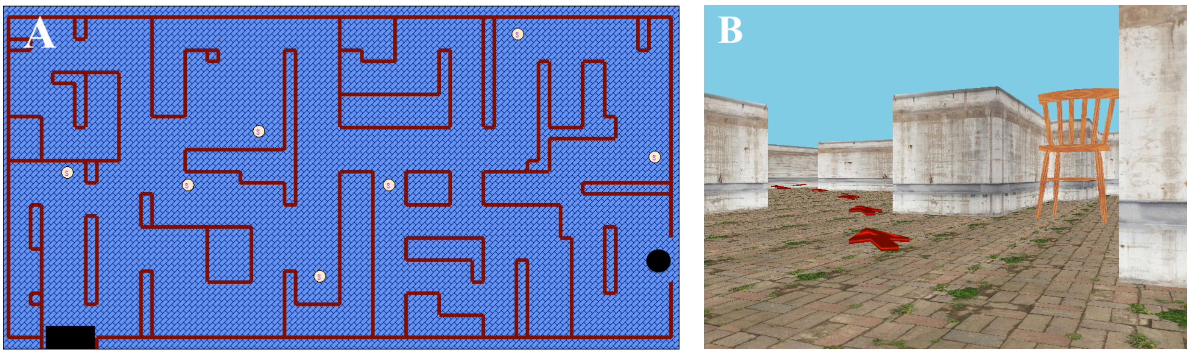

Figure 1. (A) a 2D map of the route maze; a black filled circle denotes a starting point, white filled circles refer to local landmarks locations and a black filled rectangle marks the end point of the maze; (B) a sample frame of the rendered 3D virtual environment used in the route-learning task; the arrows direct participants from the starting position to the end point of the maze.

In the second phase, for route testing, the participants were asked to walk all the way back to the starting point of the same maze as in the route learning phase, using exactly the same path they had taken in order to reach the end point in the first part of the route experiment. This time no red arrows were present to help the subjects and they only had one trial to complete the virtual walk, although all seven local landmarks remained in their previous locations. As in the first phase of the task, navigational performance measures such as time, the length of the path, velocity and the number of mistakes were recorded. This condition tested the route memory of participants and their ability to follow environmental cues in form of local landmarks.

2.3.3 Personality and individual differences questionnaires

Upon completion of the maze task, the study followed procedures of similar studies in the field (Castelli et al., 2008; Chai & Jacobs, 2009; Livingstone & Skelton, 2007) and all participants were asked to fill out the battery of self-report personality and individual differences questionnaires (see Method). This phase took 10 to 15 minutes on average.

2.3.4 Statistical analysis

Pearson's correlations were performed to explore the relationship between personality, individual differences and navigational performance. Further, four separate multiple linear regression analyses (stepwise method) were carried out to identify potential predictors of each navigational performance indicator (criterion variables).

3. *Results*

Based on the time taken to complete the maze in the route learning phase of the route task, two participants who were more than two standard deviations slower than the group mean were excluded from further analysis. The mean age of the remaining 31 participants was 22.90 (*SD* = 3.62). All inference tests were two-tailed.

Table 1 shows mean scores and standard deviations for all navigational performance measures in both learning and testing phases of the route task.

Table 1

Mean Scores and Standard Deviations for All Navigational Performance Measures for Both Learning and Testing Phases of the Route Task (N = 31)

	Learning phase	Testing phase
Measure	M (SD)	M (SD)
Time	58.74 (6.17)	150.58 (74.99)
Path	95.14 (3.46)	169.27 (66.62)
Velocity	1.63 (0.16)	1.20 (0.26)
Errors	0.42 (0.50)	5.55 (4.38)

Table 2 presents mean scores and standard deviations for all personality and individual differences questionnaires, which the participants were asked to complete after the route task.

Table 2.

Mean Scores and Standard Deviations for All Personality and Individual Differences Questionnaires Used During the Study (N = 31)

Scale	M (SD)
State-Trait Anxiety Inventory	9.68 (2.89)
Wayfinding Anxiety Scale	20.55 (7.46)
International Wayfinding Strategy Scale:	
Route Strategy	3.82 (0.55)
Survey Strategy	2.78 (0.46)
Eysenck Personality Questionnaire:	
Extraversion	8.68 (2.52)
Psychoticism	3.16 (1.92)
Neuroticism	7.26 (3.62)
Immersive Tendencies Questionnaire:	
Involvement	33.39 (9.02)
Games	5.52 (3.08)
Focus	30.90 (5.49)
Total	119.42 (16.27)
Computer Experiece	11.89 (1.62)

3.1 Relationship between personality, individual differences and navigation variables

The Pearson's *r* test was used to explore the relationship between personality traits, individual difference, other related factors and the measures of navigational performance (time, path, velocity and errors) in the experimental route task (Table 3).

