May reducing driving-related phobia recover developmental topographical disorientation? A case report

Published Version:
Guariglia, C., Russo, S., Nori, R., Bonavita, A., Piccardi, L. (2026). May reducing driving-related phobia recover developmental topographical disorientation? A case report. APPLIED NEUROPSYCHOLOGY. ADULT, 33(2), 588-600 [10.1080/23279095.2025.2462619].

Availability:
This version is available at: https://hdl.handle.net/11585/1035813 since: 2026-01-08

Published:
DOI: http://doi.org/10.1080/23279095.2025.2462619

May reducing driving-related phobia recover Developmental Topographical Disorientation? A case report

Cecilia Guariglia[1,2,3], Samuele Russo[1], Raffaella Nori[4], Alessia Bonavita[1], and Laura Piccardi[1,5*]

[1] Department of Psychology, Sapienza University of Rome, Italy
[2] Department of Medicine and Health Sciences, University of Molise, Italy
[3] IRCCS Fondazione Santa Lucia, Rome, Italy
[4] Department of Psychology, University of Bologna, Italy
[5]San Raffaele Cassino Hospital, Cassino (FR), Italy

Abstract

Developmental Topographical Disorientation (DTD) is more common than expected in healthy populations and can cause psychological disorders, leading to feelings of frustration and failure due to poor navigation. Due to the strict relation and the frequent association between DTD and psychological disorders, it is crucial to understand the impact of spatial anxiety and specific phobias, such as driving-related fear (DRF), on one's ability to autonomously navigate in the environment. Here, we report the case of a girl with DTD and DRF who struggled to learn driving routes due to her phobia. Her score in learning a computerized environment (CE) was low, and her performance in the other rating scales was below the cut-off, confirming the presence of DTD. However, after receiving psychological treatment for her DRF, she became faster in moving through CE, but the assessment of navigational skills still indicated the presence of DTD, suggesting the independence of the two disorders.

When addressing both DTD and psychological disorders, clinicians must prioritize which issue to tackle first. Here are some suggestions to help decide when to prioritize one aspect over the other to provide the best possible care for the patient.

Impact and implications: Over the last decade, there has been a noticeable rise in the number of people experiencing Developmental Topographical Disorientation (DTD). This is a learning disability that affects the ability to navigate through one's surroundings. Individuals with DTD find themselves getting lost in familiar places daily, which can have a significant impact on their quality of life. As more people become aware of this disorder, they often seek help from diagnostic centers. This study offers recommendations for clinicians, including tips for accurately assessing the disorder (such as differential diagnosis) and suggesting effective treatment options for any associated psychological issues.

Keywords: developmental topographical disorientation; navigational disorders; EMDR; psychological diseases; visuospatial memory; driving phobia; fear of driving; amaxophobia; neurodevelopmental disorders

Cecilia Guariglia https://orcid.org/0000-0001-7474-6030

Samuele Russo https://orcid.org/0000-0002-1846-9996

Raffaella Nori https://orcid.org/0000-0002-0629-5802

Alessia Bonavita https://orcid.org/0000-0001-7793-263X

Laura Piccardi https://orcid.org/0000-0002-1322-5538

We have no conflict of interest to disclose. This study was not preregistered. The data are available from the corresponding author upon reasonable request. Cecilia Guariglia supervised the methodology, writing, and final editing. Samuele Russo performed the RDI-EMDR therapy. Raffaella Nori contributed to the conceptualization and performed data extraction. Alessia Bonavita led cognitive assessment and performed data extraction and analysis. Laura Piccardi was the lead for supervision and resources, conceptualization, and methodology. All the authors equally contributed to write the original draft.

All Authors approved the final version of the manuscript.

Correspondence concerning this article should be addressed to Prof. Laura Piccardi, Department of Psychology, Sapienza University of Rome, Via dei Marsi 78, 00185 Roma RM. Email: laura.piccardi@uniroma1.it; https://spatialcognitionlab.com/

Burles and Iaria (2020) identified 1,211 Developmental Topographical Disorientation (DTD) individuals among 4028 participants aged 18 to 65 recruited through an online platform, while Piccardi and colleagues (2022) observed 54 individuals in a sample of 1,698 individuals aged 18 to 35. In both samples, all the DTD individuals reported having suffered from DTD since childhood. The fact that DTD is a relatively unknown phenomenon has put an enormous social burden on affected people. DTD individuals often complain that they feel isolated, ashamed, and reluctant to disclose their problems for fear of being judged or not accepted. The delay in characterizing this disorder is partly due to patients' reluctance to speak about and share their condition with others (Iaria, 2013; Piccardi et al., 2022a).

