Archives of Clinical Neuropsychology Advance Access published August 8, 2016

OXFORD
UNIVERSITY PRESS

Archives of CLINICAL NEUROPSYCHOLOGY

The Wayfinding Questionnaire as a Self-report Screening Instrument for Navigation-related Complaints After Stroke: Internal Validity in Healthy Respondents and Chronic Mild Stroke Patients

Michiel H. G. Claessen[1,2,*], Johanna M. A. Visser-Meily[2], Nicolien K. de Rooij[2], Albert Postma[1], Ineke J. M. van der Ham[3]

[1]*Experimental Psychology, Helmholtz Institute, Utrecht University, Utrecht, The Netherlands*
[2]*Brain Center Rudolf Magnus and Center of Excellence for Rehabilitation Medicine, University Medical Center Utrecht and De Hoogstraat Rehabilitation, Utrecht, The Netherlands*
[3]*Department of Health, Medical and Neuropsychology, Leiden University, Leiden, The Netherlands*

*Corresponding author at: Experimental Psychology, Helmholtz Institute, Utrecht University, Heidelberglaan 1, 3584 CS Utrecht, The Netherlands. Tel.: +31 30 2534281.
E-mail address: m.h.g.claessen@uu.nl (M.H.G. Claessen).

Accepted 16 June 2016

Abstract

Objective: In current stroke care, cognitive problems are usually diagnosed in a stepwise manner. More specifically, screening instruments are first applied to support healthcare professionals in deciding whether a second step (an extensive assessment) would be appropriate. None of the existing screening instruments, however, takes navigation ability into account. This is problematic, as navigation impairment after stroke has been shown to be common, more so than previously thought. The Wayfinding Questionnaire (WQ) is therefore presented as a screening instrument for navigation-related complaints after stroke. The internal validity of the WQ was investigated in two samples of participants to establish the final version.
Method and Results: In Study 1, the WQ was administered in a representative sample of 356 healthy participants. Its factor structure was investigated using a principal component analysis. This procedure resulted in deletion of four items and revealed a three-factor structure: "Navigation and Orientation," "Spatial Anxiety," and "Distance Estimation". In Study 2, a confirmatory analysis was performed to directly verify the factor structure as obtained in Study 1 based on data of 158 chronic mild stroke patients. Fit indices of the confirmatory analysis indicated acceptable model fit. The reliability of the three subscales was found to be very good in both healthy participants and patients.
Conclusions: These studies allowed us to determine the final version of the WQ. The results indicated that the WQ is an internally valid and reliable instrument that can be interpreted using a three-factor structure in both healthy respondents and chronic mild stroke patients.

Keywords: Spatial navigation; Stroke; Spatial anxiety; Questionnaire; Screening instrument; Neuropsychological practice

Introduction

In the past decades, the neuropsychological literature has consistently reported that cognitive impairment is commonly observed after stroke and might affect up to 50% of stroke patients (e.g., Duits et al., 2008). This finding is reason for concern, as the presence of cognitive impairment has been associated with a negative influence on the outcome as well as with significant functional problems in daily life (e.g., Galski et al., 1993; Zinn et al., 2004). It is thus vitally important to adequately assess cognitive problems after stroke, given that the information obtained from the assessment can contribute to the rehabilitation treatment, for instance in establishing the treatment strategy or in providing advice to patients and their caregivers (Duits et al., 2008). It should, however, also be noted that an extensive cognitive assessment is a rather costly and time-consuming procedure that might not be required for all stroke patients.

doi:10.1093/arclin/acw044

To achieve efficiency in stroke care, cognitive problems in stroke patients are usually assessed in two stages. Screening instruments are applied in the first stage to obtain an indication of the cognitive complaints that patients have. These instruments are meant to support healthcare professionals in deciding whether or not it would be advisable to refer a patient for a detailed cognitive assessment (i.e., for the second assessment stage). As an example of such a screening instrument, the CLCE-24 has been developed as a checklist for the detection of cognitive and emotional problems after stroke and is suitable to be used by healthcare professionals other than the trained (neuro)psychologist (Van Heugten et al., 2007). Obviously, screening instruments are intended to be quick to administer, low in costs and require limited effort of the patient.

Screening instruments, such as the CLCE-24, cover a broad range of cognitive domains to be as sensitive as possible to cognitive complaints that are known to be common after stroke. None of the existing screening instruments, however, takes into account the ability to navigate. This is striking, as adequate navigation ability is crucial for engaging in the instrumental daily life activities that allow for independent functioning in the community (McCusker et al., 1999). For instance, we usually drive from home to the office in the morning. At the end of the day, we have to stop by the supermarket to buy the ingredients for dinner on the way home and we might go out to visit a friend who lives in another part of the city in the evening. People are thus required to find their way around to be able to participate in such activities.

A series of recent group and case studies has convincingly shown that brain damage resulting from stroke may have detrimental effects on the ability to navigate (e.g., Busigny et al., 2014; Claessen et al., 2016; Ino et al., 2007; Mendez & Cherrier, 2003; Van Asselen et al., 2006; Van der Ham et al., 2010). Using self-report measures, it has even been found that complaints about the ability to navigate are relatively common after mild stroke (± 29%; Van der Ham et al., 2013). All of these findings indicate that navigation ability might generally be neglected in stroke care, given the fact that adequate screening instruments for the detection of complaints about navigation impairment are currently lacking. The goal of the current paper is therefore to present a short but comprehensive self-report screening instrument of navigation-related complaints that can be used in clinical practice to decide whether formal testing of navigation ability is appropriate. If so, an objective navigation test could be applied to determine the presence and severity of the navigation impairment (see for various examples: Arnold et al., 2013; Barrash et al., 2000; Claessen et al., 2016; Maguire et al., 1996).

The Wayfinding Questionnaire (WQ), as presented by Van der Ham and colleagues (2013), appears to be the perfect starting point for the development of a screening instrument of navigation-related complaints. Although the WQ has been used as a self-report instrument of navigation ability in mild stroke patients before, it has not yet been investigated in terms of its psychometric properties. The WQ was initially designed to account for the cognitive complexity that characterizes navigation behavior (Brunsdon, Nickels, and Coltheart, 2007; Wiener, Büchner, and Hölscher, 2009; Wolbers & Hegarty, 2010) and therefore includes items concerning navigation (strategy), mental transformation, distance estimation, orientation, and sense of direction (see Table 1). Moreover, the WQ also takes the emotional aspects of navigation behavior, that is, "spatial anxiety," into account. Spatial anxiety denotes anxious feelings related to performing navigation tasks (Lawton, 1994, 1996) and worrying about getting lost (Schmitz, 1997). Spatial anxiety is a highly relevant concept in the context of navigation, as higher levels have been associated with less adequate and efficient navigation behavior (Walkowiak, Foulsham, and Eardley, 2015).

To summarize, our purpose was to investigate the psychometric properties of the WQ (Van der Ham et al., 2013) with the aim to establish it as a short but comprehensive screening instrument for navigation-related complaints after stroke. As such, the WQ could help healthcare professionals in determining whether or not objective testing of navigation ability is warranted. As a first step in the validation process, the WQ was submitted to a careful analysis of its internal validity (i.e., factor structure and reliability) in a series of two studies in the current paper.

STUDY 1: Factor structure and reliability of the WQ in a healthy sample

Method

Participants. In this study, data of 356 healthy participants (185 female, 52%) with a mean age of 48.0 years (*SD* = 11.2; range = 18–87) were used for analysis. The majority of these data were extracted from databases of a number of other experiments (manuscripts in preparation) in which we had asked healthy people to complete the WQ. Furthermore, the remaining participants were recruited specifically for this study by the experimenters in several ways (e.g., via social media, word of mouth, and our acquaintances). Their mean educational level was 5.8 (*SD* = 1.0; range = 2–7) based on the classification system by Verhage (1964; possible range: 1 = "primary level education" to 7 = "finished university level education"). The assessment of the WQ was performed manually (paper-and-pencil) or digitally after the participant had signed an informed consent form. The study procedures satisfied the regulations as set by the local ethical review board and the Helsinki Declaration.

