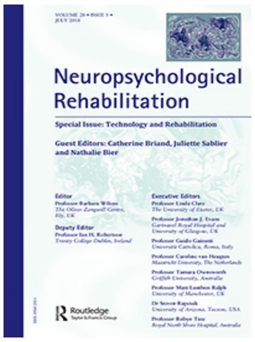

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A case study of topographical disorientation: behavioural intervention for achieving independent navigation

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ABSTRACT

This study introduces an intervention that enabled a man (LH) with acquired topographical disorientation (TD) to travel independently without fear of getting lost. Adapting an errorless method, LH learned to use a smartphone to find his routes accurately and reliably. A time-series design (A_1-B_1-A_2-B_2) was used: In all phases, LH was given a printed map on which city locations were indicated. He had to walk to the indicated locations while naturalistic outcomes were recorded. In Phases A, he navigated without his smartphone, and in Phases B, with it. In Phases A, LH made numerous surplus direction changes, and openly expressed his frustration. In Phases B, he did not have surplus direction changes and could calmly find his routes. Before intervention, LH and his wife were frustrated and worried about his way-finding. They rated their confidence in his navigational ability and his actual ability in way-finding to various locations as low. After intervention, they were more confident that LH could travel by himself without getting lost and rated his ability as much higher for various scenarios. As a consequence of intervention LH gained greater independence and quality of life.

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KEYWORDS TD; rehabilitation; technology-assisted intervention

Introduction

Following an acquired brain injury some individuals report topographical disorientation (TD), a severe deficit in navigating one's environment (e.g., Aguirre & D'Esposito, 1999; Clarke, Assal, & De Tribolet, 1993; Habib & Sirigu, 1987; Maguire, Burke, Phillips, & Staunton, 1996; Mendez & Cherrier, 2003; Pai, 1997; Pallis, 1955; Takahashi, Kawamura, Shiota, Kasahata, & Hirayama, 1997). Most people with this disorder lose their ability and confidence to go almost anywhere alone, whether walking, biking or taking public transport. Driving privileges may be lost. These challenges create a barrier to keeping up with social, vocational and day-to-day responsibilities. While some individuals may manage to go out on their own, the possibility of getting lost often creates significant anxiety both for these individuals and people close to them. The purpose of this study was two-fold: (1) to

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describe an intervention for TD that, in addition to aiding in navigation, instills confidence by removing fear of getting lost, and (2) to evaluate its efficacy. This was carried out through a case study featuring a man with severe TD following a closed head injury.

TD has been recognised as a specific deficit since 1890, and is now considered a disorder (e.g., Davis & Coltheart, 1999; Katayama, Takahashi, Ogawara, & Hattori, 1999; Landis, Cummings, Benson, & Palmer, 1986; della Rocchetta, Cipolotti, & Warrington, 1996; Suzuki, Yamadori, Hayakawa, & Fujii, 1998). Research on TD has mainly focused on elucidating its underlying mechanisms, and its correlated anatomical substrates.

TD has been characterised by one or more of the following difficulties: poor recognition of well-known buildings/places (topographical agnosia), imagery of locations, and visuo-spatial layout representation that may be related to poor egocentric and/or allocentric spatial orientation. De Renzi and colleagues (e.g., De Renzi, 1985; De Renzi, Faglioni, & Villa, 1977) proposed theoretical models of TD in which the disorientation is generally characterised as being dependent on difficulties recognising locations, or reaching their mnemonic representations (topographical agnosia vs. amnesia, respectively). Aguirre and D'Esposito (1999) further qualified TD by defining four types: egocentric disorientation (impairment to represent locations of objects relative to self-location), heading disorientation (impairment in determining direction based on recognised landmarks), landmark agnosia (impairment in using salient features/landmarks for direction), and anterograde disorientation (impairment in forming new space and environment representations). While TD can be due to the failure of a single neurocognitive process, it most often arises from a mélange of deficits. Indeed, individuals exhibit a combination of these difficulties and learn to compensate to various degrees. Antonakos (2004) illustrated various types of symptoms by describing in detail three individuals suffering from TD of varying severities. Over time, these three individuals had naturally developed compensatory strategies, such as using landmarks, direction (e.g., written instructions), and scanning, in order to gain navigation independence.

Anatomically, the bilateral medial occipital and posterior parahippocampal cortices, the right hippocampus, and the right inferotemporal region have been shown to be involved in route learning (Barrash, Damasio, Adolphs, & Tranel, 2000). Perception and learning of multiple topographical scenes appear to be correlated with activation in the bilateral medial occipitotemporal cortices and right inferotemporal cortex. Formation of integrated representations of places and their spatial relationships seems to be related to the bilateral posterior parahippocampal gyri, and the right hippocampus (e.g., Aguirre & D'Esposito, 1999; Alsaadi, Binder, Lazar, Doorani, & Mohr, 2000; Barrash, 1998; Maguire, Frackowiak, & Frith, 1997; Martinaud et al., 2012).

While numerous studies on the underlying processes and their correlated neuroanatomy exist, few clinical interventions for people suffering from TD per se have been described. As some degree of compensation is possible, and as many individuals have this condition within the context of several cognitive strengths, developing interventions for this population appears to be both hopeful and necessary. Only three studies have described interventions for individuals whose cognitive impairment is TD per se: Davis and Coltheart (1999), Brunsdon, Nickels, Coltheart, and Joy (2007), and Bouwmeester, van de Wege, Haaxma, and Snoek (2014). In addition, one study describes an intervention for a woman who has always had topographical amnesic disorder (Incoccia, Magnotti, Iaria, Piccardi, & Guariglia, 2009).

Davis and Coltheart (1999) designed an intervention in order to help a woman who had TD navigate independently within a specific area of her home town. Their treatment involved providing mnemonic techniques to assist her in learning the names and locations of streets. The woman successfully managed to memorise this material, and, in turn, could navigate efficiently within the specific learned district of her town. Navigation outside of the targeted area would require additional training.

Brunsdon et al. (2007) successfully trained a 6.5-year-old boy to efficiently navigate routes that he frequently used at his school. In their evaluation and intervention, they carefully considered the cognitive strengths and weaknesses of the child, and helped him gain independence at school. Training targeted a limited number of routes, and involved learning specific landmarks around the school grounds.

Bouwmeester et al. (2014) designed an intervention in order to increase the independence of a man who had severe heading disorientation. Since this man could read maps, and had sufficient memory, he was encouraged to develop gradual compensatory strategies, such as first learning specific landmarks and their relative locations, and then adding written instructions. This man successfully applied these strategies in order to navigate a limited number of routes crucial for his weekly functioning, such as going to the swimming pool. While the above interventions were successful, significant relearning of skills would have to occur for each additional novel destination.

Incoccia et al. (2009) trained a young woman to use verbal instructions to follow a path and to further generate her own instructions to create paths for navigating in novel environments. With encouragement to use landmarks and verbal instructions, their patient felt more competent at using language-based strategy in order to increase her navigational autonomy.

In clinical settings, patients with deficient way-finding abilities are encouraged to use verbal strategies in order to navigate better. They are taught to break down their route into sub-segments that can be described verbally, and to learn these segments in the correct order before going on an outing (e.g., Botez-Marquand & Botez, 1992; Clarke et al., 1993; Landis et al., 1986). This compensatory strategy only works for relatively simple routes, and is not a natural and flexible way of navigating. Again, its generalisation is limited.