Everyone has likely experienced getting lost at some point, whether struggling to locate their car in a busy shopping mall parking lot or to reach the final goal by navigating through an unfamiliar town is a shared experience, that sometimes may also become anxiogenics. Getting lost can be frustrating, but it is usually easy to fix with a map or some help. It won't have any lasting impact. However, the same experiences may have a devastating effect when lived by individuals suffering from DTD, a lifelong pathological condition in which some people get lost daily, not only in unfamiliar surroundings but in familiar places and environments that they should know very well, like their neighborhoods or homes (e.g., Iaria & Barton, 2010; Piccardi et al., 2022). Indeed, DTD occurs in individuals with average cognitive skills, no brain injuries or neurological or psychiatric disorders, who have never developed evolved navigational skills, and who have experienced severe navigational and spatial topographical orientation problems since childhood. After the first description of DTD in 2009 (Iaria et al., 2009), several studies investigated the prevalence of this disorder that it is more widespread than previously believed, as demonstrated by two recent surveys by Burles and Iaria (2020), and Piccardi et al. (2022). Incidence at the moment ranges from 3 to 30 % of healthy individuals. Apart from individual differences in associated disorders and in the presence/absence of levels of neuroticism, DTD individuals are characterized for sharing some specific difficulties: all of them. Everyone struggled with learning new routes and reported that even familiar surroundings could be confusing and disorienting. Spatial disorientation, in some cases, appeared to be more related to the processing of navigational memory (Iaria et al., 2009; Bianchini et al., 2010; 2014; Palermo et al., 2014), while some individuals rely on environmental perceptual features for processing, others do not (Piccardi et al., 2019); some show poor processing of visuospatial features (Iaria et al., 2005). Familiarity seems to be frequent, suggesting the presence of genetic components in DTD. Indeed, Barclay and colleagues (2016) observed that 10 out of 19 relatives of 6 DTD individuals also showed DTD and Burles and Iaria (2020) confirmed the presence of some relatives affected by navigational disorders in the families of DTD individuals. Kim and colleagues (2015) found, in an individual with DTD, an atypical response profile in the retrosplenial cortex (RSC) and an atypical functional coupling to the place-parahippocampal area (PPA) compared with other individuals without DTD. This deviant functional profile of RSC is not due to compromised structural connectivity, suggesting that the RSC may play a key role in navigation-related processing and that an alteration of the RSC's functional properties may serve as the neural basis for DTD. At the same time, Nemmi et al. noted that Dr Wai employed different brain networks compared to the ones activated in control individuals without DTD. Indeed, the only areas of overlap observed between Dr Wai and the control group were in the occipital lobe, specifically the calcarine and lingual gyri. These regions are likely associated with the initial stage of the landmark identification process. In contrast, unlike controls, Dr Wai exhibited no activation in the medial temporal areas. Several studies have indicated that activations in these areas play a crucial role in navigational processes, landmark recognition, and landmark-based navigation (Epstein, Higgins, & Thompson-Schill, 2005; Epstein et al., 2007). Additionally, lesions in these areas are typically linked to the acquired TD (Aguirre & D'Esposito, 1999; Habib & Sirigu, 1987).

In characterizing DTD, Burles and Iaria (2020) gathered information on personality traits. They found that individuals with DTDs tend to have higher neuroticism and negative affect levels, an observation suggesting that DTD individuals experience more stress reactivity, particularly linked to the fear of getting lost, which they recognize as a significant stressor in their lives. Heightened levels of neuroticism or negative emotions may not be fundamental characteristics of DTD since they have not been observed in all DTD individuals. However, given the awareness of the difficulties in spatial orientation and the recurrent experiences of getting lost, it is not surprising they may be very likely linked with DTD, with a pathological loop effect, since their presence can hinder performing daily navigational tasks. Indeed, navigational anxiety may affect navigation in several ways, such as making DTD individuals adopt maladaptive coping mechanisms or even developing agoraphobia, ultimately increasing the likelihood of self-identifying as having issues with orientation.