Table 1. Descriptive statistics (means, standard deviations (SDs), and skewness) for all 26 items of the Wayfinding Questionnaire (WQ) based on the responses of a group of 356 healthy participants

Item		Mean	*SD*	Skewness
1.	I can effortlessly walk back a route I have never walked before, the same way I walked up.	4.68	1.73	−0.57
2.	When I am in a building for the first time, I can easily point to the main entrance of this building.	4.48	1.70	−0.53
3.	If I see a landmark (building, monument, intersection) multiple times, I know exactly from which side I have seen that landmark before.	5.07	1.62	−0.82
4.	In an unknown city I can easily see where I need to go when I read a map on an information board.	5.30	1.67	−1.05
5.	When reading a map, I constantly turn the map into the direction that I am going.	3.49	2.12	0.44
6.	Without a map, I can estimate the distance of a route I have walked well, when I walk it for the first time.	4.32	1.58	−0.43
7.	I can estimate well how long it will take me to walk a route in an unknown city when I see the route on a map (with a legend and scale).	4.47	1.55	−0.66
8.	I can always orient myself quickly and correctly when I am in an unknown environment.	4.54	1.64	−0.53
9.	I always want to know exactly where I am (meaning, I am always trying to orient myself in an unknown environment).	5.04	1.65	−0.84
10.	I am afraid of losing my way somewhere.	5.15	1.72	−0.89
11.	I am afraid of getting lost in an unknown city.	5.17	1.75	−0.81
12.	In an unknown city, I prefer to walk in a group rather than by myself.	4.98	1.85	−0.70
13.	When I get lost, I get nervous.	4.71	1.85	−0.48
	How uncomfortable are you in the following situations (Items 14, 15, and 16):			
14.	Deciding where to go when you are just exiting a train, bus, or subway station.	4.92	1.57	−0.45
15.	Finding your way in an unknown building (e.g., a hospital).	5.11	1.45	−0.59
16.	Finding your way to a meeting in an unknown city or part of a city.	4.42	1.72	−0.20
17.	I find it frightening to go to a destination I have not been before.	5.49	1.72	−1.09
18.	I can usually recall a new route after I have walked it once.	4.50	1.75	−0.41
19.	I am good at estimating distances (e.g., from myself to a building I can see).	4.52	1.59	−0.52
20.	I can orient myself well.	4.89	1.66	−0.76
21.	I am good at understanding and following route descriptions.	5.19	1.47	−0.91
22.	I am good at giving route descriptions (meaning, explaining a known route to someone).	5.02	1.40	−0.75
23.	When I exit a store, I do not need to orient myself again to determine where I have to go.	4.81	1.73	−0.58
24.	I enjoy taking new routes (e.g., shortcuts) to known destinations.	4.88	1.83	−0.67
25.	I have a good sense of direction.	4.78	1.88	−0.71
26.	I can easily find the shortest route to a known destination.	4.85	1.68	−0.67

Note: Scores on the Spatial Anxiety scale were reversed such that high values represent lower spatial anxiety and thus higher navigation ability. *SD* = Standard deviation.

The Wayfinding Questionnaire. The WQ contains the 26 items as displayed in Table 1 (Van der Ham et al., 2013). The 26 items (in Dutch) were manually selected from a more extensive questionnaire (Bosch & Postma, unpublished thesis) consisting of 106 items. The construction of this extensive questionnaire was based on literature review of all domains relevant to *general* spatial ability. With the literature in mind, six domains were identified as relevant to general spatial ability: mental transformation, mental imagery, angle/distance estimation, orientation ability, navigational strategies, and spatial anxiety. In the next step, items were adapted from existing questionnaires (e.g., Blajenkova et al., 2006; Hegarty et al., 2002, 2006; Lawton, 1994; Lawton & Kallai, 2002; Pazzaglia et al., 2000; Schmitz, 1997) or newly developed to cover the six domains that were judged to be relevant to spatial ability. The selection of items for inclusion in the WQ was based on whether the item addressed large-scale spatial ability and not on the theoretical construct it covered. Further expert and nonexpert review was conducted to ensure clarity of the items. Based on this approach, no constraints are likely to be imposed on the latent factors of the WQ.

The selected 26 items concerned questions about navigation (e.g., "I can effortlessly walk back a route I have never walked before, the same way I walked up"), orientation (e.g., "I can orient myself well"), mental transformation (e.g., "When reading a map, I constantly turn the map into the direction that I am going"), distance estimation (e.g., "I am good at estimating distances [e.g., from myself to a building I can see]"), and sense of direction (e.g., "I have a good sense of direction"). A number of items on spatial anxiety (e.g., "I am afraid to lose my way somewhere") were also included. Items were formulated as statements and could be answered on a 7-point Likert scale, ranging from 1 ("not applicable to me at all") to 7 ("totally applicable to me"). Items 14, 15, and 16, however, were formulated as questions and scores of 1 to 7 represented "not uncomfortable at all" to "very uncomfortable," respectively. With the exception of Item 5 and the spatial anxiety items, the WQ-items were stated such that a higher score would reflect higher navigation ability.

Statistical analysis. Scores of Item 5 and the spatial anxiety items (Items 10–17) were reversed, such that a high score reflected high ability and low anxiety. Subsequently, descriptive statistics and skewness values were calculated. Skewness was considered to be present if this measure was below −1.0 or above +1.0.

A factor analysis (i.e., principal component analysis; PCA) was then conducted on the questionnaire scores. This is a common approach to reveal the underlying domain structure and verify item redundancy (Pett, Lackey, and Sullivan, 2003). Prior to the actual analysis, data appropriateness for this statistical procedure was established by addressing the correlation matrix using the following criteria. Firstly, mean correlations between items should be >0.30 and <0.80. The Kaiser-Meyer-Olkin (KMO) statistic as a sample adequacy measure for factor analysis should exceed 0.70 (Hutcheson & Sofroniou, 1999) and individual KMO statistics should also be >0.70. Lastly, Barlett's test of sphericity should be significant ($p < .05$), to indicate that the correlations between the items are sufficiently large for factor analysis.

The actual PCA was then applied to reveal the underlying factor structure of the WQ. The number of factors was determined based on the eigenvalues; factors with an eigenvalue higher than 1.0 were retained. The proposed factor structure was exposed to an oblique (oblimin) rotation to facilitate factor interpretation. An oblique rotation technique was used to allow factors to be correlated, as the WQ-items measured different aspects of the concept of navigation ability but not concepts that are expected to be unrelated. Factor loadings of >0.40 were defined as reflecting a meaningful relationship between the particular item and a given factor.

The reliability of the questionnaire was assessed by calculating the internal consistency (Cronbach's α) of the subscales. Reliability scores between 0.70 and 0.80 are interpreted as good, whereas scores above 0.80 reflect very good reliability (DeVellis, 1991). However, reliability scores exceeding 0.95 might indicate item redundancy (Terwee et al., 2007). Internal consistency was also assessed by correlating the mean scores on the subscales with the other subscales and the mean total score.

Lastly, the relationship between subscale scores and three demographical variables were investigated: gender (independent t-tests), age, and educational level (Pearson correlations). Alpha level was set to 0.05. The statistical procedures were conducted using IBM SPSS Statistics version 22.

Results and Discussion

Descriptives of the WQ. Descriptive statistics of the WQ are provided in Table 1. None of the items suffered from substantial skewness (only Items 4 and 17 slightly exceeded the value of −1.0).

Factor analysis. Mean inter-item correlations ranged from 0.20 to 0.54, but only the mean inter-item correlation of Item 5 did not reach the criterion of >0.30. The KMO measure of sample adequacy was 0.945; very good and well above the criterion of >0.70. Individual KMO values of sampling adequacy ranged from 0.890 to 0.975. Barlett's test of sphericity was significant, χ^2 (325) = 6912.09, $p < .001$, indicating that the correlations between the items were sufficiently high for PCA. Given the above, Item 5 was removed from further analyses.