Considering how debilitating TD is, developing way-finding rehabilitation strategies that can be applied outside the immediate training environment, is essential. This case study introduces a rehabilitation strategy for TD that is compensatory, theory-driven, considers the patient's cognitive strengths and weaknesses, and targets the difficulty that is most immediate and limiting to quality of life. It evaluates the intervention with naturalistic outcome measures directly related to real-life demands. The approach uses smartphone and GPS technology, building on the work of Svoboda and colleagues who train individuals with moderate to severe memory impairment in the use of emerging technologies (e.g., smartphones) to compensate for day-to-day memory challenges (Savage & Svoboda, 2013; Svoboda & Richards, 2009; Svoboda, Richards, Leach, & Mertens, 2012; Svoboda, Richards, Polsinelli, & Guger, 2010; Svoboda, Richards, Yao, & Leach, 2014).

This study describes an intervention using smartphone technology which aims to enable a man (LH) with TD to navigate by foot or public transport without anxiety over getting lost. The effectiveness of the intervention was evaluated with naturalistic measures provided to him and his wife, including confidence and ability ratings pertaining to his way-finding, before and after intervention. A time-series design (A-B-A-B) was used to assess LH's navigation skills directly, without (A) and with (B) the smartphone intervention in several locations within his city of residence. The final evaluation phase was completed four months following intervention thereby measuring maintenance of treatment outcome.

Case description: LH

LH was born in 1946. He has a doctorate in Science (approximately 21 years of education). He is retired and lives with his wife. Following retirement, they sold their house to travel the world. LH was in charge of planning their trips as he had excellent navigation and way-finding skills.

Soon after beginning their travels, LH and his wife had a car accident. LH acquired bilateral posterior circulation infarcts and multiple foci of parenchymal and intracranial haemorrhage secondary to trauma. He underwent a left fronto-parietal craniotomy with subdural haemorrhage evacuation. His brain imaging showed cortical laminar necrosis in the bilateral posterior and medial occipital lobes and the left inferomedial parietal lobe (see Figure 1). Specifically, his report from the Rehabilitation Institute (April 6, 2011) stated:

> CT demonstrated left subdural haemorrhage and subarachnoid haemorrhage. On 25 February 2011, he underwent left burr hole and craniotomy with subdural haemorrhage evacuation. (…) MRI on 24 March 2011 showed the following: Left frontoparietal craniotomy evident. Left frontal subdural haemorrhage measuring 9 mm, and trace right temporal subdural haemorrhage. Left parietal lobe 1 cm haematoma seen. Hemosiderin staining the surface of the left parietal and temporal lobes. Blood products seen in the right cerebellum and mid pons. Cortical laminar neurosis in the cortex of bilateral posterior and medial occipital lobes and left inferomedial parietal lobe. Overall impression of bilateral posterior circulation infarcts, and multiple foci of parenchymal and intracranial haemorrhage presumably post-traumatic.

They returned to Canada and LH was admitted to an inpatient rehabilitation facility. He and his wife purchased an apartment in a new neighbourhood of the city where they had previously resided.

The results of his neuropsychological assessments conducted at the rehabilitation centre (by Dr. Green) show that, in agreement with his past occupation and level of functioning, LH is a man of superior intelligence whose non-verbal abilities are

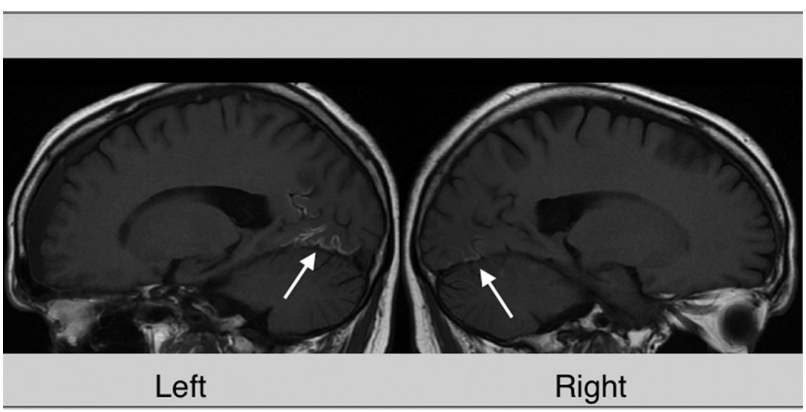

Figure 1. High signal in the occipital gyriform areas as shown by the 2011 brain scan. LH had cortical laminar necrosis in cortex of bilateral posterior and medial occipital lobes and left inferomedial parietal lobe.

greater than his verbal abilities. Immediately after his accident, it was found that his attention, speed of processing, memory for prose and word-lists, visual memory, visual object recognition, motor control and strength were lower than expected for his age and education; they were in the low average to average range. On the other hand, his verbal fluency, conceptual reasoning, problem solving, visuo-constructional abilities, and visual reasoning were as expected for his age and education; they were within the superior range. After three months in rehabilitation, LH and his wife reported improvement of fine motor control, strength, speed of processing, and memory. LH's rehabilitation team observed these significant improvements and LH was discharged from the rehabilitation unit.

Once out of the rehabilitation centre, LH realised that while his condition had greatly improved, he could not find his way beyond the corner store, could not recognise the new building in which they lived and he was no longer confident that he could reach desired locations without getting lost. His frustration and fear of getting lost further exacerbated his limited abilities to find his way and he was determined to get support, at which time he was referred to Baycrest. In order to best intervene, LH's location recognition, navigation difficulties, and visuo-perceptual abilities were assessed. Consistent with his navigation limitations, the results showed that LH had unusual difficulties recognising famous buildings visually; he could not correctly locate cardinal directions; and he had impaired colour discrimination across the entire colour spectrum. In addition, he had poor face recognition.[1] In contrast, his visual memory was relatively intact, although lower than his estimated premorbid ability. Moreover, his ability to read a road map, object recognition, text reading, low-level perceptual abilities (e.g., judgement of line orientation, size, length), space perception, and visuo-motor control were normal. Based on LH's cognitive profile, it was speculated that his TD originates from a mixture of a few difficulties: Using Aguirre and D'Esposito's taxonomy (1999), LH's landmark agnosia, heading disorientation, and anterograde disorientation appear to be the main factors responsible for his topographical challenges. LH remained capable of reading directional maps, and understanding spatial layouts of various drawings. Knowing the exact cause of his disorientation is outside the scope of this study. However, understanding his cognitive strengths and the sources of his challenges for analysing his surrounding was instrumental in designing the intervention.

Details of his neuro-cognitive profile (assessment completed at his inpatient rehabilitation centre and additional testing completed at the neuro-perceptual clinic and Memory-Link in 2011 and 2012, respectively) are shown in Table 1. His cognitive profile has remained stable since then. Before the intervention, LH had never used an iPhone; he had used other types of smartphones only for making phone calls.

Rehabilitation intervention: Training sessions

After providing psycho-educational feedback, explaining clearly how his visuo-perceptual skills were affected by his brain injury, his rehabilitation goals were narrowed to navigating around independently without fear of getting lost. Taking into consideration his cognitive strengths, i.e., good problem solving, reasoning, reading, basic functional

[1]When presented with a current picture of one of the neuropsychologists who was in the testing room in person, he mistook her for his wife. He justified his answer by stating that his wife most often has the same posture.

Table 1. LH neuropsychological results in 2011 and 2012 (just before the navigation intervention started).