Since neurotic traits are likely to be present in DTD, even if they are not characteristic DTD symptoms, when diagnosing this learning disorder, it is crucial to assess for the presence of other psychological disorders that can reduce spatial orientation efficiency, as noted in the existing literature.

For example, individuals with agoraphobia tend to have difficulty exploring unfamiliar environments due to their condition. According to Kállai et al. (1995; 2007), people with agoraphobia tend to be too worried about their physical reactions to notice environmental cues and create a cognitive map of their surroundings. Additionally, they may have difficulty remembering their environmental experiences. They were more likely to get lost, relied less on landmarks, and were less accurate in map production and retracing their steps.

According to a study by Jones et al. (1996), individuals with agoraphobia tend to explore stores differently than other customers: they pay less attention to specific environmental features. They are drawn to elements that could hinder their escape or cause anxiety, such as lifts and stairways.

A recent study by Zucchelli et al. (2021) revealed that individuals suffering from agoraphobia experience a decline in working memory (i.e., the cognitive process that allows them to hold in mind and manipulate information temporarily; Diamond, 2013). Working memory is crucial for reasoning and the guidance of decision-making and behavior. The study suggests that these individuals need help with complex spatial tasks that require them to process information simultaneously. More specifically, deficits in visuo-spatial working memory (VSWM) play a role in the relationship between agoraphobia and performance in allocentric judgments, where individuals must judge a relation between two elements in the environment without considering their position (Zucchelli et al., 2021).

Not only agoraphobic patients have deficits in exploring environments and keeping elements in the environment online, but patients with anxiety disorders, especially spatial anxiety, show deficits in spatial orientation (e.g., Lawton & Kállai, 2002; Nori et al., 2023). Spatial anxiety, which refers to apprehension and fears about navigating everyday environments, can negatively affect a person's ability to reach desired locations and explore unfamiliar places (Oliver et al., 2023),

especially when undertaking navigational tasks in environments with higher cognitive load (Nori et al., 2023). Some authors say spatial anxiety can hinder efficient and accurate spatial thinking (Alvarez-Vargas et al., 2020).
Concerning the neurobiological correlates of anxiety, both global and specific anxiety show a strong association with the limbic and paralimbic structures, characterized by increased connectivity among the amygdala, paraventricular nucleus, and hippocampus (e.g., Andreescu et al., 2015).
In this perspective, driving phobia (amaxophobia), driving anxiety (Stephens et al., 2022), or driving-related fear (DRF) can hinder spatial orientation and memory while driving. Specifically, DRF is a fear of driving that is persistent and intense and worsens when the person anticipates or encounters driving-related stimuli. This type of phobia is common among women aged between young and middle-aged adults (Taylor et al., 2002). It makes driving difficult for them or causes considerable distress when they do. Treatment is necessary for this condition as it does not improve or resolve independently and can become chronic. DRF can limit one's freedom and career prospects and cause social awkwardness.
In conclusion, several different types of disorders can severely affect navigational skills: a specific cognitive disorder (DTD) and some psychological disorders (spatial anxiety, agoraphobia, and DRF): these disorders may be selectively present in individuals or coexist in the same individual. Thus, an accurate evaluation of navigational cognitive skills and an accurate psychological assessment are necessary to correctly identify the nature of the spatial orientation difficulty and plan an effective treatment.
Here, we report the case of V.G., a 21-year-old girl without neurological or psychiatric signs affected by mild DTD and DRF. V.G. contacted us after hearing a radio interview about DTD and having consulted the Spatial Cognition Laboratory, clicking on the Italian web page devoted to this disorder[1]. She believes she might be affected by this disorder since she struggles to recall streets she has previously driven on. After exchanging emails, V.G. agreed to undergo an extensive evaluation that showed the presence of mild DTD, and intense DRF. In a thorough interview, it became evident that her challenges with spatial orientation were specifically occurring while driving. She completed the Familiarity and Spatial Cognitive Style Scale (FCSQ: Nori & Piccardi, 2012; Piccardi et al., 2011; 2022) questionnaire while imagining herself driving, but when walking, she rarely got lost, and her self-reported orientation skills were comparable to that of her peers. As V.G.'s autonomy was significantly affected by DRF, causing deep distress, we decided to prioritize and implement personalized EMDR therapy before addressing DTD with a neuropsychological treatment. This approach will help us to understand if the main problem is the presence of DRF or DTD. Indeed, if V.G. were primarily affected by DRF, EMDR therapy would have also had a positive impact on her ability to orient herself. Otherwise, if DTD were the main disorder, her spatial orientation would remain unaffected. Two weeks after the end of EMDR therapy, V.G. was again submitted to the assessment of her spatial navigation abilities as well as psychological testing concerning spatial anxiety and agoraphobia, including mobility inventory. The independent ethical committee of the IRCCS Fondazione Santa Lucia approved the study. V. G. gave her written informed consent to participate.