The PCA was conducted on the remainder of the WQ-items. Three factors with an eigenvalue higher than 1.0 were retained, commonly explaining 62.5% of the variance. The initial factor structure was subjected to an oblimin rotation to facilitate factor interpretability. Table 2 displays the factor loadings of the WQ-items on the rotated three-factor structure. No items showed substantial cross-loadings (i.e., all items loaded above 0.40 on a single factor), which further supports the validity of the three-factor structure. The first factor ("Navigation and Orientation") consisted of fourteen items addressing several cognitive aspects of navigation ability, such as pointing ability (e.g., Item 2), orientation (e.g., Item 8), and sense of direction (e.g., Item 25). All spatial anxiety items loaded on the second factor ("Spatial Anxiety"). Lastly, three items addressing estimation of distances commonly loaded on the third factor ("Distance Estimation").

Reliability analysis (internal consistency). Cronbach's α was found to be very high (0.922) for the Spatial Anxiety subscale (8 items) as well as for the three items of the Distance Estimation subscale (Cronbach's α = 0.830). Cronbach's α of the Navigation and Orientation subscale was also very high (0.947), but such a high Cronbach's α-value (i.e., around or exceeding 0.95) may indicate item redundancy within the scale. Therefore, Pearson correlations were calculated between Navigation and Orientation items and we screened for correlations higher than 0.80. Correlations between three item-pairs exceeded this criterion: Item 1 and 2 (0.842), Item 8 and 25 (0.803) and Item 20 and 25 (0.834). Consequently, Items 1, 20, and 25 were removed. Item 1 was removed because of its conceptual similarity to Item 18. In respect of the other two pairs, Items 8, 20, and 25 were conceptually very similar (i.e., orientation and sense of direction). Item 8 was retained because it had the lowest skewness value. Cronbach's α had now slightly decreased to 0.921. Internal consistency was still very high, but no longer approaching 0.95. Therefore, 11 items were retained in the Navigation and Orientation subscale.

Further assessment of internal consistency revealed significant weak to moderate correlations between mean subscale scores: Navigation and Orientation and Distance Estimation ($r = 0.648$, $p < .001$), Navigation and Orientation and Spatial Anxiety ($r = 0.510$, $p < .001$) and Distance Estimation and Spatial Anxiety ($r = 0.382$, $p < .001$). Subscale scores were also strongly and significantly correlated with the total score: Navigation and Orientation ($r = 0.867$, $p < .001$), Spatial Anxiety ($r = 0.774$, $p < .001$) and Distance Estimation ($r = 0.824$, $p < .001$).

Relationship with demographical variables. Women scored lower on all three WQ-subscales than men (see Table 3). Because equality of variances could not be guaranteed for the subscales Navigation and Orientation and Distance Estimation (Levene's test: both p's $< .001$), corrections of degrees of freedom were applied to these tests. Subscale scores were not related to age and educational level, except for two weak positive correlations between Navigation and Orientation and age ($r = 0.132$, $p = .013$) and Spatial Anxiety and educational level ($r = 0.156$, $p = .003$).

Interim summary of Study 1. The internal validity of the WQ was verified in a large group of healthy people. The final version comprised 22 of the original 26 items, divided over three subscales: Navigation and Orientation (11 items), Spatial Anxiety (8 items), and Distance Estimation (3 items). All subscales were characterized by very good internal consistency, weakly to moderately correlated to the other subscales, and strongly related to the total WQ-score.

Table 2. Factor loadings for the Principal Component Analysis of the Wayfinding Questionnaire (WQ) items (i.e., the pattern matrix) based on the responses of 356 healthy participants

Item		Factor 1	Factor 2	Factor 3
1.	I can effortlessly walk back a route I have never walked before, the same way I walked up.	0.856		
2.	When I am in a building for the first time, I can easily point to the main entrance of this building.	0.770		
3.	If I see a landmark (building, monument, intersection) multiple times, I know exactly from which side I have seen that landmark before.	0.750		
4.	In an unknown city I can easily see where I need to go when I read a map on an information board.	0.450		
6.	Without a map, I can estimate the distance of a route I have walked well, when I walk it for the first time.			0.796
7.	I can estimate well how long it will take me to walk a route in an unknown city when I see the route on a map (with a legend and scale).			0.867
8.	I can always orient myself quickly and correctly when I am in an unknown environment.	0.753		
9.	I always want to know exactly where I am (meaning, I am always trying to orient myself in an unknown environment).	0.612		
10.	I am afraid of losing my way somewhere.		0.847	
11.	I am afraid of getting lost in an unknown city.		0.873	
12.	In an unknown city, I prefer to walk in a group rather than by myself.		0.734	
13.	When I get lost, I get nervous.		0.859	
	How uncomfortable are you in the following situations (Items 14, 15, and 16):			
14.	Deciding where to go when you are just exiting a train, bus, or subway station.		0.724	
15.	Finding your way in an unknown building (e.g., a hospital).		0.712	
16.	Finding your way to a meeting in an unknown city or part of a city.		0.701	
17.	I find it frightening to go to a destination I have not been before.		0.810	
18.	I can usually recall a new route after I have walked it once.	0.841		
19.	I am good at estimating distances (e.g., from myself to a building I can see).			0.788
20.	I can orient myself well.	0.798		
21.	I am good at understanding and following route descriptions.	0.631		
22.	I am good at giving route descriptions (meaning, explaining a known route to someone).	0.482		
23.	When I exit a store, I do not need to orient myself again to determine where I have to go.	0.750		
24.	I enjoy taking new routes (e.g., shortcuts) to known destinations.	0.507		
25.	I have a good sense of direction.	0.899		
26.	I can easily find the shortest route to a known destination.	0.771		

Note: Only factor loadings higher than 0.4 are shown.

Table 3. Comparison of the mean scores on the three WQ-subscales for female and male healthy participants

Subscale	Females ($n = 185$)	Males ($n = 171$)	t-value	p-value	Effect-size r
Navigation and Orientation	4.49 (1.31)	5.35 (1.02)	−6.97	<.001	0.35
Spatial anxiety	4.58 (1.38)	5.44 (1.23)	−6.18	<.001	0.31
Distance estimation	3.78 (1.37)	5.15 (0.93)	−11.11	<.001	0.52

Note: Standard deviations are displayed between parentheses. Scores on the Spatial Anxiety scale were reversed such that high values represent lower spatial anxiety and thus higher navigation ability.

STUDY 2: Confirmatory factor analysis of the WQ in mild stroke patients

Method

Participants, Materials, and Procedure. Participants were chronic mild stroke patients who had visited the rehabilitation clinic of De Hoogstraat Revalidatie or the rehabilitation department of the University Medical Center Utrecht (Utrecht, the Netherlands) between 2007 and 2012. These inclusion criteria were applied: first or recurrent stroke, age 18 years or older, at least six months since first stroke event, and living at home after rehabilitation. Reasons for exclusion from participation in the study were the following: unable to communicate in Dutch, severe global aphasia, and severe mobility problems (i.e., patients had to be able to walk or bike outside without supervision). In total, 158 patients agreed to participate (by signing an informed consent form) and were sent and requested to complete the 26-item-version of the WQ (see Study 1). The patient group (64 female; 40.5%) had a mean age of 60.1 years (*SD* = 13.1, range = 22–96). Further breakdown of participants into age categories reveals the distribution as presented in Fig. 1. Mean educational level in the patient sample was 5.2 (*SD* = 1.4, range = 2–7; Verhage, 1964). Stroke characteristics are presented in Table 4. Time, since the most recent stroke event, was 40.5 months on average (*SD* = 25.6, range = 5–195). This information was available for 140 patients. The study protocol complied with the Helsinki Declaration and was approved by the medical ethical committee of the University Medical Center Utrecht (no. 12–198).