General intellectual functioning		
Cognitive abilities	Test names	Results
Verbal Intellectual Quotient (IQ)	WASI *	Verbal IQ: 136: Very superior
Performance IQ	WASI	Performance IQ: 118: High average
VERBAL SKILLS		
Reasoning	Similarities; WAIS-III*	SS: 12–16: High average to Superior
Memory		
Semantic Memory	Vocabulary (WAIS-III)	SS: 14–15: Superior
Working Memory	Digit Span (WAIS-III)	SS: 13: High average
Verbal Learning	RAVLT*	Z score (z): -0.44: Average
Short Delay Recall	RAVLT	z: -1.50: Borderline
Delayed Recall	RAVLT	z: -1.05: Low average
Recognition	RAVLT	z: 0.21: Average
Logical Memory	WMS*	
Immediate Recall		SS: 11: Average
Delayed Recall		SS: 10: Average
Fluency		
Phonemic	CFL*	*z*: 0: Average
Semantic	Animals *	*z*: −1.24: Low average
Naming to Visual Confrontation	BNT*KBNA	*z*: −1.03: Low average with Word Finding Difficulties >16%ile: Normal
NON VERBAL SKILLS		
Conceptual Reasoning	Matrix Reasoning (WAIS-III)	SS: 16–17: Superior
Memory		
Working Memory	Visual Span Backward (WAIS-III) Spatial Location (KBNA)	SS: 10: Average SS: 12: High average
Learning	RVDLT*	*z*: −1.39: Low average
Delay Recall	Delayed Visual Reproduction (KBNA)	SS: 8: Average
Recognition	RVDLT Picture Recognition (KBNA) Complex Figure (KBNA)	z: −1.11: Low average >16%ile: Normal SS: 10: Average
Visuo-constructional abilities	Block Design (WAIS-III) Complex Figure Copy-Clock Drawing (KBNA)	SS: 15–16: Superior SS: 16: Superior
Visuo-Perceptual Abilities		
Reading	WTAR* MAE*	Standard Score: 122: Superior 67%ile: Average
Line Orientation	Judgement of Line Orientation	Normal: Perfect score
Colour Perception	Identification of 14 colour patches Naming colour of 10 familiar objects Farnsworth-Munsell 100-Hue Test	9 correct answers 10 correct answers but with hesitation Impaired colour discrimination: Poor at all wavelengths
Object and Space Perception	VOSP	Object Perception: Shape Detection Screening Test: Pass Incomplete Letters: Pass Silhouettes: Pass Object Decision: Pass Progressive Silhouettes: Fail Space Perception: Dot Counting: Pass Position Discrimination: Pass Number Location: Pass Cube Analysis: Pass
Recognition	Delayed Visual Reproduction (KBNA)	SS: 8: Average

(*Continued*)

Table 1. Continued.

General intellectual functioning		
Cognitive abilities	Test names	Results
Faces	Benton Facial Recognition Test 35 pictures of well-known individuals: Current Hollywood Actors, Canadian Politicians, and Hospital Staff members Faces of Famous People (80 faces: 20 per each last 4 decades; from Anaki, Boyd, & Moscovitch, 2007)	Normal Recognised 6 faces (did not recognise hospital staff members even when present in the testing room) Recognised 9 out of 45 known faces
Buildings	30 well-known famous buildings Imagery (30 questions requiring comparisons of the buildings previously shown)	Recognised 11 17 correct answers

*These tests were administered by Dr. Green when LH was an inpatient at his rehabilitation centre, other tests were parts of our neuro-perceptual evaluation. WASI = Weschler Abbreviated Test of Intelligence; WAIS-III = Weschler Scale of Intelligence–III; SS = standard score; RAVLT = Rey Auditory Verbal Learning Test; WMS = Wechsler Memory Scale; CFL = Form of verbal fluency test from the Controlled Oral Word Association Test; BNT = Boston Naming Test; KBNA = Kaplan Baycrest Neurocognitive Assessment; RVDLT = Rey Visual Design Learning Test; WTAR = Weschler Test of Adult Reading; MAE = Multilingual Aphasia Examination; VOSP = The Visual Object and Space Perception Battery;

memory, and ability to read road maps, as well as his high level of intellectual functioning, it was agreed that LH could likely learn to use a smartphone to plan and follow routes, dynamically locate himself within his environment, and access the compass application (app). The iPhone was most suited for his needs.

A two-phase intervention: (1) skill acquisition phase, and (2) generalisation phase was designed.

Skill acquisition phase

The goal of the first phase was the acquisition and efficient execution of steps needed to use the navigation apps on his iPhone (Maps and Compass). LH acquired the skills for using Maps so that he could enter the departure address (and/or find his current position) and destination address, find a route to navigate between the locations (either by walking or taking public transit), while dynamically following his own position, and knowing the cardinal directions while he travelled.

Step-by-step instruction in app use was guided by the errorless-fading-of-cues protocol offered to individuals with memory impairment at the Memory-Link Program at Baycrest (Svoboda et al., 2010; Svoboda et al., 2012; Svoboda & Richards, 2009, for description of their training). The goal of errorless learning is to minimise errors during the acquisition of new information or new skills. In the errorless-fading-of-cues protocol, the software app is broken down into its individual steps and the trainer gradually fades guidance (verbal prompts and physical pointing) as steps are learned and entered independently by the patient, thereby reducing errors.

In this case, steps necessary for the apps Maps and Compass were determined. Each app (Maps and Compass) was broken down into its component steps comprising one trial (e.g., Step 1: Turn on device; Step 2: Slide to unlock; Step 3; Tap contact; 4: Tap Direction; 5: Tap Route; 6. Tap Flip; 7: Tap List; 8: Tap Square Button; Turn Off. Each training session was composed of 10 trials. Each component step received its own score (range 0–4: 4 = maximum environmental support; 0 = no environmental support). The cuing hierarchy provided by the trainer comprised: 4 = full explanation and demonstration;

3 = the same verbal explanation as above but pointing to the next step prior to LH executing it; 2 = either verbal guidance or pointing to the correct response prior to LH executing it; 1 = confirmation of a correct query, and 0 = no environmental support provided. Criterion for moving to the next stage of training was 98% correct responding within a single training session. The percentage correct for each session was derived by the formula (1-[average numeric value of cues/4]×100).

The rationale for applying this errorless learning approach to LH was his decline in memory (borderline to average range on many of the tests) relative to estimated premorbid ability, as suggested by his advanced education and superior intellectual function. With LH this approach was efficient for the early acquisition of all steps necessary for accessing his apps. He quickly learned all steps necessary for using his Maps and Compass apps, and became rapidly independent at using them. Ten training sessions – two one-hour sessions a week – were necessary for LH to acquire and be able to apply the learned skills without prompting.

In fact, strictly using an errorless learning protocol with LH was not ideal beyond the initial skills acquisition phase; he became frustrated with this fading-of-cues approach, and needed to engage in more flexible discourse, planning and structuring of the intervention sessions. His perceived involvement and ability to direct the course of sessions became crucial to the success of the intervention. Indeed, once LH acquired basic skills, he was able to explore, initiate, and establish useful strategies beyond those learned in his first sessions. His initiatives were integrated in the second phase of the intervention.

Generalisation phase

The goal of the second phase was to generalise his skills outside the clinical setting by facilitating and automating his access to Maps within the context of day-to-day way finding. This phase was crucial for improving his functional independence, and importantly, for reducing his anxiety while in the mist of finding his way during his outings. Indeed, while LH easily acquired skills to use his iPhone (in the skill acquisition phase), he clearly expressed his needs to be actively involved in the development of his compensatory strategy. His own involvement had to become an integral part of the intervention; being actively involved contributed to building confidence in his own abilities to problem solve when in a difficult navigation situation, which in turn served to reduce his fear of going out and getting lost.