Method

Case Report

V.G. is a 21-year-old Italian woman who commutes via public transport, particularly trains, to the university she attended, located in a different city from her residence.
She lives with her parents and a younger brother. Her parents are both lawyers who specialize in road accidents and insurance cases. In 2020, V.G. acquired her driving license and started to commute by car until the COVID pandemic she experienced severe anxiety while driving, which may be linked to two traumatic events. Firstly, at the young age of 7, she learned about her maternal grandfather's tragic demise resulting from a car accident that occurred when his vehicle plunged into a ravine. Secondly, in September 2022, she narrowly avoided being involved in a car accident after neglecting to yield to another vehicle. She also revealed that her father, due to his extensive knowledge of road accidents and associated statistics, exhibits frightening behavior and often shouts at her while she is driving. Despite this event, V.G. has not ceased using the car.
When V.G. contacted us, she inquired about her spatial orientation problem and the discomfort caused by driving. In fact, V.G. believed she was suffering from DTD and requested an evaluation and treatment.

Neuropsychological Assessment at baseline

We investigate V.G.'s spatial navigation abilities along with mental imagery abilities and psychological disorders sometimes present along with DTD. The questionnaires and tests used are described below.

The Anamnesis Questionnaire (Piccardi et al., 2022) collected information with a series of questions regarding problems with spatial orientation experienced since early age, possible history of neurological or major psychiatric illness, previous traumatic brain injury, learning disabilities, and alcohol or drug abuse. Regarding neurological outcomes, the questionnaire assesses the presence of head trauma, ischemic attacks, encephalitis, brain infections, and pre-and perinatal complications. On the psychiatric side, the questionnaire investigates depression, anxiety, psychosis, obsessive-compulsive disorder,

[1] https://spatialcognitionlab.com/disorientamento-topografico/

eating disorders, post-traumatic stress disorder, schizophrenia, and phobias. It also gathers information on the duration of the condition, the assumption of pharmacological treatment, and whether the person is currently on medication.
Furthermore, it inquiries about alcohol consumption frequency and whether the respondent has used or uses drugs such as cannabis, amphetamines, cocaine, etc. If so, the questionnaire questions about the specific substances used, timeline and frequency of drug use.
V.G. did not report any neurological or psychiatric disorders or substance/alcohol misuse.

Familiarity and spatial cognitive style scale (FSCS; Nori & Piccardi, 2012; Piccardi et al., 2011). The FSCS assessment consists of several subscales, including Sense of Direction (SOD), Town Knowledge (TK), Spatial cognitive style (SCS: Landmark, Route, and Survey), and Right-left Confusion (RLC). Ability in each item is rated on a Likert scale with 1 as poor-level ability and 5 as high-level ability. An individual is classified as affected by Developmental Topographical Disorientation (DTD) if his/her total SOD score falls 2 Standard Deviations (SD) below the mean (95% CI) reported by Nori and Piccardi (2012) (see Table 1). Therefore, we considered the SOD's subscale. We considered the following four diagnostic criteria proposed by Iaria and Barton (2010): i) frequently getting lost (1 to 5 times a week) in familiar environments; ii) have experienced spatial orientation problems since an early age; iii) absence of any other cognitive difficulties that may impact daily activities; iv) no known brain lesions, malformation, or conditions affecting the central nervous system, except migraine. Moreover, we considered two additional criteria: v) no active psychiatric disorders or use of psychotropic drugs; vi) no substance abuse behavior.