Statistical analysis. Only the 22 items of the validated version of the WQ (see Study 1) were taken into account in this study. The spatial anxiety items (Items 10–17) were reversed, such that a high score reflects high ability and low anxiety. Eight missing scores due to ambiguous responding (0.2% of the total number of data points) were substituted with the patient's median score. The missing scores occurred in six patients (3.8% of the total sample), more specifically, four patients had one and two patients had two missing scores.

A confirmatory factor analysis (CFA – a structural equation modeling approach) was applied to verify the three-factor structure of the WQ as found in healthy participants (see Study 1) in chronic mild stroke patients. This technique enables testing the model fit of a dataset to a specific factor structure of observed (or manifest) and underlying latent variables and to directly compare the model fit with alternative factor structure models.

This statistical procedure was undertaken using the IBM SPSS Amos software (Arbuckle, 2013). This program applies maximum-likelihood techniques to estimate the model parameters based on the covariance matrix of the manifest variables. Three indices of model fit, as recommended by Hu and Bentler (1998), were considered. Firstly, a non-significant χ^2 statistic indicates that the specified model is an adequate fit to the data. However, as χ^2 is highly influenced by sample size, the χ^2/df statistic has been proposed, with values lower than 2.0 reflecting good model fit. Two further fit statistics were taken into account as well: The Comparative Fit Index (CFI) and the Standardized Root Mean Square Error of Approximation (RMSEA). A CFI value higher than 0.90 is considered a fair fit, whereas a value exceeding 0.95 indicates a good fit. An RMSEA value of 0.08 or lower reflects a fair fit and a value of 0.05 or below is an indication of good model fit.

Reliability (i.e., internal consistency) of the subscales and their relationships with three demographical variables were investigated in a similar manner as Study 1. An alpha level of 0.05 was applied. Except for the CFA, the statistical procedures were conducted using IBM SPSS Statistics version 22.

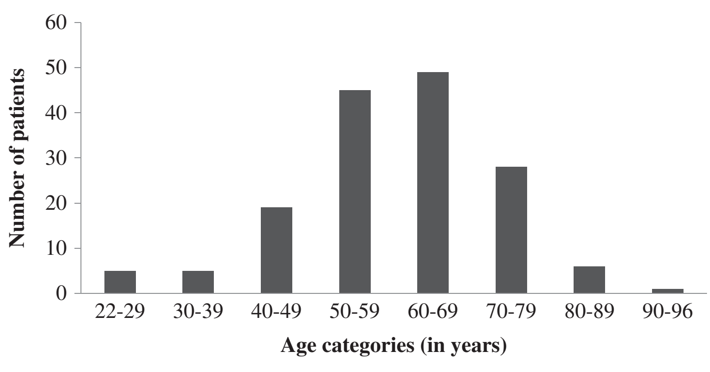

Fig. 1. Distribution of mild stroke patients over age categories.

Table 4. Stroke characteristics (type and location) of the patient group (n = 158)

	n (%)
Stroke type	
Ischemic stroke	110 (69.6%)
Hemorrhagic stroke	
Intracerebral	27 (17.1%)
Subarachnoid	4 (2.5%)
Missing	17 (10.8%)
Stroke location	
Supratentorial region	
Left	64 (40.5%)
Right	53 (33.5%)
Bilateral	2 (1.3%)
Infratentorial region	
Left	8 (5.1%)
Right	3 (1.9%)
Bilateral	9 (5.7%)
Missing	19 (12.0%)

Note: Patients are classified based on the stroke characteristics of their first stroke event. Twelve patients (7.6%) suffered from two stroke events; three patients (1.9%) suffered from three stroke events.

Results and Discussion

Descriptives of the WQ. Descriptive statistics of the WQ-items are provided in Table 5. None of the items suffered from substantial skewness given values range from −0.6 to +0.2.

Confirmatory factor analysis. The fit of the data with a one-factor model was tested to establish a baseline and because such a model has the highest possible parsimoniousness. This unitary model represented all 22 WQ-items on a single latent variable. All fit statistics demonstrated a very poor fit of the data to the one-factor model: χ^2 (209) = 1278.53, p < .001; χ^2/df = 6.12; CFI = 0.54; RMSEA = 0.18.

Next, the fit of the data with the three-factor structure (Study 1) was tested. The three distinct factors (Navigation and Orientation, Spatial Anxiety, and Distance Estimation) were allowed to correlate. The fit statistics provided a better, but still weak fit to the data: χ^2 (206) = 605.29, p < .001; χ^2/df = 2.94; CFI = 0.83; RMSEA = 0.11. Nonetheless, the three-factor model fitted substantially better than the one-factor model: $\Delta\chi^2$ (3) = 673.24, p < .001.

The modifications indices revealed, among others, two plausible correlations between the error terms of item pairs. Consequently, two correlations between error terms were added to the three-factor model, namely between Items 10 and 11, and between Items 21 and 22. Content overlap is very high for both item pairs: Item 11 describes a more specific situation than Item 10, and Items 21 and 22 share overlap in addressing the ability to understand and to provide route descriptions, respectively. The adjusted three-factor model (with the two correlations between error terms included) was a significant improvement over the three-factor model, $\Delta\chi^2$ (2) = 191.57, p < .001, and the fit statistics met or closely approached criteria for acceptable fit: χ^2 (204) = 413.72, p < .001; χ^2/df = 2.03; CFI = 0.91; RMSEA = 0.08. The adjusted three-factor model including its factor loadings is depicted in Fig. 2.

Reliability analysis (internal consistency). All three subscales showed very good internal consistency: Navigation and Orientation (0.904), Spatial Anxiety (0.923), and Distance Estimation (0.826). A correlation analysis revealed weak to strong correlations between subscales: Navigation and Orientation and Distance Estimation (r = 0.756, p < .001), Navigation and Orientation and Spatial Anxiety (r = 0.353, p < .001) and Distance Estimation and Spatial Anxiety (r = 0.198, p = .013). Moreover, all mean subscale scores showed strong correlations with the total score: Navigation and Orientation (r = 0.875, p < .001), Spatial Anxiety (r = 0.670, p < .001), and Distance Estimation (r = 0.823, p < .001).

Relationship with demographic variables. Female patients scored significantly lower than male patients on all three subscales (see Table 6). None of the subscales was significantly correlated with age. Educational level was weakly and significantly related to the Navigation and Orientation subscale (r = 0.163, p = .04) and the Spatial Anxiety subscale (r = 0.204, p = .01).

Table 5. Descriptive statistics (means, standard deviations (SDs), and skewness) for the final 22 items of the Wayfinding Questionnaire (WQ) items based on the responses of 158 chronic mild stroke patients

