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The effect of gender and spatial anxiety on navigation ability

Nala Groot

Master Thesis Clinical Neuropsychology

Faculty of Behavioural and Social Sciences – Leiden University

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Student number: 1466461

Daily Supervisor: Ineke van der Ham, Department of Health, Medical and Neuropsychology; Leiden University
CNP-co-evaluator: Rebecca Schaefer, Health, Medical and Neuropsychology Unit; Leiden University

Content

Abstract

The objective of the current study was to investigate how gender and spatial anxiety affect navigation ability. This information can be used to develop diagnostic and treatment tools for people who are impaired in their navigation ability, as these tools are not yet available. Previous studies regarding navigation ability have investigated the effects of gender and spatial anxiety on navigation ability, as separate factors. However, none have looked into how the two factors relate to navigation ability when combined, in which spatial anxiety could mediate the relationship between gender and navigation ability. If spatial anxiety mediates the effect of gender on navigation ability, this means that previous findings regarding gender might have been partly caused by spatial anxiety, leading to the possibility that the previously reported effects could actually be different. Healthy university students (N = 87) participated in virtual reality (VR) based navigation tasks, based on the Virtual Tübingen programme, to measure their navigation ability, and filled out the Wayfinding Questionnaire, to measure their spatial anxiety levels. Gender and spatial anxiety were not found to affect navigation ability, ruling out spatial anxiety as a mediator in the relationship between gender and navigation ability. Women are found to experience higher levels of spatial anxiety than men. There were no differences in performance on the navigation tasks, nor did men or women perform better or worse on specific navigation tasks. The current study could not confirm that gender and spatial anxiety affect navigation ability. Further research is required, as the current findings contradict previous reports. It is important to take gender traits, gender role attitudes and bias into account, in addition to biological gender and spatial anxiety, adding different testing times for spatial anxiety. Developing more accurate testing tools and methods could improve the validity and reliability of the results.

Introduction

Navigation is a skill that is crucial in a person's daily life. It enables a person to find their way to a new location, and allows them to remember the route to a familiar destination. However, not everyone is equally skilled at finding their way. The objective of this study was to investigate navigational differences between people and look into possible explanations as to where these differences originate from. One of these explanations could be gender, as multiple studies have found men and women to perform differently from one another (Lawton, 1994; Nori, Mercuri, Giusberti, Bensi, & Gambetti, 2009; Levay, Gonda, & Labadi, 2016). Another factor that could affect navigational performance is spatial anxiety, which is thought to have a negative effect on navigation ability (Nori et al., 2009; Levay et al., 2016). The current study will look further into individual variation in navigation ability, by researching the relationship between gender and navigation ability, as well as by investigating the potential role of spatial anxiety as a mediator.

In the current study, the ability to navigate is viewed as a construct which incorporates three fundamentally different components: landmark-based, location-based and path-based navigation (Claessen & Van der Ham, 2017). Landmark-based navigation is based on recognising landmarks. Location-based navigation is associated with being able to recall location knowledge and use this knowledge to indicate the direction of one location relative to another. This can be separated into allocentric (object-to-object) and egocentric (self-to-object) perspectives (Zhong & Kozhevnikov, 2016). The last component is path-based navigation, which consists of knowledge of paths that connect locations. This can be separated into route (the route from an egocentric perspective) and survey (map-like, allocentric perspective, which is not associated with the position of the person) perspectives (Claessen & Van der Ham, 2017).

Not only are these components functionally dissociable, they are discernible on a neural level as well. Several parts of the brain are thought to be associated with navigation ability, which might show functional or structural differences between people. This could be an explanation for differences in the ability to navigate. Additionally, this information can be used to explain why specific brain damage can cause particular navigational problems. Areas involved in navigation are, among others, the parahippocampal cortex, which is associated with creating representations of the outside world (Epstein et al., 2005), the retrosplenial cortex and hippocampus to create survey-based, map-like representations (Wolbers & Büchel, 2005) and the prefrontal cortex, which enables the executive functioning needed to create and retrieve these representations (Ciaramelli, 2008). A representation like this is called a cognitive map, a “flexible internal representation of the structure of the environment that is not associated with a specific orientation” (Wolbers & Hegarty, 2010).