Table 3

Pearson Product-Moment Correlations between Personality Traits, Individual Differences and Navigation Measures (N = 31)

Variable	Time	Path	Velocity	Errors
Computer Experience	-.358*	-.385*	.135	-.406*
State-Trait Anxiety	.183	.203	-.157	.222
Wayfinding Anxiety	.363*	.450*	-.104	.376*
IWSS: Route Strategy	-.083	-.121	.039	-.373*
IWSS: Survey Strategy	-.380*	-.363*	.362*	-.409*
EPQR-S: Extraversion	-.224	-.223	.128	.167
EPQR-S: Psychoticism	.255	.429*	.170	.335^
EPQR-S: Neuroticism	-.154	-.081	.202	-.093
ITQ: Involvement	-.302^	-.357*	.029	-.354^
ITQ: Games	-.139	-.170	.034	-.393*
ITQ: Focus	-.080	-.182	-.049	-.275
ITQ: Total	-.340^	-.412*	.059	-.496**

Note. IWSS=International Wayfinding Strategy Scale.
EPQR-S=Eysenck Personality Questionnaire Revised – Short Form.
ITQ=Immersive Tendencies Questionnaire.

^p < .1. *p < .05. **p < .01.

A post-hoc statistical power analysis revealed that for the sample size of 31 subjects the observed power for all significant correlations was found to be in the range from 0.52 to 0.82 (medium to high). The effect sizes for these correlations were moderate to strong. Moreover, correcting the correlations coefficents for the sample size (adjusted *r*) did not change the *r* values significantly.

3.1.1 *Psychoticism*

The Pearson's correlations showed that, participants who reported higher scores on the psychoticism subscale of the Eysenck Personality Questionnaire (Eysenck et al., 1985), covered significantly longer paths than subjects with lower scores on this measure (r=.429, p=.016). The effect size was moderate and 18.4% of the variation was explained.

3.1.2 *Wayfinding anxiety*

Participants who experience higher levels of wayfinding anxiety, as measured by the Wayfinding Anxiety Scale (Lawton & Kallai, 2002), spent significantly more time on completing the task and covered significantly longer distances than those with lower wayfinding anxiety scores (r=.363, p=.044; and r=.450, p=.011; respectively). The effect sizes of both positive correlations were moderate and 13.2% of the variation in the time data and 20.25% of the variation in the path data was explained by these correlations.

3.1.3 *Immersive tendencies*

Subjects who reported stronger overall immersive tendencies and higher scores on the involvement subscale of the Immersive Tendencies Questionnaire (Witmer & Singer, 1998), travelled significantly shorter distances than participants with lower immersive tendencies and involvement (r=-.412, p=.021; and r=-.357, p=.049; respectively). The effect sizes for both negative correlations were moderate. 17% of the variance in the overall immersive tendencies scores and 12.7% of the variance in the involvement subscale data was explained by these correlations. Furthermore, higher overall score on immersive tendencies resulted in a significantly lower number of errors made during the task (r=-.496; p=.005). The effect size was moderate and 24.6% of the variance was explained.

3.1.4 *Application of the survey strategy*

Individuals who use the survey strategy more often (as measured by orientation subscale of the International Wayfinding Strategy Scale, Lawton & Kallai, 2002), were able to finish the task significantly faster and travelled significantly shorter distances than those, who do not rely on this strategy (*r*=-.380, *p*=.035; and *r*=-.363, *p*=.045; respectively). The effect sizes were moderate; 14.4% of the variance in the time data, whereas 13.2% of the variance in the path data was explained by these correlations. Moreover, the use of survey strategy correlated significantly and positively with the velocity of virtual walks (*r*=.362, *p*=.045). The effect size was moderate and 13.1% of the variation was explained by this correlation.