Item		Mean	*SD*	Skewness
2.	When I am in a building for the first time, I can easily point to the main entrance of this building.	4.30	1.90	−0.34
3.	If I see a landmark (building, monument, intersection) multiple times, I know exactly from which side I have seen that landmark before.	4.86	1.82	−0.57
4.	In an unknown city I can easily see where I need to go when I read a map on an information board.	4.59	1.98	−0.33
6.	Without a map, I can estimate the distance of a route I have walked well, when I walk it for the first time.	3.92	2.01	−0.07
7.	I can estimate well how long it will take me to walk a route in an unknown city when I see the route on a map (with a legend and scale).	3.83	1.98	−0.01
8.	I can always orient myself quickly and correctly when I am in an unknown environment.	3.93	1.97	−0.02
9.	I always want to know exactly where I am (meaning, I am always trying to orient myself in an unknown environment).	4.76	1.92	−0.49
10.	I am afraid of losing my way somewhere.	4.46	2.07	−0.35
11.	I am afraid of getting lost in an unknown city.	4.48	2.09	−0.28
12.	In an unknown city, I prefer to walk in a group rather than by myself.	4.03	2.37	−0.02
13.	When I get lost, I get nervous.	4.25	2.24	−0.15
	How uncomfortable are you in the following situations (Items 14, 15, and 16):			
14.	Deciding where to go when you are just exiting a train, bus, or subway station.	4.56	1.91	−0.22
15.	Finding your way in an unknown building (e.g., a hospital).	4.62	1.99	−0.37
16.	Finding your way to a meeting in an unknown city or part of a city.	3.90	1.97	+0.19
17.	I find it frightening to go to a destination I have not been before.	4.73	2.02	−0.38
18.	I can usually recall a new route after I have walked it once.	4.32	1.97	−0.24
19.	I am good at estimating distances (e.g., from myself to a building I can see).	4.41	1.88	−0.34
21.	I am good at understanding and following route descriptions.	4.42	2.03	−0.42
22.	I am good at giving route descriptions (meaning, explaining a known route to someone).	4.48	1.93	−0.41
23.	When I exit a store, I do not need to orient myself again to determine where I have to go.	4.82	1.98	−0.60
24.	I enjoy taking new routes (e.g., shortcuts) to known destinations.	3.99	2.21	+0.06
26.	I can easily find the shortest route to a known destination.	4.52	2.05	−0.41

Note: Scores on the Spatial Anxiety scale were reversed such that high values represent lower spatial anxiety and thus higher navigation ability. *SD* = Standard deviation.

Interim summary of Study 2. The three-factor structure as established in healthy participants (see Study 1) was supported in chronic mild stroke patients in Study 2. The CFA provided evidence for reasonable model fit of the data with the three factors (Navigation and Orientation, Spatial Anxiety, and Distance Estimation). All subscales were characterized by very good internal consistency, weakly to strongly correlated to the other subscales, and strongly related to the total WQ-score.

General discussion

In current clinical practice, screening instruments for cognitive complaints are used on a regular basis in stroke patients to decide whether or not extensive cognitive testing is needed. Existing screening instruments have, however, neglected an important cognitive function, that is, navigation ability. Our aim was therefore to develop a short but comprehensive screening instrument for navigation-related complaints after stroke. The WQ, as presented earlier by Van der Ham and colleagues (2013), was considered the perfect starting point for developing such an instrument. First, in contrast to existing self-report instruments of navigation ability (e.g., the SBSOD; Hegarty et al., 2002), the WQ takes both the cognitive complexity and the emotional aspects of navigation behavior into account. Moreover, the WQ has already been used as a self-report instrument of navigation ability in mild stroke patients (Van der Ham et al., 2013). However, its psychometrical properties had not yet been evaluated. As a first step in the validation process, we examined its internal validity (i.e., factor structure and reliability) in both healthy participants (Study 1) and chronic mild stroke patients (Study 2). The intended result of this approach was to end up with the final version of the WQ, which can be used for further validation studies.

The two studies reported in this paper provide evidence in favor of the internal validity of the WQ as a self-report screening instrument of navigation-related complaints. The results showed that 22 out of the 26 original items were valid and best divided over three subscales: “Navigation and Orientation,” “Spatial Anxiety,” and “Distance Estimation”. This three-factor structure was found to be valid in both healthy participants and mild stroke patients, suggesting that the subscale scores can be interpreted in the same way in these groups. Each of these results will be discussed in more detail below.

In the first study, the WQ was completed by a large, heterogeneous group of healthy participants. The exploratory factor analysis (EFA) led to deletion of four WQ-items. One item was removed because it was related very poorly to the others and

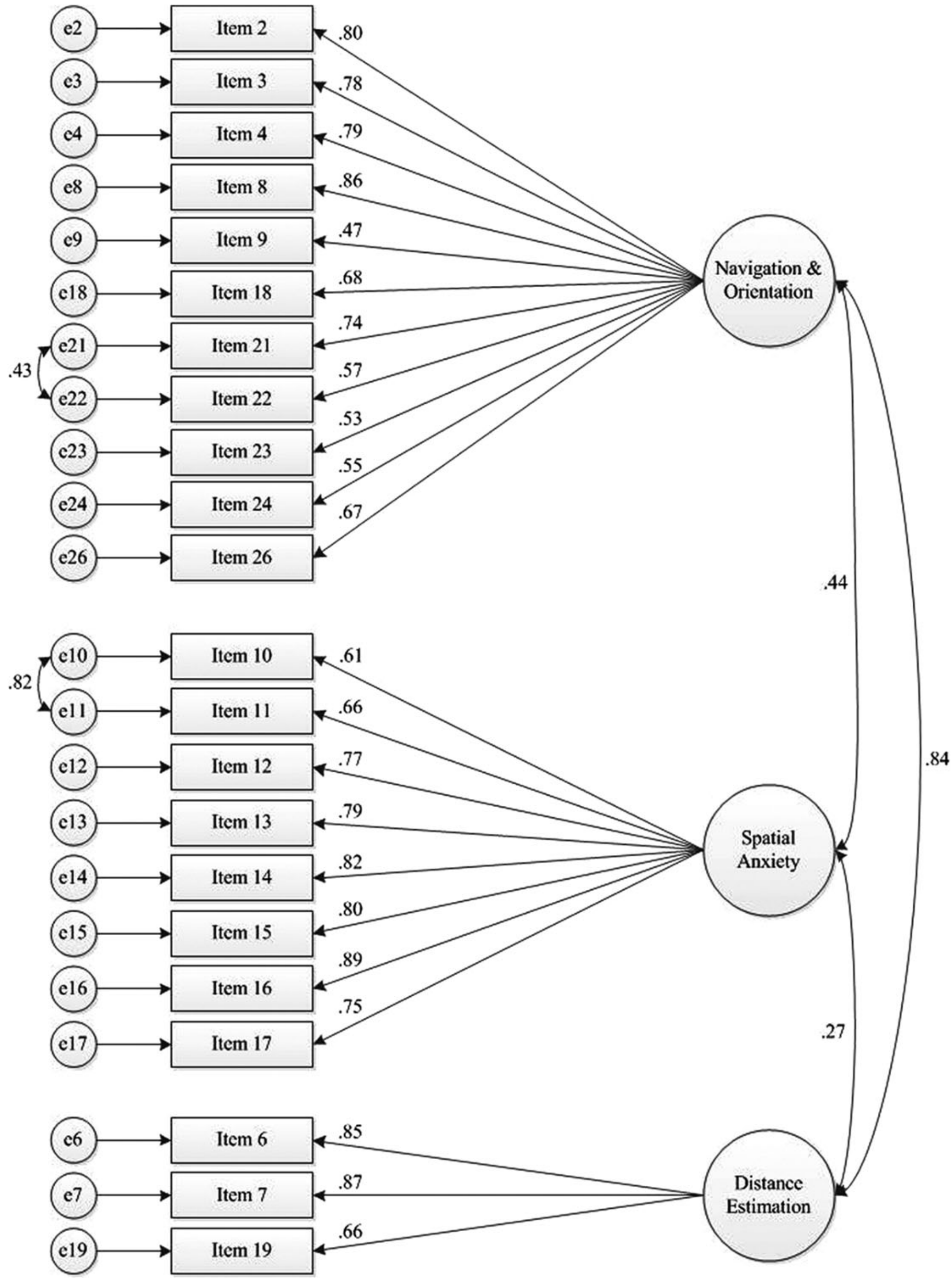

Fig. 2. The confirmatory factor analysis (CFA) results (i.e., standardized estimates) are displayed for the adjusted three-factor model. Boxes represent observed variables (WQ items) and variables in ovals represent latent factors. All estimates are significant (p's < .05). The results are based on the responses of a group of 158 chronic mild stroke patients.

three items were deleted due to substantial content overlap. The EFA suggested the existence of three separate latent factors: Navigation and Orientation (11 items), Spatial Anxiety (8 items), and Distance Estimation (3 items). Reliability was found to be very high in this sample: The subscales displayed very high internal consistency, showed weak to moderate correlations with the other subscales and were strongly related to the total WQ-score as well.