Although it is clear the construct of navigation integrates the three described navigational components, and evidence of this can be found both functionally and structurally, there are other personal factors that could possibly affect navigation ability. One of these factors is gender. It has been reported that women appear to prefer a more route-based navigation strategy, while men often prefer a survey-based navigation strategy (Lawton, 1994; Nori et al., 2009; Levay et al., 2016). Nori et al. (2009) also investigated gender, in which they not only looked at biological gender, but additionally took personality traits (i.e. feminine or masculine) into account. A questionnaire was used to discern masculine and feminine personality traits, which were separate from biological gender (e.g. female participants could have a masculine personality and vice versa). Results showed feminine people were more likely to use route-based strategies, compared to masculine people.

In addition to gender, Nori et al. (2009) investigated spatial anxiety, which is the fear of getting lost. Spatial anxiety has been reported to be negatively related to navigational performance (Levay et al., 2016). Meaning that people who do not perform well in finding their way, in other words, get lost more often, experience a higher level of spatial anxiety. Higher levels of spatial anxiety have been reported in women, compared to men, as well as in route-based strategy use, compared to survey-based strategy use (Lawton, 1994; Schmitz, 1999). This was supported by the finding that women, or people with a feminine personality, and high levels of anxiety appear to be more likely to use route-based strategies. Men, however, or people with a masculine personality, and low levels of anxiety, appear to be more likely to use survey-based strategies (Nori et al., 2009). Unrelated to gender, Levay et al. (2016) found that an elevated spatial anxiety level was correlated with a worsened detection time and spontaneous memorisation of landmarks.

Incorporating all these different factors together, perhaps one might get a clearer understanding as to how they could affect someone’s navigation ability. As stated above, localised function in certain brain areas might explain why specific brain damage can cause particular navigational problems. However, the other factors such as gender and spatial anxiety might influence this navigational ability, without the cause of localised function. It is important to understand gender differences, as this information might be useful in understanding why men and women differ in navigation ability. Is it caused by biological gender, are gender traits the discerning factor, or could it be a combination of both? If it is known how gender influences navigation ability, this could be used in diagnostic and treatment tools, for example to determine if a person may be more inclined to use and have used a more female or male approach, which in turn can help to understand what treatment should focus on. The current study will look into the effects of biological gender, rather than gender traits, to discern if biological gender on its own, influences navigation ability. With regard to investigating spatial anxiety, this factor is relevant when taking into account that people who are no longer able to navigate correctly, might experience this fear of getting lost at higher levels. In turn, this will decrease their ability to navigate even more. If it is indeed the case that spatial anxiety has an influence on the ability to navigate, this has to be incorporated into diagnostic and treatment tools. For example, if anxiety plays a large role in the navigational problems one is experiencing, treatment needs to focus on reducing spatial anxiety, in addition to other treatment, to gain the best results. Additionally, if spatial anxiety mediates the relationship between gender and navigation ability, this gives insight into previous findings regarding gender. If spatial anxiety is a mediator, previous findings might have reported gender effects that are actually different, because of the influence of spatial anxiety.

It is important to take gender and spatial anxiety into account to understand how strongly these different factors influence navigation ability. It is known there is a high rate of people who report experiencing impaired navigation ability after sustaining brain damage. For example, as much as 29% of stroke patients report experiencing problems with navigation (Van der Ham, Kant, Postma, & Visser-Meily, 2013). However, it is yet unknown how the different factors work together within navigation ability. It is important to investigate all these different factors together, as this knowledge can be used to develop diagnostic and treatment tools for navigational problems. For example, if a large part of a patient’s navigation problems is influenced by spatial anxiety, treatment should focus more on reducing this. However, if spatial anxiety is low, it will not be useful to focus on this in treatment. Although gender can perhaps not directly be implemented into treatment, it might be useful in understanding why a similar type of brain damage results in different types of navigation impairment, in different people. Additionally, it could explain why certain treatment might not work for people, but does aid others. As of now, diagnostic and treatment tools are not yet widely available, although it is clear that people suffering from navigational problems, for example as a result of brain damage, could benefit from this.

Based on the findings above, the current study will be looking into how gender and spatial anxiety influence navigational ability. This will be done by investigating the following questions: 1) Does gender affect navigation ability, in which it is expected that women perform worse than men? 2) Does gender affect spatial anxiety, in which it is expected that women experience higher levels of spatial anxiety, compared to men? 3) Does spatial anxiety negatively affect navigation ability, in which it is expected that higher levels of spatial anxiety lead to a decrease in navigation ability? 4) Is spatial anxiety a mediator in the relationship between gender and navigation ability, in which it is expected that spatial anxiety does mediate this relationship? 5) Is there a performance difference between the different types of navigation (i.e. route and survey), in which it is expected there is no difference on a task level, however in which, 6) women perform better on route tasks versus survey tasks, while men perform better on survey tasks?