Between sessions LH was asked to use the navigation apps for various upcoming errands and outings, typically including a mixture of walking and taking public transport. His weekly outings were planned during the sessions according to LH's schedule. Early in the intervention, they consisted of going to known locations and taking transportation methods that he knew well. For example, LH travelled from his home to the nearest subway station exclusively by bus since he knew the bus number and was sure that its journey ended at the subway station. (He would have preferred to walk to the subway station, but was not confident that he could find his way when walking.) LH prudently understood that he should not risk getting lost when unsure. In order to be safe, LH always travelled from a place where he was with his wife to a known place where he could meet his friends – both his wife and friends made sure that they knew where he was at all times during these outings.

The outcome of his outings was then discussed at the following session during which time his concerns and challenges were addressed. Some concerns were addressed with training on specific software features, which provided additional "tools" for his navigational "toolkit". For example, LH was taught to use "pin-dropping" to mark a location to which he wanted to return, or a street intersection to which he needed directions. He was also taught to enter addresses in Contacts and to use the Calendar app. This logistical support helped LH manage his distress over his navigation difficulties. In addition, part of the intervention was less structured and committed to providing emotional support in dealing with his stress and reduced confidence. For instance, LH received guidance in trouble shooting various scenarios in the event that there was a smartphone malfunction (e.g., his smartphone screen froze, the internet was not available, etc.). Having this step-by-step action plan further decreased his anxiety. Over time, LH travelled alone to progressively more challenging destinations by relying on his smartphone navigation apps, and his newly acquired skills.

Another challenge, which was addressed during the generalisation phase, was LH's difficulty travelling from the nearest subway station to his home. As mentioned above, LH could use public transport effectively to travel from his home to downtown and back, but he could not walk back home without getting disoriented and lost. Part of the challenge was the layout of the subway station, resulting in LH coming out from a different exit each time. This was confusing and distressing to him as he wished to follow a familiar route that began partway home but he could not navigate to its start point. Due to his distress, he typically resorted to taking the bus home in order to avoid getting lost. An intervention was designed to teach him to navigate within the subway station to one exit point, navigate outside at street level to the beginning of his familiar route home, and consequently reduce his stress level regarding way-finding in this unique scenario. With LH, we went to the station, and listed his difficulties and challenges while he tried to exit the subway station and walk home. Solutions using directional strategies (e.g., when leaving the subway always walk to the first exit staircase), and landmarks (specific names of commercial offices on the streets encountered on his walk home) were generated while on site. LH could apply the strategies effectively after two training sessions after which he was confident that he would not get lost walking home at the time or in the future. (All steps, landmarks, and coding system used during his subway intervention are presented in Appendix A.) During the generalisation phase, LH also learned to use other software apps including entering addresses into Contacts, appointments and events into the Calendar, and learning how to access address entries via the Maps app.

As LH became more confident in his abilities to use his smartphone for navigation and problem solving, his prescribed outings were extended to less familiar locations and ways of travelling. For example, once he learned how to walk home and was confident that he could do it, he no longer took a bus to travel between his home and the subway station – he was happy to walk to and from the station.

Overall, training was client-centred, client-guided, and client-paced. LH was provided with the number of training sessions needed to learn and implement effectively the desired skills and strategies. (Twenty training sessions – two one-hour sessions a week – were necessary during the Generalisation Phase.) Towards the end of training, LH became extremely pro-active at planning and rehearsing his future outings. The night before going out, he would enter his targeted addresses into his iPhone, and find the routes to use.

Study design

LH consented to be part of the study and ethical approval was obtained from the hospital Ethical Research Board.

The effectiveness of the intervention was assessed using a single-case time-series design A_1–B_1-A_2–B_2.[2] LH's training sessions occurred between Phases A_1 and B_1. LH's navigation skills were evaluated on a real-life way-finding task in Phases A_1 and A_2, when he had not yet learned the navigational strategies using his iPhone (A_1) or was not permitted to use his iPhone (A_2), and in Phases B_1 and B_2, when he was allowed to apply his navigational iPhone strategies. Questionnaires pertaining to naturalistic behaviours regarding LH's way-finding were completed separately by LH and his wife at baseline (A_1) and following intervention (B_1).

Training lasted about five and a half months during which time LH attended on average two training sessions per week. The duration of the training was determined by LH's rate of learning the navigation and related apps. Each app was considered learned when LH had at least 98% correct execution of steps (e.g., determining the route between locations A and B). Immediately after LH finished his training, he completed the real-life navigation task and questionnaires (B_1). Phase A_2 outcome measures were completed approximately two weeks after B_1. Finally B_2 outcome measures were completed four months following training, thereby measuring maintenance of treatment gains.

An age, education and sex-matched control participant completed the same A_1 navigational task as LH (with Google map printout). Since both A_1 and B_1 locations were the same, LH's performance at both baseline (A_1) and with the use of iPhone way-finding strategies (B_1) could be compared to that of the control participant (e.g., How does LH compare to a healthy control at baseline?; and, Does the use of an iPhone equate LH's performance to that of the control participant?). The remaining navigation task locations were different from A_1 and B_1 and from each other, and all locations were unknown to LH.

Data collection

Data collection was done using the following outcome measures.

Canadian Occupational Performance Measure (COPM)

Before intervention, LH defined his rehabilitation goal as being able to "move around independently". Using the COPM, LH's rating of the importance of his goal, his performance, and satisfaction at achieving it, were measured using a 1 to 10 scale (where 1 is "the least important" and 10 "the most important").

Confidence in dealing with various navigational scenarios questionnaire

A scale was created to evaluate the intervention and generalisation to different way-finding circumstances (see Appendix B). LH completed the rating scale (1–10) pertaining to his confidence in dealing with five navigational scenarios (leading to a possible total

[2]Phases A_1, B_1, A_2, and B_2 occurred on January 6, July 20, August 2, and November 9, 2012, respectively.

score of 50). His wife completed the same questionnaire pertaining to her confidence in LH's ability.

Navigation between places of varying familiarity questionnaire

On another questionnaire, also created to evaluate the intervention, LH judged his current ability to go from one place to another, each place varying in familiarity (see Appendix C). His wife completed the same questionnaire pertaining to his ability.

Real-life navigational task

Naturalistic observations were used in order to evaluate LH's abilities to actually navigate among different unknown city locations. During each study phase, A_1–B_1-A_2–B_2, LH was given a navigational assignment during which he had to walk to three unknown locations and return to his starting position while using a printed Google map of the area. Navigation tasks in A_1, B_1, A_2, and B_2 were matched for total distance travelled between locations (within 2 km; based on Google map route suggestions) and for total number of turns required to reach the three target locations.

During these outings, LH agreed to be recorded on video and audio, and to carry an iPhone in his pocket running a Global Positioning System app (GPS^+ Pedometer) which tracked his steps, route and position. Captured on video recordings, his outing behaviours were coded by two independent judges. For each 10-second segment of all study phases (A_1, B_1, A_2, and B_2), judges noted each occurrence that LH looked/studied the printed map (and the profanities he used) while performing his navigation assignment. In addition, in phases during which LH could use his iPhone (B_1 and B_2), the judges coded each occurrence that he examined his iPhone. After making sure that the reliability of these coded behaviours was high, a percentage of time during which LH engaged these behaviours was determined. Finally, the GPS recordings were coded so that route efficiency (Optimal Google Distance/Actual distance travelled for completing the three-locations navigation assignment and returning to the starting point), and surplus direction changes (e.g., Number of direction changes done by LH minus the number of direction changes suggested by Google) were calculated.