3.1.5 Computer experience.

Participants who reported higher computer experience as measured by the Computer Experience Questionnaire (Schuemie, 2003), completed the maze significantly faster and travelled shorter distances than subjects with a low computer experience (*r*=-.358, *p*=.048 and *r*=-.385, *p*=.033, respectively). The effect sizes of these negative correlations were moderate, although only 12.8% of the variance in the time data and 14.8% of the variance in the path data was explained. Moreover, greater computer experience (measured by the Computer Experience Questionnaire, Schuemie, 2003) and higher exposure to video games (measured by the Immersive Tendencies Questionnaire, Games subscale, Witmer & Singer, 1998) were significantly and negatively correlated with the number of errors (*r*=-.406, *p*=.024; and *r*=-.393, *p*=.029; respectively). The effect sizes were moderate. 16.5% of the variance in the Computer Experience data and 15.4% of the variance in the ITQ Games Exposure data was explained.

3.2 Relationship between personality and individual differences variables

Additional Pearson's *r* tests between personality factors and other individual differences revealed several significant correlations. For example, the level of neuroticism as measured by the Eysenck Personality Questionnaire (Eysenck et al., 1985) was positively correlated with both involvement subscale and overall immersion reported by the participants in the Immersive Tendencies Questionnaire (Witmer & Singer, 1998; *r*=.620, *p*<.001; and *r*=.406, *p*=.023, respectively). The effect size of the correlation between neuroticism and involvement subscale was high-moderate to strong, whereas the effect size of the correlation between neuroticism and overall immersive tendencies score was moderate. Also, individuals, who scored higher on the involvement, exposure to video games subscales and cumulative immersion of the Immersive Tendencies Questionnaire, were more likely to use route strategy. All three correlations were significant (r=.454, p=.010; r=.563, p=.001; r=.445, p=.012; respectively) and their effect sizes were moderate.

3.3 Regression analysis

Four separate multiple linear regressions (all using the stepwise method) were carried out to determine predictive models for each of the navigational performance indicators (criterion variables):

a.) For the time taken to complete the maze as a criterion variable, a significant model emerged: $F(1,29)=4.898$, $p=.035$. However, as the model incorporates only one significant predictor (the usage of survey strategy as measured by the International Wayfinding Scale: B=-62.282, $\beta=-.380$, $p=.035$), it explains only 11.5% of the variance (Adjusted $R^2=0.115$). All other independent variables were not identified as significant predictors and were excluded from the model.

b.) For the length of the path taken as a criterion variable, a significant model was found: $F(5,25)=9.844$, $p<.001$. The model explains 59.6% of the variance (Adjusted $R^2=.596$). Five significant variables incorporated into the model are shown in Table 4.1 below.

c.) For the velocity as a criterion variable, a significant model emerged: $F(1,29)=4.382$, $p=.045$. The model explains only 10.1% of the variance (Adjusted $R^2=0.101$) as it consists of just one significant predictor: the application of the survey strategy (B=.202, $\beta=.362$, $p=.045$).

d.) For the number of errors made during the route task as a criterion variable, a significant model was found: $F(4,26)=9.297$, $p<.001$. This model explains 52.5% of the variance (Adjusted $R^2=.525$) and it includes four significant predictors as shown in Table 4.2 below.

Table 4.1

Summary of Stepwise Regression Analysis for Variables Predicting the Length of the Path (N = 31)

	Model 1			Model 2			Model 3			Model 4			Model 5		
Variable	*B*	*SE B*	□	*B*	*SE B*	□	*B*	*SE B*	□	*B*	*SE B*	□	*B*	*SE B*	□
Wayfinding Anxiety	4.03	1.48	.45*	4.04	1.38	.45**	3.48	1.27	.39*	5.61	1.53	.63**	4.38	1.42	.49**
ITQ: Involvement				-2.65	1.14	-.40*	-2.72	1.04	-.37*	-3.98	1.12	-.54**	-4.30	1.00	-.58**
Psychoticism							12.94	4.96	.37*	12.35	4.64	.36*	14.95	4.20	.43**
ITQ: Focus										5.00	2.24	.41*	5.94	2.01	.49**
Survey Strategy													-56.16	19.56	-.39**
R^2		.20			.33			.47			.55			.66	
F for change in R^2		7.38*			5.39*			6.81*			4.98*			8.24**	

Note. ITQ=Immersive Tendencies Questionnaire.

*p < .05. **p < .01.