Methods

Participants

University students were recruited at Leiden University (*N* = 87, 34 male, 52 female, 1 missing) age ranging from 18-30, *M* = 22.07, *SD* = 2.74). Participants were asked to fill out a questionnaire, which was used to screen them for psychiatric and physical disorders. Participants were excluded if they had a psychiatric disorder or had experienced any type of brain injury. Participants needed to have access to a PC/Mac and the internet. Informed consent was given by the participants at the start of the study. Participants were rewarded with 9 university credits or €27,- after completing the final block of testing. If a participant stopped prematurely, they were compensated for the last block they attended.

Measures

During the first part of the study participants were asked to first fill out a demographic questionnaire, of which only the gender response was used, and the Wayfinding Questionnaire, after which they performed navigational tasks based on the Virtual Tübingen programme.

The Wayfinding Questionnaire. This questionnaire measured self-reported navigation ability and spatial anxiety. The questionnaire consisted of 22 items, which could be answered on a 7-point Likert scale ranging from 1 “not applicable to me at all” to 7 “very applicable to me”, apart from question 14 to 16, which range from 1 “not uncomfortable at all” to 7 “very uncomfortable”. Eight of the items represented spatial anxiety, in which a higher score indicates a higher anxiety level. Which was later reversed for analysing the data. The Wayfinding Questionnaire was found to show discriminant validity with small to medium effect sizes (*d* = 0.20-0.51), internal consistency of the subscales, which showed strong correlation with the total score (De Rooij, Claessen, Van der Ham, Post, & Visser-Meily, 2017; Claessen, Visser-Meily, De Rooij, Postma, & Van der Ham, 2016b). Only the spatial anxiety subscale of this questionnaire was used in the current study.

Virtual Tübingen programme. This was a virtual reality-based programme to test navigation ability. Participants were shown a virtual route through the city of Tübingen, after which six tasks were performed, related to this route. The tasks were performed on a 17” laptop. Four of these tasks were used in the current study: Route sequence, Route continuation, Distance estimation and Location on map. During the Route sequence task participants were shown eight numbers, which represented the intersections on the route, and were asked to recall the order of the turns made during the route. This task was scored according to a percentage of correct answers (range: 0-100) and was based on route type navigation. The Route continuation task relies on the 8 intersection points shown during the virtual route. The intersection points were shown in random order and participants were asked to recall which direction was taken at the intersection point. This was a route-based navigation type task, which was scored according to the percentage of correct answers (range: 0-100). During the Distance estimation task, participants were asked to estimate the distance between two locations. They were shown three images of locations encountered on the viewed route: two images had to be compared to a goal image, after which participants had to choose which of the two images was closer in distance to the goal image. This task was based on survey type navigation and consisted of 8 trials. Scoring was done according to the percentage of correct answers (range: 0-100). During the Location on map task, participants were shown an image of a location on the route and were asked to click on the correct location on the map that corresponds to this image. This task was based on survey type navigation and consisted of 8 trials. Scoring was done according to the number of pixels the given answer deviates from the correct answer. The total score was the average deviation on the trials. This was a survey-based navigation type task. The Route sequence and Route continuation task are based on previously used tasks. Moderate overlap was found between real life and the virtual navigation tasks ($r = 0.535$), which indicates virtual tasks are a valid tool to measure navigation ability (Claessen, Visser-Meily, De Rooij, Postma, & Van der Ham, 2016a).

Procedure

The study consisted of three consecutive stages: pre-training, training and post-training, however, for the current study only the data from the pre-training stage will be used. During the first stage participants were presented with, and asked to sign an informed consent form and the procedure of the study was explained. Participants were then asked to fill out the Wayfinding Questionnaire, of which only the spatial anxiety subscale was used in the current analyses, and a general demographic questionnaire, of which only gender was used. Participants were shown a video walking through the virtual city of Tübingen twice. They were asked to perform six navigation tasks regarding the video they had just watched. Four of these tasks were used in the current study: a Route sequence task, a Route continuation task, a Distance estimation task and a Location on map task. After this a neuropsychological test battery was performed, however, data from these tests were not included in the current study.