Results

Before training, LH completed the COPM and rated the importance of his goal of navigating independently as being at 10 (the maximum rating), his ability at 3, and his satisfaction with his performance at 2, stating: "I am pissed off". Indeed, LH was very frustrated with his poor performance and inefficiency while navigating. He spontaneously expressed his frustration by swearing often while navigating and trying to find his way around. After training, LH's goal remained maximally important to him (as 10); he rated his ability to achieve it as 10, and his satisfaction as 9. From his training and practice, LH became well aware that he could use his smartphone to navigate efficiently, and self-initiated planning and preparations the evening before navigating the unfamiliar outings (e.g., entering the addresses where he planned to go into his contact list, rehearsing the routes, choosing the best option).

The confidence ratings provided by LH and his wife with respect to managing various navigation tasks before and after the intervention are presented in Figure 2.

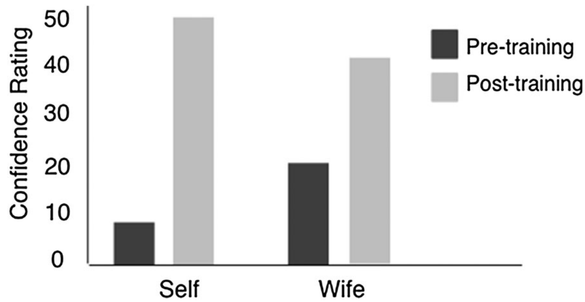

Figure 2. Sum of confidence rating of being able to accomplish five navigation demands (sum of score for a maximum of 50) obtained from LH and his wife, pre- and post-training.

Following intervention, both LH and his wife were significantly more confident that he could accomplish navigation outings successfully.

LH's ratings of his pre- and post-ability to navigate between locations varying in familiarity improved following intervention (see Figure 3). This was most evident in the more challenging scenarios of travelling between two unfamiliar locations (i.e., two unknown restaurants). LH reported a clear relation between his improved satisfaction, confidence, and evaluation of his abilities to navigate from various locations (even to unknown locations) and a decreased stress related to his navigational demands.

The data from the naturalistic outing video recordings are consistent with LH's ratings reflecting greater capability for independent navigation. Two independent judges rated the recorded behaviours, and among all types of behaviour coded, the average inter-judge reliability was 94.0% agreement (*SD* = 1.5%; Range = 92–100).

Figure 4 illustrates LH's percent route efficiency and the number of surplus direction changes throughout all phases of the study. The results show that route efficiency is greater, and the surplus directional changes are lower in Phases B when LH could apply learned navigational strategies with his smartphone. His performance was worse than that of the age- and education-matched control participant, with

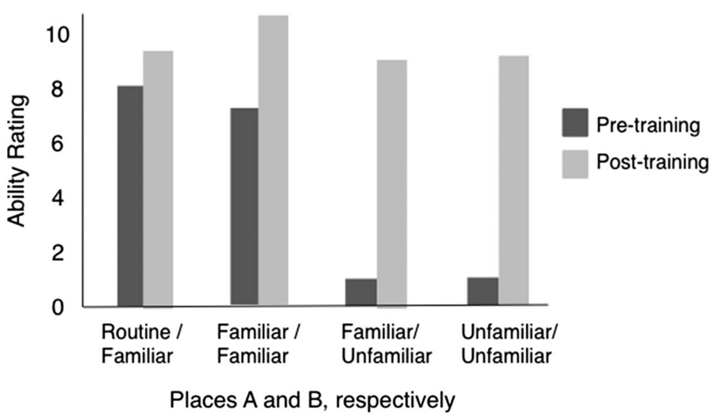

Figure 3. LH's ability rating (pre- and post-training) of going from place A to B on a scale of 1 to 10 where 1 is the minimum that represents "Not able to do it", and 10 is the maximum that represents "Can do it extremely well".

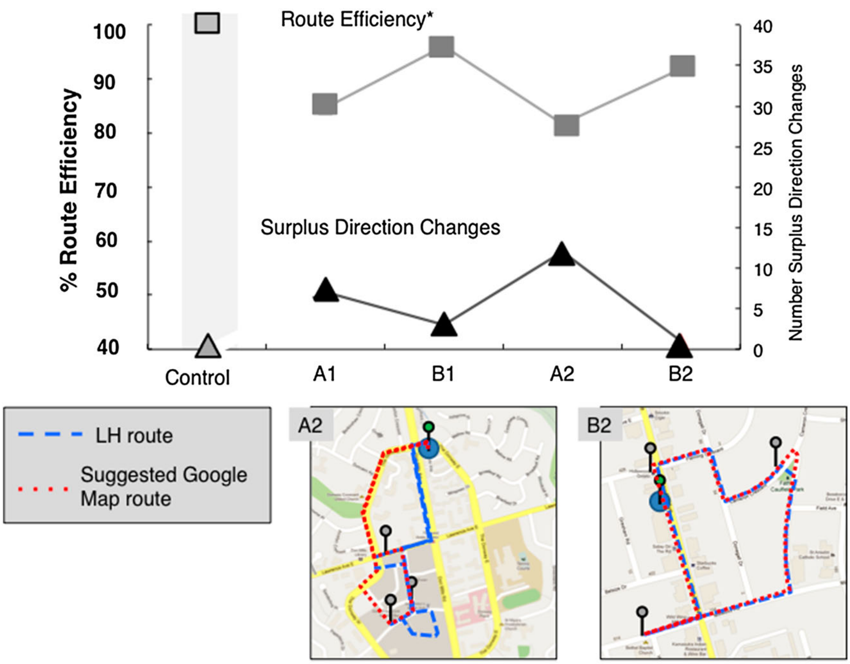

Figure 4. Top: LH's percent route efficiency (Optimal Google distance/Actual distance for three locations and returning to the starting point), and the number of surplus direction changes (Actual turns minus Optimal of number of turns suggested by Google) throughout all phases of the study. (Each symbol width includes one standard error.) The grey column on the left illustrates the control's percent route efficiency, and the number of surplus direction changes during his outing (equivalent condition to Phase A_1). Bottom: Illustration of LH's route compared to that proposed by Google Map at outing A_2 and B_2.

attenuation of discrepancy during Phases B when LH used his iPhone (see control data on the left side of Figure 4).

In addition, in order to achieve his navigation task, LH spent a smaller percentage of time studying his printed map in Phases B than in A (see Figure 5). During the first

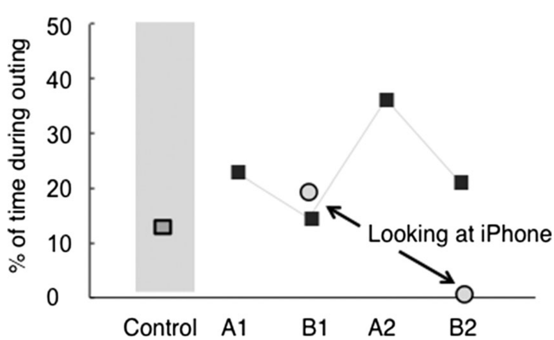

Figure 5. The squares illustrate the percent of time during which LH looked at his printed map during each phase. The grey column on the left represents the percent of time during which the control looked at his printed map during his outing (equivalent condition to Phase A_1). The circle represents the percent of time during which LH looked at his iPhone while accomplishing his outing tasks.