Table 6. Comparison of the mean scores on the three WQ-subscales for female and male chronic mild stroke patients

Subscale	Females (n = 64)	Males (n = 94)	t-value	p-value	Effect-size r
Navigation and Orientation	4.00 (1.32)	4.76 (1.40)	−3.44	.001	0.27
Spatial anxiety	3.94 (1.66)	4.68 (1.64)	−2.77	.006	0.22
Distance estimation	3.36 (1.63)	4.53 (1.56)	−4.53	<.001	0.34

Note: Standard deviations are displayed between parentheses. Scores on the Spatial Anxiety scale were reversed such that high values represent lower spatial anxiety and thus higher navigation ability.

The three-factor solution, as proposed in Study 1, was directly verified in a representative group of 158 chronic mild stroke patients. Confirmatory factor analysis (CFA – a structural equation modeling technique) enabled direct assessment of the model fit of the patients' WQ-item scores with the three-factor structure resulting from the EFA in Study 1. Although model fit was not perfect, the fit indices provided support for an acceptable fit. It should be mentioned that perfect model fit would have been rather unexpected, as healthy participants and mild stroke patients are obviously different in their neuropsychological status. Moreover, there were differences in age and educational level between the healthy participants and the patients. More specifically, the patients were somewhat older and slightly lower in educational level than the healthy participants. Nonetheless, the finding of an acceptable model fit indicates that no substantial difference exists in the manner in which the healthy participants and patients perceived and responded to the questionnaire items. In addition, these results allow patients' WQ-subscale scores to be interpreted in the same way as in healthy participants. Reliability was very high in the patient sample as well: Internal consistency of the subscales was very high, correlations between the subscales were weak to strong in degree and the subscale scores were also strongly related to the total WQ-score.

Hence, the statistical analyses provided support, in both healthy participants and patients, for the existence of three latent factors underlying the 22 items of the final WQ (see Appendix A). Firstly, 11 items covered multiple aspects related to the more general concepts of "navigation" and "orientation," which supports the notion of navigation ability as a complex cognitive capacity (Brunsdon et al., 2007; Wiener et al., 2009; Wolbers & Hegarty, 2010). Secondly, eight items concerned the emotional aspects associated with navigation, that is, experiencing anxious feelings when performing navigation tasks (Lawton, 1994, 1996) and feeling worried about getting lost (Schmitz, 1997). We consider the inclusion of the concept of "spatial anxiety" highly important, as it has been shown to affect navigation ability in a negative way (Schmitz, 1997; Walkowiak, Foulsham, and Eardley, 2015). In addition, preliminary evidence suggests that spatial anxiety is not a situation-specific derivative of general anxiety. Walkowiak and colleagues (2015) have recently shown that, in contrast to spatial anxiety, general anxiety (based on the well-known State-Trait Anxiety Inventory) was not related to objective measures of navigation ability (Walkowiak et al., 2015). These findings suggest that individuals with high general anxiety are not necessarily high in spatial anxiety and vice versa. Lastly, three items addressed the specific ability to estimate distances (Montello, 1997, 2009; Proffitt, 2006; Thorndyke, 1981), either based on direct experience (Item 6 and 19) or a map (Item 7).

Investigation of the relationship between the subscale scores and gender revealed that men scored higher on all three subscales[1] than female participants in both samples. This finding is borne out by a large number of studies that have revealed gender differences in favor of males in navigation ability (e.g., Coluccia & Louse, 2004; Hegarty et al., 2006; Münzer & Hölscher, 2011) and lower levels of spatial anxiety in males (e.g., Lawton 1994, 1996). With regard to future research, these marked gender differences underline the need for development of separate WQ-norms for men and women.

In contrast, the relationships between the WQ-subscale scores and two other demographical variables, that is, age and educational level, were not as clear-cut as in the case of gender. In respect of age, previous research has convincingly shown that actual navigation ability is negatively affected by increasing age (e.g., Cushman, Stein, and Duffy, 2008; Moffat, 2009). However, no such effect (i.e., no significant correlations, except for one weak positive correlation in the healthy sample) was found with regard to the WQ-subscales. Interestingly, Taillade, N'Kaoua, and Sauzéon (2016) have provided evidence for this combination of findings in a single study. These authors reported age-differences in objectively measured navigation performance favoring younger adults, whereas such a difference was not identified when comparing self-reported navigation ability between groups of young and older adults.

The absence of a significant correlation between self-reported navigation ability on the WQ and age is thus in congruence with this recent paper as well as many earlier studies (see Taillade et al., 2016), and might result from several factors. Older people might have higher levels of experience with navigation than younger adults and, consequently, more successful navigation episodes to base their self-estimates on (Taillade et al., 2016). Another explanation might lie in metacognitive

[1] Scores on the Spatial Anxiety items were reversed such that high values represent lower spatial anxiety and thus higher navigation ability.

difficulties in older adults, which might hinder them in providing accurate self-estimates. Last, domain-specific age stereotypes might influence self-reported cognitive abilities in the elderly, that is, negatively affecting self-estimates of memory function but not of spatial abilities (see Taillade et al., 2016). Hence, older individuals tend to overestimate their current navigation abilities.

Weak positive relationships were identified between some of the WQ-subscales and educational level. These results indicate that people with a higher level of education tend to report better navigation and orientation ability and lower spatial anxiety as compared with lower-educated people.

Several strengths of this paper deserve to be mentioned. Studies 1 and 2 rely on large samples of healthy participants and chronic mild stroke patients, respectively. The patient group consisted of patients with various stroke types and lesion locations (see Table 4) allowing initial generalization to stroke patients in general. Additional studies based on even larger samples per stroke type and patients with more severe stroke pathology could be helpful in confirming the generalizability of the current findings. A further strength is the confirmatory approach taken in Study 2. The factor structure as established in healthy participants (Study 1) was directly verified in a representative sample of mild stroke patients and was found to be internally valid and reliable in this latter group as well. Given that the WQ is short (22 items), it seems particularly feasible as a screening instrument of navigation-related complaints in stroke patients.

A few limitations of this paper should also be mentioned. First, the two studies specifically focused on establishing the latent factor structure of the WQ and examining its reliability. Further research should therefore scrutinize the validity of the WQ. It should also be mentioned that only chronic stroke patients were included for participation in the study. Further studies could take other relevant acquired brain injury patient groups into account, for instance, patients suffering from traumatic brain injury (e.g., Livingstone & Skelton, 2007) and Alzheimer patients (e.g., Cushman, Stein, and Duffy, 2008; delpolyi, Rankin, Mucke, Miller, and Gorno Tempini, 2007; Pai & Jacobs, 2004) as navigation impairment also occurs regularly in these patient groups.

Another limitation lies in the fact that the WQ-scores rely on accuracy of the patient's insight into actual navigation performance in daily life. The dependence on self-insight is a common issue with the use of self-report measures in brain-damaged patients, as insight in actual cognitive performance can be diminished or even absent after suffering from stroke (Orfei, Caltagirone, and Spalletta, 2009; Starkstein, Jorge, and Robinson, 2010). Future research on the WQ could explore the feasibility of a caregiver version to overcome full reliance on the patient's self-insight. This would help in capturing navigation problems in patients who are unable to provide an accurate indication of their abilities.

Notwithstanding these limitations, the current studies allowed us to draft the final version of the WQ based on the data of healthy respondents. Results showed that the WQ-subscales are reliable in both healthy participants and mild stroke patients. Furthermore, the three-factor structure was found to be a valid interpretation frame in both of these groups. We have shown that the WQ is not only a short but also comprehensive instrument (22 items) as it covers the cognitive complexity of navigation ability and takes spatial anxiety into account as well. As the next step in the validation process of the WQ, we are currently examining further aspects of its validity as well as its clinical utility (De Rooij et al., in preparation). In case this follow-up study results in further substantiation of the validity and usefulness of the WQ, we consider this instrument to be eligible for implementation in clinical practice as an assessment instrument for navigation-related complaints after stroke.