Design

The current study was part of a larger study, which investigated navigational problems in stroke patients. The current study was performed using a within-subject and between-subject design. The within-subject factors were the performance on the navigational tasks and the level of spatial anxiety. The between-subject factor was gender.

Statistical analyses

Statistical analyses were performed using SPSS. The participant who did not report their gender was removed from analyses concerning gender. Before conducting the analyses, a composite Z-score was calculated for the navigation ability; Route sequence, Route continuation, Distance estimation and Location on map. A mediation analysis was performed to investigate questions 1 through 4 in which the relationship between the independent variable gender and dependent variable navigation ability was tested, the mediating factor being spatial anxiety. A visual of this is shown in Figure 1. Navigation ability was based on the Z-scores of the aforementioned described Tübingen tasks, and spatial anxiety on the mean score on the spatial anxiety subscale from the Wayfinding Questionnaire. Gender was a dichotomous variable, while navigation ability and spatial anxiety were interval variables. Assumptions of normality, linearity of both independent and dependent variables, normality and homoscedasticity of residuals were checked, and multicollinearity of the independent variables was examined by assessing VIF values.

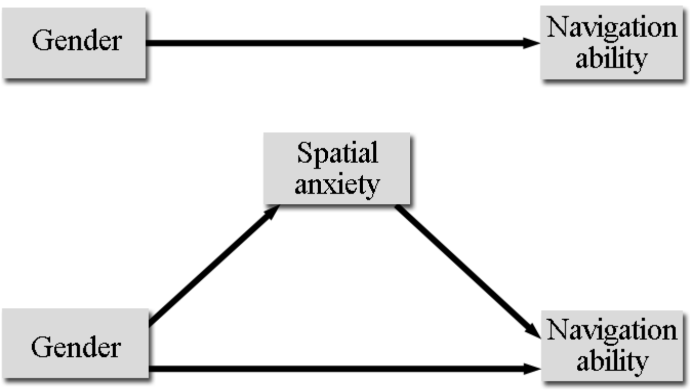

Figure 1. Mediation model for gender and navigation ability, mediated by spatial anxiety.

First, a linear regression analysis was performed to investigate the relationship between gender and navigation strategy (1). It was expected that men would perform better on navigation ability. Second, a linear regression was performed to investigate the relationship between gender and spatial anxiety (2). It was expected that women experience a higher level of spatial anxiety, compared to men. Third, a linear regression was performed to investigate the relationship between spatial anxiety and navigation ability (3). It is expected to find that higher levels of spatial anxiety were correlated with lower performance on navigation ability. Lastly, a multiple linear regression and the Sobel test would be performed to investigate the relationship between gender, spatial anxiety and navigation ability together and the significance of the indirect effect of spatial anxiety, in case gender and spatial anxiety were found to have a significant effect on navigation ability and gender was found to have a significant effect on spatial anxiety (4). It was expected that female gender and spatial anxiety would have a significant negative effect on navigation ability and that spatial anxiety would be a significant mediating factor in the relationship between gender and navigation ability.

To investigate questions 5 and 6, regarding the differences on performance on the different navigation tasks (Route sequence, Route continuation, Distance estimation and Location on map; 5) and compare the performance on the tasks within gender (6), a repeated measures ANOVA was performed. This was done both with and without gender as a variable. Assumptions of normality and sphericity were checked and the data was checked on significant outliers. The Z-scores of the Route sequence, Route continuation, Distance estimation and Location on map tasks were used as within-subject variables and gender as a between-subjects variable. It was expected that women would perform higher on the Route sequence and Route continuation task, compared to the Distance estimation and Location on map tasks. It was expected that the men's performance would show the opposite. Performance on the navigation tasks in general was also investigated, to see if there were differences within navigation performance in general. No significant differences were expected, as the differences are expected to be found within the genders, and not in general.

Results

Before conducting the regression analyses, the assumptions of normality, linearity of both independent and dependent variables, normality and homoscedasticity of residuals were checked, and multicollinearity of the independent variables was examined by assessing VIF values. No violations were found.

A simple linear regression was performed to investigate hypothesis 1, that males would perform better on navigation ability, compared to females. The results of this regression analysis are displayed in Table 1 and Table 2.