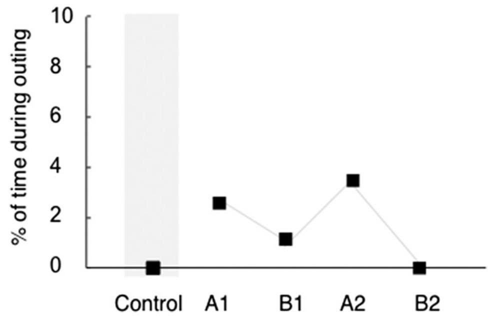

Figure 6. The squares illustrate the percent of time during which LH used profanities during each phase. The grey column represents the equivalent for the control (as in Phase A_1).

outing when LH was permitted to use his iPhone (Phase B_1), he spent more time looking at his printed map than did the control. However, note that he spent the equivalent amount of time looking at his iPhone and the printed map. He looked at the latter less than during baseline (Phase A_1). Interestingly, during the second outing with his iPhone (Phase B_2), he also spent less time looking at the printed map, but did not look at his iPhone. Instead, he studied his iPhone information carefully before initiating the navigation task. Finally, LH used profanities less in Phases B than Phases A (see Figure 6). The control did not use profanities.

Discussion

This study describes and illustrates the efficacy of a compensatory training programme designed to overcome topographical disorientation. Using modern smartphone and GPS technology, LH could navigate beyond the mastery of only a few locations without the fear of getting lost.

The intervention enabled LH efficiently and confidently to use his navigational smartphone apps to cope with various way-finding challenges and to deal effectively with a unique way-finding scenario involving navigation within a subway station and finding a consistent route home. In addition, LH reported that when feeling unsure during an outing, he could take a few minutes to regroup, problem solve, find a strategy of navigation, and continue his journey calmly, with the confidence that he would succeed. Overall the intervention reduced his fear, frustration and stress over his navigation challenges.

The success of this intervention is due in great part to the fact that it is client-centred and multi-faceted. Indeed, in order to be most successful, cognitive rehabilitation must be tailored to individual patients according to the following considerations: (1) their neuropsychological profile is well known; (2) their goals and desires adjusted in discussion with them and/or their caretakers so that they are realistically attainable in light of their cognitive impairment; (3) the skills taught maximise the utility of their cognitive strengths while overcoming their weaknesses; (4) the treatment, in this case learning regime, leads to a sense of capacity and mastery of the desired skills; and that (5) ecologically valid and real-life relevant skills and outcomes are taught and measured, respectively.

Through psychoeducation, LH was guided to understand his cognitive state, and its anatomical correlates. Like other individuals with landmark agnosia, there was involvement of his ventral cortex and parahippocampal regions, likely contributing to his anterograde deficit, and his egocentric spatial issues likely stemmed from posterior parietal cortex involvement. Bilateral posterior temporal involvement is consistent with dyschromatopsia and prosopagnosia. At first, LH wanted to regain perfect visual recognition and colour vision. Once he understood better the nature of his agnosic difficulties, dyschromatopsia and their related pathology, he acknowledged that complete recovery was most probably unrealistic, and that compensatory strategies needed to be learned.

Despite the fact that LH had recognition difficulties for both faces and places, he was never too bothered by his prosopagnosic challenges, and did not request remediation for them; it was his TD that he identified as being most debilitating for his activities of daily living. Thus, remediation was offered only for his navigation impairment. Once LH acknowledged his impairments and determined his most pressing needs, he decided that his intervention should aim at making sure that he could "move around independently" without fear of getting lost.

Once these concrete goals were established, the approach was tailored so that it relied most on LH's cognitive strengths and least on his difficulties. Indeed, despite his inability to recognise landmarks, his difficulties with orienting himself in space, and anterograde deficit in learning new locations, LH was able to navigate due to his good organisational and problem solving skills, his sufficient memory, and his good ability to read maps/interpret spatial layout. Accordingly, while errorless learning was first used to teach LH basic skills to use iPhone apps, his involvement was quickly integrated into training. LH was required to describe in detail his weekly navigation experiences and challenges, and participate in the generation of possible solutions to his problems. Training targeted skills necessary to use navigational apps, cope with obstacles (e.g., no network connection, malfunctioning device, etc.) and strategically plan and implement way-finding strategies so that they could be applied independently to untrained routes.

Equipped with techniques on how to use the latest smartphone technology, and strong organisational skills, LH developed strategies for navigation that extended much beyond those directly taught during training. For example, throughout the programme, LH started establishing goal-oriented actions related to his navigational skills. He developed and learned goal-management strategies related to his outings: He planned his outings in advance and established sub-goals and steps to reach his destinations. His willingness to engage in managing his goals, paired with his remaining abilities to read maps, and strong organisational skills reinforced his learning, and his sense of competence.

Through the intervention, LH gained mastery and a sense of competency. Before intervention, when feeling lost, he would not be able to remain calm which, in turn, exacerbated his deficiencies in way-finding and navigation. After a while, LH became confident that even when feeling uneasy during an outing, he would be capable of using specific features of his iPhone, and of engaging in potential problem-solving solutions. Lindqvist and colleagues (Lindqvist, 2012; Lindqvist & Borell, 2010, 2012; Lindqvist, Nigård, & Borell, 2013) have recognised that acquiring a sense of mastery is essential for successful rehabilitation. Specifically, Lindqvist et al. (2013, p. 393) suggest that. "the very knowledge that the participants had the possibility to use the

AT could be sufficient to allow them to feel assured through the achievement of a sense of capacity." The results support this suggestion.

Finally, it is crucial to emphasise that interventions should target ecologically valid skills and outcomes. The intervention happened beyond the offices; we went out into the city (e.g., to a subway station) in order to assess LH's difficulties and to find possible solutions with him. Providing access to the internet, the skills LH acquired have enabled him to navigate from and to places not studied during training, whether they were familiar or not, and to do so whether walking and/or taking public transport. As he said, the iPhone gave him a "security blanket", so that he no longer feared getting lost. Previous compensatory strategies for TD were successful, although limited, in that they only helped individuals to find their way around a few targeted places (Bouwmeester et al., 2014; Brunsdon et al., 2007; Davis & Coltheart, 1999). In agreement with the findings of Lindqvist and colleagues (Lindqvist, 2012; Lindqvist et al., 2013; Lindqvist & Borell, 2010; Lindqvist & Borell, 2012), this is further evidence showing how assistive technology can make patients more autonomous. LH and his wife both recognised that he gained autonomy beyond his immediate environment, and thus attained a greater quality of life.

Rehabilitation approaches need to be tailored based on each individual's cognitive profile. It is believed that using errorless learning with the latest technology related to navigation, while maximising personal relevance, by taking account of the patient's cognitive strengths and limitations, and by using ecologically valid and real-life relevant outcomes, the current approach has great potential (Cicerone, 2005; Hart, 2009; Whyte & Hart, 2003; Wilson, 2002).

Respecting these constraints, the approach can be adapted and used with individuals experiencing navigational challenges caused by different issues than those of LH. For example, it could be used with individuals suffering from a TD caused by lesions different from those of LH (Aguirre & D'Esposito, 1999), or neurodegenerative disorders that cause deficits in addition to TD. The intervention could be adapted and used with adult individuals who have developmental TD – a life-long inability to orient within the environment despite intact sensory and intellectual function, and in the absence of any structural lesion (e.g., Bianchini et al., 2010; Bianchini et al., 2013; Iaria, 2013; Iaria & Barton, 2010; Incoccia et al., 2009; Kim, Aminoff, Kastner, & Behrmann, 2015; Palermo et al., 2014). Even people with visuo-spatial and constructional difficulties that hinder their navigation abilities (e.g., for right-brain damaged individuals experiencing imagery and/or perceptual neglect, as exemplified in Byrne, Becker, & Burgess, 2007; Guariglia, Palermo, Piccardi, Giuseppe, & Incoccia, 2013; Palermo, Ranieri, Nemmi, & Guariglia, 2012) may be able to benefit from this kind of intervention as long as it could rely more heavily on landmarks. For example, addresses and contacts could be encoded using pictures of the locations. Individuals who have memory impairment also have difficulties finding their way around new neighbourhoods. Extending the approach of the Memory-Link programme, people with amnesic difficulties could learn to use Maps in conjunction with the Calendar app. The acquisition phase of the intervention would need to rely exclusively on extensive errorless learning training. This approach has proven to be useful in amnestic individuals not only for learning skills to use smartphone calendar apps and reminders, but also for maintaining learned skills over a long time period (Svoboda et al., 2014). On the other hand, unlike LH, most amnestic individuals do not have difficulties with cardinal directions, nor with recognising and experiencing a sense of familiarity from seeing previously known places and locations. As such, it is possible that relying on maps and compass during navigation be less necessary.