The Spatial Anxiety Scale (SAS; Lawton, 1994) evaluates anxiety levels during everyday activities that necessitate spatial or navigational abilities, including locating destinations of unfamiliar appointments within a city or navigating through intricate office layouts for the first time. Comprising of 8 items, the scale requires participants to rate their anxiety levels on a 5-point Likert scale, ranging from "Not at all" (1) to "Very Much" (5). Elevated scores on this scale correspond to heightened levels of spatial anxiety (see Table 1).

The Mobility Inventory for Agoraphobia (MIA, Chambless et al., 1985) evaluates the extent of avoidance behavior and the frequency and severity of panic attacks using a 5-point Likert scale, ranging from "I never avoid" (1) to "I always avoid" (5). The MIA includes the Avoidance Accompanied and Avoidance Alone scales. Each scale consists of five subsets identifying different threatening places or situations. The subsets encompass various places (e.g., elevators, supermarkets), large spaces (both indoor and outdoor), means of transportation (e.g., cars, trains), driving or travelling on motorways, and different types of situations (accompanied by others, alone) plus additional situations suggested by participants, such as queuing or crossing a bridge.
V.G. was also asked to provide information on the number of panic attacks experienced in the last seven days and the past three weeks.

The Agoraphobic Cognitions Questionnaire (ACQ, Chambless et al., 1984) assesses negative thoughts related to the harmful consequences of experiencing anxiety. The 14 items cover physiological outcomes (for ex., the fear of having a heart attack) and behavioral outcomes (for ex., the fear of hurting someone or going crazy) during anxiety episodes. Each item is rated on a 5-point Likert scale, ranging from "never occurs" (1) to "always occurs" (5). Individual responses on each item are averaged to calculate the total score. The cut-off score for agoraphobia is the average value of 1.52.

The *Object and Spatial Imagery Questionnaire* (OSIQ; Blajenkova et al., 2006; Vannucci et al., 2006) evaluates individual trends to use visual imagery and visualization in thinking and learning; it is composed of 30 items on a 5-point Likert scale ranging from 1 (totally disagree) to 5 (totally agree). Specifically, the OSIQ includes 15 object items intermixed with 15 spatial items that are averaged to form the score of the OSIQ object scale and the OSIQ spatial scale. The higher the item score for each scale is, the more participants use visual mental imagery strategy.

The *Mental Imagery Questions* (MIQ; Palermo et al., 2022) is a self-report questionnaire including six questions about the ability to imagine single items such as faces, environmental landmarks, and objects (MIQ-single items). Additionally, the questionnaire assesses the ability to imagine past and future events (MIQ-events) and to solve visuospatial problems, including mental rotation of abstract items (MIQ-spatial); it also includes one question regarding the presence of mental images in dreams.

The *Short Vividness Task* (SVT; modified short version by Palermo et al., 2013) assesses the self-rated degree of richness, details, and clarity of mental images of everyday objects. The SVT consists of five items requiring participants to close their eyes and imagine one of the 5 items (bottle, knife, boot, tie, and glass). After the object visualization, participants rate the vividness of their mental image on a Likert scale ranging from 1 to 7 (self-evaluation). Then, they select the picture that best matches their mental image among four pictures of the object depicted with varying degrees of vividness (multiple-choice evaluation). The maximum score of the self-evaluation is 35, while that of the multiple-choice is 20.

The *Color Imagery Task* (CIT) This task, which is a modified from Color 3 of the Complete Visual Mental Imagery Battery – (CVMIB, Palermo et al., 2016), could be performed without voluntarily creating a mental image, as it could trigger involuntary imagery. Participants are shown two black-and-white drawings of common fruits or vegetables and asked to identify which one has the darker color. The task included ten items; both accuracy and response time were recorded.