Table 1. *Regression analysis of gender and navigation ability*

Model		df	F	Sig.
1	Regression	1	0.070	0.792[b]
	Residual	84		
	Total	85		

a. Dependent Variable: Navigation ability
b. Predictors: (Constant), Gender

Table 2. *Regression analysis of gender and navigation ability*

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	t	Sig.
1	(Constant)	0.058	0.292	0.200	0.842
	Gender	-0.099	0.375	-0.265	0.792

a. Dependent Variable: Navigation ability

Gender does not significantly affect navigation ability (F(1, 84) = 0.070, p = 0.792), with an R^2 of 0.001. Table 2 displays a participants' predicted navigation ability is 0.058 - 0.099 (gender). In this case gender can only be male (0) or female (1).

A simple linear regression was performed to investigate the hypothesis 2, that females would experience higher levels of spatial anxiety, compared to males. The results of this regression analysis are displayed in Table 3 and Table 4.

Table 3. *Regression analysis of gender and spatial anxiety*

Model		df	F	Sig.
1	Regression	1	5.168	0.026[b]
	Residual	84		
	Total	85		

a. Dependent Variable: Spatial anxiety
b. Predictors: (Constant), Gender

Table 4. *Regression coefficients of gender on spatial anxiety*

		Unstandardized Coefficients			
Model		B	Std. Error	t	Sig.
1	(Constant)	5.493	0.164	33.577	0.000
	Gender	-0.478	0.210	-2.273	0.026

a. Dependent Variable: Spatial anxiety

Gender was found to significantly influence spatial anxiety (F(1, 84) = 5.168, p = 0.026), with an R^2 of 0.058. This indicates there is a significant negative relationship between gender and spatial anxiety. Table 4 displays a participants' predicted spatial anxiety is 5.493 - 0.478 (gender). Again, gender can only be male (0) or female (1). This indicates that females score significantly lower than males. A lower score indicates a higher anxiety level.

A simple linear regression was performed to investigate hypothesis 3, that higher levels of spatial anxiety result in lower performance on navigation ability. The results of this regression analysis are displayed in Table 5 and Table 6.

Table 5. *Regression analysis of spatial anxiety and navigation ability*

Model		df	F	Sig.
1	Regression	1	1.512	0.222[b]
	Residual	85		
	Total	86		

a. Dependent Variable: Navigation ability
b. Predictors: (Constant), Spatial anxiety

Table 6. *Regression coefficients of spatial anxiety on navigation ability*

		Unstandardized Coefficients			
Model		B	Std. Error	t	Sig.
1	(Constant)	-1.191	0.985	-1.209	0.230
	Spatial anxiety	0.229	0.186	1.230	0.222

a. Dependent Variable: Navigation ability

Spatial anxiety was found not to significantly influence navigation ability ($F(1, 85) = 1.512$, $p = 0.222$), with an R^2 of 0.017. Table 6 displays a participants' predicted navigation ability is -1.191 + 0.229 (spatial anxiety), in which spatial anxiety is the individual score on the Spatial anxiety subscale of the Wayfinding Questionnaire, and again that it is not a significant positive relationship.

Due to gender and spatial anxiety not having a significant effect on navigation ability, the multiple linear regression of both gender and spatial anxiety's effect on navigation ability and the Sobel test were not performed, as hypothesis 4, that anxiety is a significant mediator in the relationship between gender and navigation ability, was already rejected based on the aforementioned findings.

A repeated measures ANOVA was performed to investigate hypothesis 5, that there would be no difference on the performance on four different navigation tasks, two of which represent route-based navigation (Route sequence and Route continuation), while the other two represent survey-based navigation (i.e. Distance estimation and Location on map) and 6, that women used more route-based navigation, while men used more survey-based navigation. Assumptions of normality and sphericity were checked and the data was checked on significant outliers. A Huynh-Feldt correction was used because the assumption of sphericity was violated. Although the assumption of normality was violated for the variables Route sequence, Route continuation and Direction estimation, it was decided to continue with the repeated measures ANOVA, based on histograms and Q-Q plots. This means the results should be interpreted more carefully.

A repeated measures ANOVA with a Huynh-Feldt correction showed that that the navigation ability did not significantly differ between the four navigation tasks ($F(2.679, 225.041) = 0.135$, $p = 0.924$, partial $\eta^2 = 0.002$), nor did it show a significant interaction between navigation task and gender ($F(2.679, 225.041) = 1.468$, $p = 0.227$, partial $\eta^2 = 0.017$).