Funding

This work was supported by a "Meerwaarde" grant [840.11.006] and a Veni grant [451-12-004 to I.H.]. Both grants were provided by the Netherlands Organisation for Scientific Research (NWO).

Conflict of Interest

None declared.

Acknowledgements

We would like to acknowledge Sander Bosch's work on a previous version of the WQ in his unpublished Bachelor thesis. We are also grateful to Merel Braspenning for her help with data acquisition.

Appendix

Wayfinding Questionnaire (WQ)

The following 22 statements are about navigation ability. For each of these statements, please **circle the number that best describes your ability to navigate**.
The numbers 1 to 7 represent the following:

1	2	3	4	5	6	7
Not at all applicable to me	*Almost never applicable to me*	*Rarely applicable to me*	*Sometimes applicable to me*	*Often applicable to me*	*Almost always applicable to me*	*Fully applicable to me*

1. When I am in a building for the first time, I can easily point to the main entrance of this building.

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

2. If I see a landmark (building, monument, intersection) multiple times, I know exactly from which side I have seen that landmark before.

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

3. In an unknown city I can easily see where I need to go when I read a map on an information board.

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

4. Without a map, I can estimate the distance of a route I have walked well, when I walk it for the first time.

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

5. I can estimate well how long it will take me to walk a route in an unknown city when I see the route on a map (with a legend and scale).

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

6. I can always orient myself quickly and correctly when I am in an unknown environment.

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

7. I always want to know exactly where I am (meaning, I am always trying to orient myself in an unknown environment).

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

8. I am afraid of losing my way somewhere.

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

9. I am afraid of getting lost in an unknown city.

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

10. In an unknown city, I prefer to walk in a group rather than by myself.

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

11. When I get lost, I get nervous.

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

How uncomfortable are you in the following situations (items 12, 13 and 14):

12. Deciding where to go when you are just exiting a train, bus, or subway station.

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

13. Finding your way in an unknown building (for example a hospital).

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

14. Finding your way to a meeting in an unknown city or part of a city.

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

15. I find it frightening to go to a destination I have not been before.

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

16. I can usually recall a new route after I have walked it once.

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

17. I am good at estimating distances (for example, from myself to a building I can see).

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

18. I am good at understanding and following route descriptions.

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

19. I am good at giving route descriptions (meaning, explaining a known route to someone).

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

20. When I exit a store, I do not need to orient myself again to determine where I have to go.

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

21. I enjoy taking new routes (for example shortcuts) to known destinations.

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

22. I can easily find the shortest route to a known destination.

Not at all applicable to me	1	2	3	4	5	6	7	*Fully applicable to me*

Scoring instructions:

Response possibilities range from 1 (“not at all applicable to me”) to 7 (“fully applicable to me”) for Navigation and Orientation and Distance Estimation items. On Items 12, 13, and 14, scores of 1 to 7 represented “not uncomfortable at all” to “very uncomfortable,” respectively.

Navigation and Orientation subscale: Item 1, 2, 3, 6, 7, 16, 18, 19, 20, 21, and 22

Spatial Anxiety subscale: Item 8, 9, 10, 11, 12, 13, 14, and 15

Distance Estimation subscale: Item 4, 5, and 17

References

Arbuckle, J. L. (2013). IBM® SPSS® AmosTM 22: User’s Guide.

Arnold, A. E., Burles, F., Krivoruchko, T., Liu, I., Rey, C. D., Levy, R. M., & Iaria, G. (2013). Cognitive mapping in humans and its relationship to other orientation skills. *Experimental Brain Research*, *224* (*3*), 359–372. doi:10.1007/s00221-012-3316-0.

Barrash, J., Damasio, H., Adolphs, R., & Tranel, D. (2000). The neuroanatomical correlates of route learning impairment. *Neuropsychologia*, *38*, 820–836. doi:10.1016/S0028-3932(99)00131-1.

Blajenkova, O., Kozhevnikov, M., & Motes, M. A. (2006). Object-spatial imagery: A new self-report imagery questionnaire. *Applied Cognitive Psychology*, *20* (*2*), 239–263. doi:10.1002/acp.1182.

Brunsdon, R., Nickels, L., & Coltheart, M. (2007). Topographical disorientation: Towards an integrated framework for assessment. *Neuropsychological Rehabilitation*, *17* (*1*), 34–52. doi:10.1080/09602010500505021.

Busigny, T., Pagès, B., Barbeau, E. J., Bled, C., Montaut, E., Raposo, N., Albucher, J.-F., Chollet, F., & Pariente, J. (2014). A systematic study of topographical memory and posterior cerebral artery infarctions. *Neurology*, *83* (*11*), 996–1003. doi:10.1212/WNL.0000000000000780.

Claessen, M. H. G., Visser-Meily, J. M. A., De Rooij, N. K., Postma, A., & Van der Ham, I. J. M. (2016). A direct comparison of real-world and virtual navigation performance in chronic stroke patients. *Journal of the International Neuropsychological Society*, *22* (*4*), 467–477. doi:10.1017/S1355617715001228.

Coluccia, E., & Louse, G. (2004). Gender differences in spatial orientation: A review. *Journal of Environmental Psychology*, *24*, 329–340. doi:10.1016/j.jenvp.2004.08.006.

Cushman, L. A., Stein, K., & Duffy, C. J. (2008). Detecting navigational deficits in cognitive aging and Alzheimer disease using virtual reality. *Neurology*, *71*, 888–895. doi:10.1212/01.wnl.0000326262.67613.fe.

deIpolyi, A. R., Rankin, K. P., Mucke, L., Miller, B. L., & Gorno-Tempini, M. L. (2007). Spatial cognition and the human navigation network in AD and MCI. *Neurology*, *69*, 986–997. doi:10.1212/01.wnl.0000271376.19515.c6.

DeVellis, R. F. (1991). *Scale development: Theory and applications*, (*Vol. 26*). London, UK: SAGE. Applied Social Research Methods Series.

Duits, A., Munnecom, T., Van Heugten, C., & Van Oostenbrugge, R. J. (2008). Cognitive complaints in the early phase after stroke are not indicative of cognitive impairment. *Journal of Neurology, Neurosurgery & Psychiatry*, *79*, 143–146. doi:10.1136/jnnp.2007.114595.

Galski, T., Bruno, R., Zorowitz, R., & Walker, J. (1993). Predicting length of stay, functional outcome, and aftercare in the rehabilitation of stroke patients. The dominant role of higher-order cognition. *Stroke*, *24*, 1794–1800. doi:10.1161/01.STR.24.12.1794.

Hegarty, M., Montello, D. R., Richardson, A. E., Ishikawa, T., & Lovelace, K. (2006). Spatial abilities at different scales: Individual differences in aptitude-test performance and spatial-layout learning. *Intelligence*, *34* (*2*), 151–176. doi:10.1016/j.intell.2005.09.005.

Hegarty, M., Richardson, A. E., Montello, D. R., Lovelace, K., & Subbiah, I. (2002). Development of a self-report measure of environmental spatial ability. *Intelligence*, *30* (*5*), 425–447. doi:10.1016/S0160-2896(02)00116-2.

Hu, L., & Bentler, P. M. (1998). Fit indices in covariance structure modeling: Sensitivity to under parameterized model misspecification. *Psychological Methods*, *3*, 424–453. doi:10.1037/1082-989X.3.4.424.

Hutcheson, G., & Sofroniou, N. (1999). *The multivariate social scientist*. London, UK: SAGE.

Ino, T., Doi, T., Hirose, S., Kimura, T., Ito, J., & Fukuyama, H. (2007). Directional disorientation following left retrosplenial hemorrhage: A case report with fMRI studies. *Cortex*, *43*, 248–254. doi:10.1016/S0010-9452(08)70479-9.