The short version of the Computerized Ecological Navigational Battery (LBS) (Bonavita et al. 2022; Teghil et al., 2019; Nemmi et al. 2017; Boccia et al., 2015) mirrors the complexity of spatial navigation in an ecological environment and allows the evaluation of the ability to acquire and use different formats of spatial knowledge about a novel environment recording accuracy (total number of correct answers) and response times.
The LBS battery includes the following subtests.
1) *Route knowledge.* In this first subtest, participants watch a video of a path from the first-person perspective of a car driver. At each crossroad encountered along the route, the video stops, and participants are asked to indicate, by pressing one of three directional arrows on the keyboard (left, right, up), in which direction (left, right, straight-ahead) the car goes. The video is shown three times and provides feedback about correct and incorrect responses. In the first attempt, the answers are given by chance. In the second and third attempts, participants must respond by remembering the correct answers learned in the previous attempts. Accuracy in the third attempt is computed as a score (Max accuracy = 9).
2) *Landmark knowledge.* In this second subtest, participants view the image of one crossroad at the center of the screen. They must decide if the picture represents one of the crossroads encountered during the path by tapping the S key for yes or the N key for no on the keyboard (Max accuracy = 18).
3) *Survey knowledge.* During this subtest (fig. 1b), at the center of the screen, participants see a picture of a satellite map of the test environment with the learned path marked with a red line. At the same time, the image of one of the crossroads is shown on the left upper corner, and a placeholder along the path in correspondence with one of the crossroads. Participants must indicate, using the S key to say yes or the N key to say no the keyboard, whether the placeholder represents the correct position of the shown crossroad (Max accuracy = 18).
4) *Landmark ordering.* The last subtest consists of a 1-back task. Pictures of the crossroads are presented in an uninterrupted series at the center of the screen. Participants must indicate if the current displayed crossroad preceded or followed the previous one by pressing the forward arrow (after) or the backward (before) arrow on the keyboard. If the crossroad is identical to the previous one, they must press the spacebar (Max accuracy = 72).

--- insert figure 1 about here ---

Baseline procedure
All the questionnaires and tests were administered online since V.G. lived in a different region and refused to travel.
An interview was conducted to better understand the spatial orientation difficulties that emerged and the nature of these disorders using an online meeting platform.

Baseline results
The evaluation revealed the presence of DTD and FDR, and the absence of any difficulties in generating, visualizing, and transforming mental images (see Table 1).

--- insert Table 1 about here ---

Results of questionnaires also showed the absence of clinical evidence of agoraphobia, despite a predominant trend to avoid car driving and discomfort toward driving.

During the interview, it became clear that V.G.'s difficulties with spatial orientation are most pronounced when she is driving. She expressed frustration and a consistent inability to remember routes, which led to constant tension while driving. As a result, to feel safe V.G. often relies on others accompanying her during drives. V.G. claimed that her difficulties stemmed from a genuine phobia of driving, resulting from vicarious trauma as well as first-hand traumatic experiences and constant reminders from her family about the dangers of travelling by car. She asked for a reduction of driving fear. V.G. scores for each subtest of LBS were compared with those of a control group (N = 23) matched for gender, and we extracted the control group data from previously published studies (Bonavita et al., 2022). Since the control groups are matched with V.G. for age (M = 23.96; SD = 1.72) and education (M = 15.48; SD = 1.65), we used the Singlims.exe statistical software (Crawford & Garthwaite, 2002) to perform a single-case Bayesian analysis (Crawford & Howell, 1998) consistent with literature on individual case description (e.g., Boccia et al., 2019; Bianchini et al., 2010; Martelli et al., 2009; Kober et al., 2013). This approach is the most suitable for single case studies, allowing to prevent the overestimation of an effect (Wetzels et al., 2011). The Bayesian framework allows for the integration of prior knowledge while quantifying the uncertainty in our estimates, making it especially valuable when working with single cases where traditional large-sample statistical approaches may be inappropriate. This statistical approach thus provides a more rigorous framework for comparing individual cases against normative data while maintaining appropriate control over Type I error rates (e.g., Crawford & Garthwaite, 2005).

V.G. performed significantly worse than controls in the accuracy of the landmark knowledge subtest but not in the response time. No significant differences were observed in the other subtests of LBS, both in accuracy and response time (see Table 2).