As stated above, no significant differences in performance between the four tasks, or interaction between gender and navigation task was found. This indicates there were no significant differences in navigation ability on the four navigation tasks, on its own and within the two genders. Supporting this finding, Figure 2 displays a visual of how the mean scores on the navigation tasks differ per gender, with error bars displaying the standard error of the mean (SEM). The unstandardized performance scores on the tasks are displayed in Table 7.

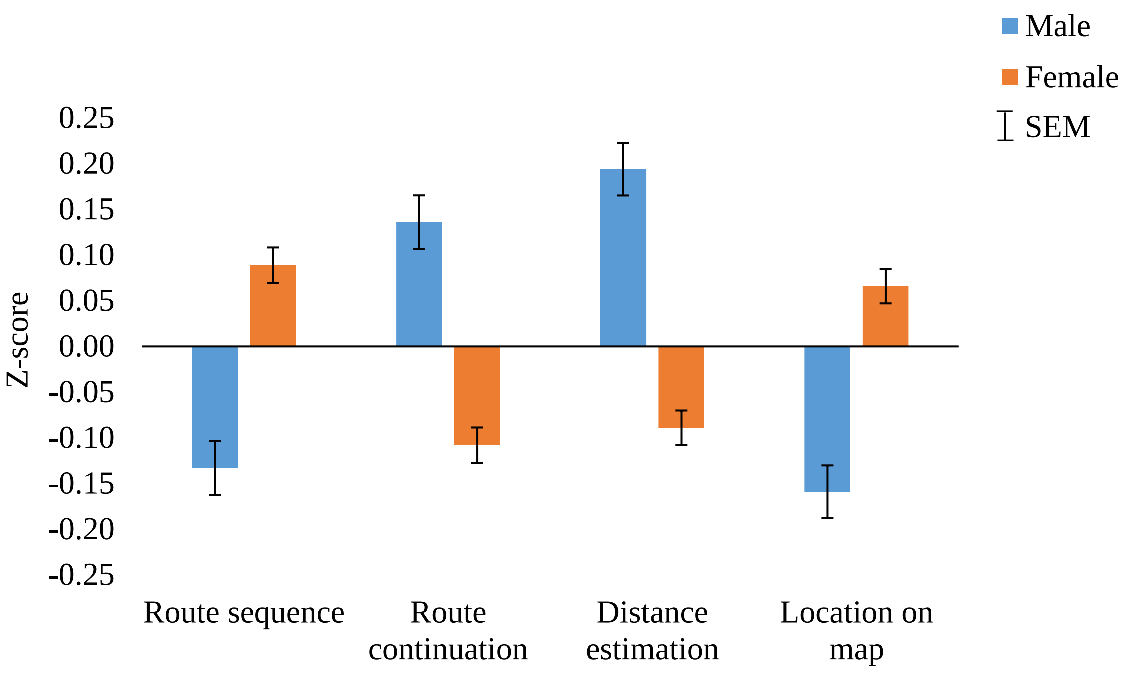

Figure 2. Means per navigation task and gender, with SEM in error bars

Table 7. *Unstandardized performance on the navigation tasks per gender*

Gender	Navigation task	N	Minimum	Maximum	Mean	Std. Deviation
Male	Route sequence	34	0.00	100.00	57.35	28.39
	Route continuation	34	37.50	100.00	71.32	18.08
	Distance estimation	34	25.00	100.00	69.49	19.02
	Location on map	34	8.88	363.38	130.82	84.58
Female	Route sequence	52	0.00	100.00	63.22	29.44
	Route continuation	52	25.00	100.00	66.59	20.22
	Distance estimation	52	25.00	100.00	63.70	20.60
	Location on map	52	12.50	272.75	146.26	53.76

Discussion

It is important to gain more knowledge of the workings of navigation ability, to understand what factors make up, or affect the ability to navigate. The current study aimed to investigate how gender and spatial anxiety influence navigation ability, to understand how individual factors explain differences in navigation ability between people. This knowledge can then be used for developing the most effective diagnostic and treatment tools. As there are people suffering from navigation impairment after brain damage, for example approximately 30% after a stroke (Van der Ham et al., 2013), there is a need to develop these diagnostic and treatment tools, as they are currently not yet available. Healthy university students were recruited to participate in a VR based experiment in which their gender was registered and the performance on four navigation tasks and the spatial anxiety levels were measured.