Lindqvist et al. (2013) have prescribed assistive technology (AT) to patients suffering from Alzheimer's disease (AD) in order to improve their quality of life. While most of their patients benefited best from AT in their home (e.g., sensors as reminders of ongoing tasks), one of their patients was provided with a mobile phone/GPS. A GPS was used, since, despite her progressive illness and fear of getting lost, this woman most wanted to continue engaging in her favourite activity of going for walks in the forest. While Lindqvist et al. do not describe how their patient acquired her skills for using her GPS, she was able to use it to a point that she was no longer fearful to go out for walks in the forest near her house. Her success exemplifies the usefulness of using a smartphone for improving navigation by an individual who suffers from memory and executive function difficulties, thus improving autonomy and freedom.

While the current strategies lead to improved independence and quality of life, constraints must be carefully managed. Trainees or caretakers must remain informed about the rapidly changing technology and development of new apps that may directly impact the use of learned smartphone skills. Through rehabilitation programmes, and/or family networks, support for keeping up with the latest technological development needs to be offered on a long-term basis. Moreover, a trainee who likes to travel abroad (like LH does) needs to overcome the difficulties related to using the technology in a different language, and accessing the internet from remote locations. Moreover, while it is clear that all rehabilitation programmes need to take the residual cognitive capacities of the person into account, it is unclear what are the lower limits of cognitive functioning that would allow such programme to be implemented. Clearly, it is effective for individuals who function at a high level in domains other than the one related to the impairment, as was the case with LH. It remains an open question whether individuals who are functioning at a lower level could also benefit from the programme. Despite these limitations, many individuals should benefit from this rehabilitation approach.

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References

Aguirre, G. K., & D'Esposito, M. (1999). TD: A synthesis and taxonomy. *Brain*, *122*(9), 1613–1628. doi:10.1093/brain/122.9.1613

Alsaadi, T., Binder, J. R., Lazar, R. M., Doorani, T., & Mohr, J. P. (2000). Pure TD: A distinctive syndrome with varied localization. *Neurology*, *54*(9), 1864–1866.

Anaki, D., Boyd, J., & Moscovitch, M. (2007). Temporal integration in face perception: Evidence of configural processing of temporally separated face parts. *Journal of Experimental Psychology: Human Perception and Performance*, *33*(1), 1–19.

Antonakos, C. L. (2004). Compensatory wayfinding behavior in TD from brain injury. *Journal of Environmental Psychology*, *24*, 495–502.

Barrash, J. (1998). A historical review of TD and its neuroanatomical correlates. *Journal of Clinical and Experimental Psychology*, *20*(6), 807–827.

Barrash, J., Damasio, H., Adolphs, R., & Tranel, D. (2000). The neuroanatomical correlates of route learning impairment. *Neuropsychologia*, *38*, 820–836.

Bianchini, F., Incoccia, C., Palermo, L., Piccardi, L., Zompanti, L., Sabatini, U., … Guariglia, C. (2010). Developmental TD in a healthy subject. *Neuropsychologia*, *48*(6), 1563–1573. doi:10.1016/j.neurospychologia.2010.01.025

Bianchini, F., Palermo, L., Piccardi, L., Incoccia, C., Nemmi, F., Sabatini, U., & Guariglia, C. (2013). Where am I? A new case of developmental TD. *Journal of Neuropsychology*, *8*(1), 107–124. doi:10.1111/jnp.12007

Botez-Marquand, T., & Botez, M. I. (1992). Visual memory deficits after damage to the anterior commissure and right fornix. *Archives of Neurology*, *49*(3), 321–324.

Bouwmeester, L., van de Wege, A., Haaxma, R., & Snoek, J. W. (2014). Rehabilitation in a complex case of TD. *Neuropsychological Rehabilitation*, *25*(1), 1–14. doi:10.1080/09602011.2014.923318

Brunsdon, R., Nickels, L., Coltheart, M., & Joy, P. (2007). Assessment and treatment of childhood TD: A case study. *Neuropsychological Rehabilitation*, *17*(1), 53–94.

Byrne, P., Becker, S., & Burgess, N. (2007). Remembering the past and imagining the future: A neural model of spatial memory and imagery. *Psychological Review*, *114*(2), 340–375.

Cicerone, K. D. (2005). Methodological issues in evaluating the effectiveness of cognitive rehabilitation. In P. W. Halligan & D. T. Wade (Eds.), *Effectiveness of rehabilitation for cognitive deficits* (pp. 43–58). Oxford: Oxford University Press.

Clarke, S., Assal, G., & De Tribolet, N. (1993). Left hemisphere strategies in visual recognition, topographical orientation and time planning. *Neuropsychologia*, *31*(2), 99–113.

Davis, S. J. C., & Coltheart, M. (1999). Rehabilitation of TD: An experimental single case study. *Neuropsychological Rehabilitation*, *9*(1), 1–30.

De Renzi, E. (1985). Disorders of spatial orientation. In J. A. M. Frederiks (Ed.), *Handbook of clinical neurology, vol. 1 (45): Clinical neuropsychology* (pp. 405–422). Amsterdam: Elsevier Science.

De Renzi, E., Faglioni, P., & Villa, P. (1977). Topographical amnesia. *Journal of Neurology, Neurosurgery and Psychiatry*, *40*, 498–505.

Guariglia, C., Palermo, L., Piccardi, L., Giuseppe, I., & Incoccia, C. (2013). Neglecting the left side of a city square but not the left side of its clock: Prevalence and characteristics of representational neglect. *PLoS ONE*, *8*(7), e67390. doi:10.1371/journal.pone.0067390

Habib, M., & Sirigu, A. (1987). Pure TD: A definition and anatomical basis. *Cortex*, *23*(1), 73–85.

Hart, T. (2009). Treatment definition in complex rehabilitation interventions. *Neuropsychological Rehabilitation*, *19*(6), 824–840.

Iaria, G. (2013). Developmental TD: Lost every day. *The Lancet Neurology*, *12*(8), 745. doi:10.1016/S1474-4422(13)70133-9

Iaria, G., & Barton, J. J. S. (2010). Developmental TD: A newly discovered disorder. *Experimental Brain Research*, *206*, 189–196. doi:10.1007/s00221-010-2256-9

Incoccia, C., Magnotti, L., Iaria, G., Piccardi, L., & Guariglia, C. (2009). TD in a patient who never developed navigational skills: The (re)habilitation treatment. *Neuropsychological Rehabilitation*, *19*(2), 291–314. doi:10.1080/09602010802188344

Katayama, K., Takahashi, N., Ogawara, K., & Hattori, T. (1999). Pure TD due to right posterior cingulate lesion. *Cortex*, *35*(2), 279–282. doi:10.1016/S0010-9452(08)70801-3

Kim, J. G., Aminoff, E. M., Kastner, S., & Behrmann, M. (2015). A neural basis of developmental TD. *The Journal of Neuroscience*, *35*(37), 12954–12969. doi:10.1523/JNEUROSCI.0640-15.2015

Landis, T., Cummings, J. L., Benson, D. F., & Palmer, E. P. (1986). Loss of topographical familiarity: An environmental agnosia. *Archives of Neurology*, *43*, 132–136.