Lawton, C. A. (1994). Gender differences in wayfinding strategies: Relationship to spatial ability and spatial anxiety. *Sex Roles*, *30* (*11–12*), 765–779. doi:10.1007/BF01544230.

Lawton, C. A. (1996). Strategies for indoor wayfinding: The role of orientation. *Journal of Environmental Psychology*, *16* (*2*), 137–145. doi:10.1006/jevp.1996.0011.

Lawton, C. A., & Kallai, J. (2002). Gender differences in wayfinding strategies and anxiety about wayfinding: A cross-cultural comparison. *Sex Roles*, *47* (*9–10*), 389–401. doi:10.1023/A:1021668724970.

Livingstone, S. A., & Skelton, R. W. (2007). Virtual environment navigation tasks and the assessment of cognitive deficits in individuals with brain injury. *Behavioural Brain Research*, *185* (*1*), 21–31. doi:10.1016/j.bbr.2007.07.015.

Maguire, E. A., Burke, T., Phillips, J., & Staunton, H. (1996). Topographical disorientation following unilateral temporal lobe lesions in humans. *Neuropsychologia*, *34* (*10*), 993–1001. doi:10.1016/0028-3932(96)00022-X.

McCusker, J., Bellavance, F., Cardin, S., & Belzile, É. (1999). Validity of an activities of daily living questionnaire among older patients in the emergency department. *Journal of Clinical Epidemiology*, *52* (*11*), 1023–1030. doi:10.1016/S0895-4356(99)00084-0.

Mendez, M. F., & Cherrier, M. M. (2003). Agnosia for scenes in topographagnosia. *Neuropsychologia*, *41*, 1387–1395. doi:10.1016/S0028-3932(03)00041-1.

Moffat, S. D. (2009). Aging and spatial navigation: What do we know and where do we go? *Neuropsychology Review*, *19*, 478–489. doi:10.1007/s11065-009-9120-3.

Montello, D. R. (1997). The perception and cognition of environmental distance: Direct sources of information. In Hirtle S. C., & Frank A. U. (Ed.), *Spatial information theory: A theoretical basis for GIS*, (pp. 297–311). Berlin: Springer-Verlag, Lecture Notes in Computer Science 1329.

Montello, D. R. (2009). A conceptual model of the cognitive processing of environmental distance information. In K. S. Hornsby, C. Claramunt, M. Denis, & G. Ligozat (Eds.), *Spatial information theory* (pp. 1-17). Proceedings of COSIT ‘09. Berlin, Heidelberg: Springer-Verlag, Lecture Notes in Computer Science 5756.

Münzer, S., & Hölscher, C. (2011). Entwicklung und Validierung eines Fragenbogens zu räumlichen Strategien [Development and validation of a questionnaire of environmental strategies]. *Diagnostica*, *57* (*3*), 111–125. doi:10.1026/0012-1924/a000040.

Orfei, M. D., Caltagirone, C., & Spalletta, G. (2009). The evaluation of anosognosia in stroke patients. *Cerebrovascular Diseases*, *27* (*3*), 280–289. doi:10.1159/000199466.

Pai, M.-C., & Jacobs, W. J. (2004). Topographical disorientation in community-residing patients with Alzheimer’s disease. *International Journal of Geriatric Psychiatry*, *19* (*3*), 250–255. doi:10.1002/gps.1081.

Pazzaglia, F., Cornoldi, C., & De Beni, R. (2000). Differenze individuali nella rappresentazione dello spazio e nell’abilità di orientamento: Presentazione di un Questionario autovalutativo [Individual differences in spatial representation and orientation ability: A self-rating questionnaire]. *Giornale Italiano di Psicologia*, *3*, 241–264. doi:10.1421/310.

Pett, M. A., Lackey, N. R., & Sullivan, J. J. (2003). *Making sense of factor analysis: The use of factor analysis for instrument development in health care research*. Newbury Park, California: Sage.

Proffitt, D. R. (2006). Distance perception. *Current Directions in Psychological Science*, *15* (*3*), 131–135. doi : 10.1111/j.0963-7214.2006.00422.x.

Schmitz, S. (1997). Gender related strategies in environmental development: Effect of anxiety on wayfinding in and representation of a three-dimensional maze. *Journal of Environmental Psychology*, *17* (*3*), 215–228. doi:10.1006/jevp.1997.0056.

Starkstein, S. E., Jorge, R. E., & Robinson, R. G. (2010). The frequency, clinical correlates, and mechanism of anosognosia after stroke. *The Canadian Journal of Psychiatry*, *55* (*6*), 355–361.

Taillade, M., N'Kaoua, B., & Sauzéon, H. (2016). Age-related differences and cognitive correlates of self-reported and direct navigation performance: The effect of real and virtual test conditions manipulation. *Frontiers in Psychology*, *6*. doi:10.3389/fpsyg.2015.02034article 2034.

Terwee, C. B., Bot, S. D. M., De Boer, M. R., Van der Windt, D. A. W. M., Knol, D. L., Dekker, J., & De Vet, H. C. W. (2007). Quality criteria were proposed for measurement properties of health status questionnaires. *Journal of Clinical Epidemiology*, *60* (*1*), 34–42. doi:10.1016/j.jclinepi.2006.03.012.

Thorndyke, P. W. (1981). Distance estimation from cognitive maps. *Cognitive Psychology*, *13*, 526–550. doi:10.1016/0010-0285(81)90019-0.

Van Asselen, M., Kessels, R. P. C., Kappelle, L. J., Neggers, S. F. W., Frijns, C. J. M., & Postma, A. (2006). Neural correlates of human wayfinding in stroke patients. *Brain Research*, *1067* (*1*), 229–238. doi:10.1016/j.brainres.2005.10.048.

Van der Ham, I. J. M., Kant, N., Postma, A., & Visser-Meily, J. M. A. (2013). Is navigation ability a problem in mild stroke patients? Insights from self-reported navigation measures. *Journal of Rehabilitation Medicine*, *45*, 429–433. doi:10.2340/16501977-1139.

Van der Ham, I. J. M., Van Zandvoort, M. J. E., Meilinger, T., Bosch, S. E., Kant, N., & Postma, A. (2010). Spatial and temporal aspects of navigation in two neurological patients. *NeuroReport*, *21*, 685–689. doi:10.1097/WNR.0b013e32833aea78.

Van Heugten, C., Rasquin, S., Winkens, I., Beusmans, G., & Verhey, F. (2007). Checklist for cognitive and emotional consequences following stroke (CLCE-24): Development, usability and quality of the self-report version. *Clinical Neurology and Neurosurgery*, *109* (*3*), 257–262. doi:10.1016/j.clineuro.2006.10.002.

Verhage, F. (1964). Intelligence and age: Study with Dutch people from age 12 to 77. Dissertation. Assen: Van Gorcum. (In Dutch).

Walkowiak, S., Foulsham, T., & Eardley, A. F. (2015). Individual differences and personality correlates of navigational performance in the virtual route learning task. *Computers in Human Behavior*, *45*, 402–410. doi:10.1016/j.chb.2014.12.041.

Wiener, J. M., Büchner, S. J., & Hölscher, C. (2009). Taxonomy of human wayfinding tasks: A knowledge-based approach. *Spatial Cognition & Computation*, *9*, 152–165. doi:10.1080/13875860902906496.

Wolbers, T., & Hegarty, M. (2010). What determines our navigational abilities? *Trends in Cognitive Sciences*, *14* (*3*), 138–146. doi:10.1016/j.tics.2010.01.001.

Zinn, S., Dudley, T. K., Bosworth, H. B., Hoenig, H. M., Duncan, P. W., & Horner, R. D. (2004). The effect of poststroke cognitive impairment on rehabilitation process and functional outcome. *Archives of Physical Medicine and Rehabilitation*, *85*, 1084–1090. doi:10.1016/j.apmr.2003.10.022.