The first hypothesis was that women would generally perform worse at navigating, compared to men. However, this could not be supported by the current findings, as no differences in performance between men and women were found. This contradicts previous findings regarding gender differences in navigational performance (Lawton, 1994; Schmitz, 1999; Nori et al., 2009; Levay et al., 2016). A possible explanation for this could be related to an expectancy bias and differences between how strong this bias might have been in the past when previous research was performed, compared to current times. It was found that if there was a performance expectancy, of either men or women performing better, the performance of men and women, respectively, increased on a mental rotation task (Heil, Jansen, Quaiser-Pohl, & Neuburger, 2012). This means that if there is an expectancy of men performing better, compared to women, this could influence the performance of both men and women. Perhaps in the past this expectancy bias was stronger, explaining a difference between men and women, and has decreased over time.

Another explanation could be that most studies tend to focus on differences in how men and women navigate, and do not state that women perform worse than men. Perhaps women do not generally perform worse while navigating, compared to men, but they simply use different strategies. This ties in with hypotheses 5, that there are no differences on a task level (i.e. no differences between performance on the four navigation tasks), and 6, that there are differences in performance within gender, in which women perform better on route versus survey tasks (i.e. Route sequence and Route continuation versus Distance estimation and Location on map). No differences were found in performance on a task level, nor within the genders. This indicates that within the gender groups (male or female), the performance did not differ between the four navigation tasks. Women do not perform better on route tasks, compared to survey tasks and men do not perform better on survey tasks, compared to route tasks. In these hypotheses, the expectation relied on performance on these tasks, and not on whether either route or survey strategy was preferred, as this was not measured in the current study. However, the aforementioned articles did find differences in strategy use between the genders. Additionally, an fMRI study shows there are neural differences between men and women, substantiating the possibility of different strategy use (Grön, Wunderlich, Spitzer, Tomczak, & Riepe, 2000). In the current study, no differences were found between the performance on the different navigation tasks, which was expected. In combination with the finding regarding gender differences, this could indicate that there are no differences in the general performance, because there are no differences within and between the genders. This means that performance on navigation as a whole is likely to be stable within a person. However, this does not say anything regarding differences in preferred strategy use between women and men.

Combining both expectancy bias and differences in strategy use, instead of performance on different strategy based tasks, changing gender role attitudes could explain why the current findings contradict previous reports. Nori et al. (2009) reported that strategy use was related, not only to biological gender, but to gender traits, specifically femininity or masculinity. The masculine/feminine trait-mediated the relationship between biological gender and navigation ability. This could be interesting, as the gender traits, social construct and attitudes towards both of these have changed over time. Whereas in the past feminine traits were more corresponding with female gender, and masculine traits with male gender, this is not necessarily so anymore in current times (Barth, 2016; March, van Dick, & Bark, 2016). March et al. (2016) reported feminine traits were given to people in a homemaker role, while male traits were given to a person in an employee/breadwinner role, regardless of their biological gender. Although nothing can be said specifically about associations with navigation ability, the general gender role attitudes (e.g. regarding women being the primary homemaker, and men being the primary breadwinner, or women working) have become more liberal and egalitarian, for example compared to 1994, when Lawton reported on gender differences in navigational performance (Cotter, Hermsen, & Vanneman, 2011; Knight & Brinton, 2017). If this is indeed the case, this could explain why biological gender was found to have an effect in the past, but not anymore, as gender traits have become less in line with biological gender.

In addition to the effect of gender, the current study looked into how spatial anxiety affects navigation ability. Hypothesis 2 stated that women would experience higher levels of anxiety, which led to hypothesis 3, that people with higher spatial anxiety levels would perform worse when navigating, perhaps regardless of gender. Hypothesis 1, 2 and 3 combined were the base for hypothesis 4, in which spatial anxiety was expected to be a mediator in the relationship between gender and navigation ability. Although it was found that women experience a higher level of spatial anxiety, this did not influence navigation ability. Nor did spatial anxiety affect navigation ability. This contradicts previous findings, which indicate that spatial anxiety has a negative effect on navigation ability, and is correlated with route strategy use (Lawton, 1994; Schmitz, 1999; Nori et al., 2009; Levay et al., 2016). The current study found that women did experience higher levels of spatial anxiety, compared to men, despite the fact that they did not differ in performance, nor did spatial anxiety influence navigation ability. However, it was not tested if spatial anxiety correlated with specific strategy use, only with performance. The expected mediation of spatial anxiety on gender and navigation ability was not found, as neither gender, nor spatial anxiety had an effect on navigation ability. However, the current study did not confirm women used route-based navigation more, as this was not measured. Perhaps spatial anxiety is still related to route-based navigation use, separate from gender, although this does not influence the outcome that spatial anxiety is not related to navigation performance in general.