Lindqvist, E. (2012). *Assistive technology as cognitive support in everyday life for persons with dementia or stroke* (Thesis). Karolinska Institutet, ISBN: 978–91–7457–814–0.

Lindqvist, E., & Borell, L. (2010). The match between experienced difficulties in everyday activities after stroke and assistive technology for cognitive support. *Technology and Disability*, *22*, 89–98. doi:10.3233/TAD-2010-0294

Lindqvist, E., & Borell, L. (2012). Computer-based assistive technology and changes in daily living after stroke. *Disability and Rehabilitation: Assistive Technology*, *7*(5), 364–371.

Lindqvist, E., Nigård, L., & Borell, L. (2013). Significant junctures on the way towards becoming a user of assistive technology in Alzheimer's disease. *Scandinavian Journal of Occupational Therapy*, *20*(5), 386–396.

Maguire, E. A., Burke, T., Phillips, J., & Staunton, H. (1996). TD following unilateral temporal lobe lesions in humans. *Neuropsychologia*, *34*, 993–1001.

Maguire, E. A., Frackowiak, R., & Frith, C. D. (1997). Recalling routes around London: Activation of the right hippocampus in taxi drivers. *Journal of Neuroscience*, *17*(18), 7103–7110.
Martinaud, O., Pouliquen, D., Gérardin, E., Loubeyre, M., Hirsbein, D., Hannequin, D., & Cohen, L. (2012). Visual agnosia and posterior cerebral artery infarcts: An anatomical-clinical study. *PLoS ONE*, *7*(1). doi:10.1371/journal.pone.0030433
Mendez, M. F., & Cherrier, M. M. (2003). Agnosia for scenes in topograhagnosia. *Neuropsychologia*, *41*, 1387–1395.
Pai, M. C. (1997). TD: Two cases. *Journal Formosan Medical Association*, *96*, 660–663.
Palermo, L., Piccardi, L., Bianchini, F., Nemmi, F., Giorgio, V., Incoccia, C., Sabatini, U., & Guariglia, C. (2014). Looking for the compass in a case of developmental TD: A behavioral and neuroimaging study. *Journal of Clinical and Experimental Neuropsychology*, *36*(5), 464–481. doi:10.1080/13803395.2014.904843
Palermo, L., Ranieri, G., Nemmi, F., & Guariglia, C. (2012). Cognitive maps in imagery neglect. *Neuropsychologia*, *50*, 904–912.
Pallis, C. A. (1955). Impaired identification of faces and places with agnosia for colours. Report of a case due to cerebral embolism. *Journal of Neurology, Neurosurgery, and Psychiatry*, *18*, 218–224. doi:10.1136/jnnp.18.3.218
della Rocchetta, A. I., Cipolotti, L., & Warrington, E. K. (1996). TD: Selective impairment of locomotor space? *Cortex*, *32*, 727–735.
Savage, K. R., & Svoboda, E. (2013). Long-term benefits of the memory-link programme in a case of amnesia. *Clinical Rehabilitation*, *27*(6), 521–526.
Suzuki, K., Yamadori, A., Hayakawa, Y., & Fujii, T. (1998). Pure TD related to dysfunction of the viewpoint dependent visual system. *Cortex*, *34*(4), 589–599.
Svoboda, E., & Richards, B. (2009). Compensating for anterograde amnesia: A new training method that capitalizes on emerging smartphone technologies. *Journal of the International Neuropsychological Society*, *15*(4), 629–638.
Svoboda, E., Richards, B., Leach, L., & Mertens, V. (2012). PDA and smartphone use by individuals with moderate-to-severe memory impairment: Application of a theory-driven training programme. *Neuropsychological Rehabilitation*, *22*(4), 408–427.
Svoboda, E., Richards, B., Polsinelli, A., & Guger, S. (2010). A theory-driven training programme in the use of emerging commercial technology: Application to an adolescent with severe memory impairment. *Neuropsychological Rehabilitation*, *20*(4), 562–586.
Svoboda, E., Richards, B., Yao, C., & Leach, L. (2014). Long-term maintenance of smartphone and PDA use in individuals with moderate-to-severe memory impairment. *Neuropsychological Rehabilitation*, *25*(3), 1–21.
Takahashi, N., Kawamura, M., Shiota, J., Kasahata, N., & Hirayama, K. (1997). Pure TD due to right retrosplenial lesion. *Neurology*, *49*, 464–469.
Whyte, J., & Hart, T. (2003). It's more than a black box; it's a Russian doll. *American Journal of Physical Medicine and Rehabilitation*, *82*, 639–652.
Wilson, B. A. (2002). Towards a comprehensive model of cognitive rehabilitation. *Neuropsychological Rehabilitation*, *12*(2), 97–110.

Appendix A

Intervention subway station

In order to walk home, when coming back from downtown, follow these steps as you walk out of the subway train.

	3	2	1	0
1. Go to front of subway (first 3 wagons)				
2. Go up staircase – look for "Taste" (front) & "Second Cup" (left side)				
3. Look for the booth – go towards it (turn right)				
4. Once past the booth, turn right – go up the staircase				
5. Once outside – turn on your compass; find NORTH				
6. Start walking North (uphill) – cross Yonge & Eglinton				
7. Look for "What a bagel" and opposite side: "Rexall Pharma" & "Pickle Barrell"				
8. Continue walking up hill and find Bar "Duke of Kent" at the end of the same block				

Coding system:

3: verbal direction and pointing to location
2: verbal direction
1: answer questions
0: no help

Appendix B

Confidence in Dealing with Various Navigational Scenarios Questionnaire

The following questions ask how confident you are in managing various navigation demands.

For the following situations, please circle the appropriate number from 1 (not confident) to 10 (very confident) that best describes how confident you feel about navigation demands.

	Not confident									Very confident
Finding your way to an appointment (doctor, dentist)?	1	2	3	4	5	6	7	8	9	10
Meeting a friend for lunch at a new restaurant in the downtown Toronto core.	1	2	3	4	5	6	7	8	9	10
Going to the local grocery store to pick up a few items.	1	2	3	4	5	6	7	8	9	10
Running a number of errands in Toronto and finding your way to each destination.	1	2	3	4	5	6	7	8	9	10
Finding your way to a destination after making a wrong turn.	1	2	3	4	5	6	7	8	9	10

Appendix C

Navigation between Places of Varying Familiarity Questionnaire

1. How would you rate your current ability to go from your home to your pharmacy (both are routine and familiar)?

1	2	3	4	5	6	7	8	9	10
Not able to do it									Can do it extremely well

2. How would you rate your current ability to go from your daughter's to your friend's homes (both are familiar but not routine)?

1	2	3	4	5	6	7	8	9	10
Not able to do it									Can do it extremely well

3. How would you rate your current ability to go from your home (familiar) to an unknown restaurant (unfamiliar)?

1	2	3	4	5	6	7	8	9	10
Not able to do it									Can do it extremely well

4. How would you rate your current ability to go from and to unknown restaurants (both are unfamiliar)?

1	2	3	4	5	6	7	8	9	10
Not able to do it									Can do it extremely well