Table 4.2

Summary of Stepwise Regression Analysis for Variables Predicting the Number of Errors (N = 31)

	Model 1			Model 2			Model 3			Model 4		
Variable	*B*	*SE B*	□	*B*	*SE B*	□	*B*	*SE B*	□	*B*	*SE B*	□
ITQ: Total	-.13	.04	-.50**	-.12	.04	-.44**	-.11	.04	-.42**	-.12	.03	-.43**
Survey Strategy				-3.25	1.47	-.34*	-3.70	1.34	-.39*	-4.24	1.25	-.44**
Psychoticism							.84	.32	.37*	.96	.29	.42**
Extraversion										.56	.23	.32*
R^2		.25			.36			.49			.59	
F for change in R^2		9.47**			4.90*			7.01*			6.19*	

Note. ITQ=Immersive Tendencies Questionnaire.

*$p < .05$. **$p < .01$.

4. Discussion

The outcomes of this research support several of our proposed hypotheses on the relationship between personality factors, individual differences and navigational performance in virtual environments.

4.1 Factors affecting navigation in the virtual route learning task

4.1.1 Psychoticism

The current study is the first which has identified a direct relationship between psychoticism and navigational performance indicators. Specifially, it is shown that psychoticism was positively correlated with the length of the path taken in the virtual route task and it has also been positively correlated with the number of errors made during the exploration of the virtual scene. Moreover, psychoticism has been identified as one of the strongest predictors in multiple linear regression models for these two performance measures. High levels of psychoticism as a personality construct have been linked with the concepts of impulsivity and sensation-seeking (Pickering, 2004; Zuckerman, 2005). We propose that these two sub-traits of psychoticism may cause the larger number of errors and the longer length of the path taken during the virtual walk. Although further investigation of the causality underlying this relationship is needed, this proposal is consistent with the more erratic and exploratory nature of wayfinding in participants high on psychoticism.

4.1.2 Wayfinding anxiety

The impact of wayfinding anxiety was noticeable most significantly in the correlations with time taken to complete the maze, the length of the path covered while searching for the correct route and the number of errors made during a virtual walk. More specifically, higher levels of wayfinding anxiety impaired participants' abilities to navigate efficiently around the maze. Those with high wayfinding anxiety were generally much slower, travelled significantly longer distances and made more errors than individuals who did not report high levels of wayfinding anxiety. These findings strongly support the earlier results presented by Castelli et al. (2008), Saucier et al. (2002) and Schmitz (1997), who all argued that increased trait, wayfinding anxiety may lead to worse navigational performance. Furthermore Castelli et al. (2008) reported that this decline in performance may affect two specific variables of time and the number of errors. The current study supports these findings and suggests that the wayfinding anxiety also influences the length of distance, which participants travel in order to reach the final destination. It is also interesting to point out that scores on general state anxiety as measured by the State-Trait Anxiety Inventory (Marteau & Bekker, 1992) did not correlate significantly with any of the navigational performance indicators. While it is beyond the scope of the current study, it will be important for future research to address the relationship between trait wayfinding anxiety and general state anxiety and their specific roles in human navigation.

4.1.3 Immersion and neuroticism

Unlike wayfinding anxiety, high levels of immersion exerted positive effects on navigational performance measures. Participants who usually exhibit greater degree of involvement and stronger overall immersive tendencies were more likely to travel shorter distances and made fewer errors in the virtual wayfinding task. This is in line with previous research that has found that increased feeling of immersion can improve human navigation (Nash et al., 2000; Levinthal, 2003). This study has attempted to explain this possible causal link as it was the case in the Alsina-Jurnet & Gutiêrrez-Maldonado's (2010), Alsina-Jurnet et al.'s (2011) and Weibel et al.'s (2010, 2011) experiments. All these authors argued that feelings of presence were more evident in context-specific environments, especially the ones that generated anxiety or negative emotions. However, their studies have not explored whether trait-like immersive tendencies played any particular role in formation of these feelings. Although the current study was not devised to manipulate the emotional context of a virtual scene and therefore it has not explored the mediating effect of state anxiety on the sense of presence, it has still been found that scores on the involvement subscale and the cumulative score on all three subscales of the Immersive Tendencies Questionnaire have strongly and positively correlated with neuroticism as measured by the Eysenck Personality Questionnaire. This finding means that the sense of presence in virtual environments may not only be dependent on neuroticism or particular emotional context of the scene, but also on trait-like immersive tendencies specific to each individual.