Perhaps another explanation for the lack of effect of spatial anxiety on navigation ability could be that there is a difference in the level of spatial anxiety before and during testing. In the current study participants were asked to think about certain situations and report how these situations made them feel. However, it is uncertain if this accurate when the participants are actually performing the navigation tasks.

There were several strengths in this study, that facilitated obtaining reliable results. one of these strengths was the use of VR. This allowed for a controlled environment which was the same for all the participants. For example, all participants saw the exact same environment, whereas in real life this would be nearly impossible as factors such as weather and other people cannot be controlled. VR shows moderate overlap with real-life navigation tests, indicating VR can be used to generalise the findings to real life navigation (Claessen et al., 2016a). Although VR can be used instead of real-life tests, it is important to state the overlap was moderate. Certain factors might be added to enhance this effect. In the current study participants viewed the navigation video on a computer screen. Perhaps the effect of VR compared to real life might be enhanced if participants viewed the video in a more immersive way, for example by wearing a VR head-mounted display. Additionally, this would allow for looking around and following one’s own pace, which was not possible in the current study.

Another strength of this study was the homogeneity of the sample. Participants all had a similar education level and had a maximum age difference of 13 years. This allows for a more reliable measure of gender's effect on the navigation ability, which is then less likely to be influenced by other factors. Although the sample was relatively homogeneous, the assumption of normality was violated for the distribution of scores in three of the four navigation tasks (Route sequence, Route continuation and Distance estimation). This makes the results regarding these tasks less reliable.

As of this moment, the field of navigation and neuropsychology is relatively new. This is a limitation in the sense that there is a scarce amount of previous research to compare findings to. It is more difficult to explain observations and findings, as several aspects are still unexplored or perhaps even unknown.

The current study does not provide enough knowledge to implement into practice, although it indicates there is no need for a tool to decrease spatial anxiety for the sake of improving navigation ability, nor would women and men benefit to tools fine-tuned to their gender. However, it does give guidance for new research. As gender was found to have no effect on navigation ability, it is important to conduct research into why this effect was found in previous research. In this it is vital that not only biological gender is taken into account, but also gender traits and expectancy bias, for reasons explained above.

With regard to spatial anxiety, further research can be conducted into differences between anticipated anxiety and anxiety during navigating. The Wayfinding Questionnaire was filled out before performing the navigation tasks, but perhaps there are differences when a person is actually navigating. Spatial anxiety questions could be asked during, or after the tasks to estimate if the reported spatial anxiety was actually experienced during navigation. This is useful as it can give more insight into the effect of spatial anxiety on navigation. A combination of gender traits, biological gender and spatial anxiety can also be explored. This could shed more light on the relationship between these factors and navigation ability.

Conclusion

The current study was conducted to gain more insight into the relationship between gender, spatial anxiety and navigation ability. In contrast with the expectations and aforementioned literature, it was found that gender and spatial anxiety do not influence spatial anxiety. Women did experience more spatial anxiety, as expected, although this did not affect navigation ability. This indicates that there is a difference between men and women in the level of spatial anxiety they experience, despite the fact that there is no difference in their navigational performance.

Further research is required to gain more insight into the relationship between gender, spatial anxiety and navigation ability, as the current findings contradict previous reports. To do this, the effect of biological gender needs to be compared to the effect of masculinity and femininity. Additionally, spatial anxiety could be tested during or after the navigation tasks, to obtain a more accurate score. Generally, the VR tasks can be developed more, to make the results translate better to real life navigation. Research can be done regarding gender role attitudes and bias, to prevent these factors from interfering, but also to see if they affect the relationship between gender and navigation ability, and if they could explain a difference between past and current findings regarding gender differences on navigation ability. With more accurate outcomes of future studies, the findings can be used to develop specialised diagnostic and treatment tools for people who experience impaired navigation ability as a result of brain damage, that include the factors that have an effect on navigation ability.

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