4.1.4 Survey strategy

It is widely accepted that men are more likely to employ survey-based strategies than women (Castelli et al., 2008; Martens & Antonenko, 2012). It is also believed that this is the main reason why male participants perform better in navigational tasks than females. In this study, use of survey knowledge significantly improved performance on all navigational measures, meaning that individuals employing this wayfinding strategy spent less time on finding their way, travelled much shorter distances, reached higher mean velocity and made fewer errors than subjects utilising route strategy. The positive impact of survey strategy on all the performance measures in this study strongly supports previous findings that the application of survey strategy in the route learning task leads to an improved navigation (Hund & Minarik, 2006). Moreover, it provides empirical evidence that this can explain performance differences both between and within genders. It is noteworthy that this significant influence of employed survey strategy on navigational performance was observed despite a lack of any global landmarks used in the route learning task. This suggests that the survey knowledge could be formed from the route information such as local landmarks and may rely on geometric rules and geographic information e.g. cardinal directions, which function as tools to create a mental map of an unknown area.

4.1.5 Computer experience

Computer experience significantly affected a number of navigation performance measures in the route learning task. For example, participants who reported higher computer exposure and greater experience in video games were more likely to complete the maze faster, making fewer errors and taking shorter paths than less computer experienced individuals. These findings support the claims of other authors (Head & Isom, 2010; Lin et al., 2012, Richardson et al., 2011), who suggested that higher computer experience and exposure to video games enhance navigational abilities in virtual settings. Given that the low level of computer experience has a detrimental effect on computer self-efficacy (Compeau & Higgins, 1995) and therefore performance (Ortiz de Guinea & Webster, 2012; Smith, 2002), it is possible that the navigation measures in this task are related to the lack of familiarity with the mode of presentation. We believe that it would be very interesting to investigate whether both computer experience and computer self-efficacy are related to any specific personality traits. The only research known to the authors that addressed the issue of personality correlates of computer self-efficacy (but not computer experience) was carried out recently by Saleem et al. (2011), who found positive correlations between computer self-efficacy and two personality traits, as measured by the Eysenck Personality Questionnaire: neuroticism and extraversion. However, these correlations were significant for female participants only and the results are yet to find further support in other studies.

4.2 Navigation in virtual versus natural environments.

The ultimate aim of exploring navigation in a virtual environment must be to generalise findings to understand real-world navigation. Although VE-specific influences have been identified in this research, it is important to point out that this study supports the findings of the few studies which have carried out explorations of navigation in a real-world settings (Lawton et al., 1996; Malinowski & Gillespie, 2001). We confirmed the negative effects of wayfinding anxiety on navigation performance and the positive influence of the application of survey strategy in route learning tasks. This supports the transferability of results between natural and virtual tasks. At the same time, the role of personality traits in navigation in real-world settings have not been explored. Until this has been done, the similarities in personality factors involved in real-world and virtual environments can only be inferred.

5. *Conclusion*

This study has provided quantitative support for the hypothesis that some personality traits (e.g., psychoticism, wayfinding anxiety and neuroticism) as well as some individual differences (e.g., immersive tendencies) may influence the efficiency of human wayfinding in virtual environments. The obtained results also demonstrated potential effects of adopted wayfinding strategies on navigational performance within participants of one gender only.

It is believed that in the future these and similar findings may lay the foundations for a more comprehensive model of human wayfinding in the virtual environments incorporating such variables as presence, immersive tendencies and personality traits. The currently favoured model designed by Chen & Stanney (1999) does not include these factors neither as primary nor secondary components of the wayfinding-navigation model in VEs.

It is also very likely that future research will attempt to investigate differences in navigation performance between various environments (*i.e.* natural, simulated and virtual) to provide a fully-integrated model of wayfinding and allow generalisability and transferability of findings across different real-world or artificial settings. Practical applications of these future studies may include for instance a development of highly-customisable virtual training programmes for medical, emergency services, pilots or drivers and education or learning aids for children and adults. They can also become implemented in online or offline navigational tools to improve wayfinding and spatial abilities of end-users. Moreover, given recent research into the link between personality disorder and internet use, it would also be interesting for future research to consider personality disorder as well as differences in computer use in a navigation experiment. Consequently, this and similar studies open new and exciting avenues for research not only in the cognitive and experimental domains of psychology, but also in computer science, education and usability.

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