--- insert Table 2 about here ---

Table 1 reports the scores obtained by V.G. on the questionnaires. The results of the remaining questionaries also reported in Table 1, allowed us to exclude other specific developmental disorders (e.g., aphantasia, mental imagery deficits, etc.).

Intervention Hypothesis

Due to the co-presence of DTD and DRF, we decided to verify the role of psychological disorders on DTD. We hypothesized that V.G. was affected by a mild DTD exacerbated by DRF, which in turn could have been affected by COVID-19 pandemic. Indeed, V.G. had just got her driving license and she still felt unsafe while driving when she stopped to go out and drive her car because of the pandemic. Since the rise in anxiety has been reported as a consequence of pandemic experience in young adults, it is more frequent in women (Wilzer et al., 2024; it is possible that the driving anxiety and DRF were the result of the interrupted driving experience and augmented anxiety as a consequence of pandemic, coupled to the awareness of navigational difficulties. To test this hypothesis, we decided to treat V.G.'s DRF employing an EMDR treatment (described in detail in the next paragraph) before treating her DTD. Indeed, if EMDR would significantly affect navigational disorders, then we must reject our hypothesis and conclude that V.G. was not affected by DTD and that her navigational deficits were the consequence of DRF. Vice versa, if EMDR treatment would reduce DRF, but not navigational deficits, then our hypothesis that V.G. was affected by a congenital developmental disorder of environmental navigation, namely DTD, will be confirmed.

RDI and EMDR therapy. EMDR (Eye movement desensitization and reprocessing) is a structured, noninvasive, and evidence-based treatment for unprocessed memories and related conditions based on the Adaptive Information Processing (AIP) model (Shapiro, 2007), that includes alternating bilateral stimulation (BLS) via eye movements, auditory tones, or hand taps (for details, see Shapiro 2017). It can be effectively used in remote online therapy frameworks (e.g., Fisher 2021; Kaplan et al., 2024; Fiani et al., 2023). RDI is a specific EMDR protocol introduced by Leeds in 1995 to help people stabilize and regulate affect and coping skills, which may be necessary to face trauma-focused therapy (Korn & Leeds, 2002; Leeds & Shapiro, 2000). During RDI, the client typically focuses on specific autobiographical positive memories, also called resources, that are not associated with the negative memories object of the EMDR treatment. Positive clinical experience and several single case studies (Korn & Leeds, 2002) support the usefulness of RDI as a procedure to strengthen self-capacities (Hornsveld et al., 2011).
The RDI procedure consists of seven steps: 1. Identify needed personal qualities; 2. Explore memories related to these qualities; 3. Access sensory information about the memory; 4. Verify the memory/resource is positive; 5. Use eye movements or other techniques while focusing on the memory; 6. Strengthen the resource with words and imagery; 7. Visualize using the resource in future scenarios (see Korn & Leeds 2002, pp. 1470–1471 for details).
We readapted the first phase (patient history) in V.G.'s treatment to collect the most useful information related to framing DTD, DRF, or spatial anxiety conditions (Hornsveld et al., 2011; Leeds, 2009).

Therapeutic setting
Since previous studies have shown the efficacy of online EMDR (Waterman & Cooper, 2020; Kaplan et al., 2024), and the travel refusal of V.G., we decided to administer therapy sessions online using the Zoom platform. The psychotherapy sessions were conducted by a certified level I and II EMDR psychotherapist, who used the same room with the same perspective every time for the connections.
V.G., was advised to prioritize her comfort by adopting a relaxed position, assuring that sessions would not be interrupted or disturbed (for example, wearing earphones, closing the door, and asking not to disturb the session). Guidelines to adhere to the principles of online psychotherapy were given at the beginning of the first session and strictly followed in all the sessions (Stoll et al., 2020).
The treatment for spatial anxiety and DRF lasted twelve weeks, with one session lasting 45 minutes every week. For BLS, the "Butterfly hug" was used as the recommended best practice for online EMDR therapy (Fisher, 2021) since it consists of a form of bilateral stimulation that can be self-administered.
Phases of treatment are described following.

Phase 1 – lasted 4 weeks, focusing on history-taking and treatment planning (Shapiro, 2017). The therapist assessed V.G.'s suitability for EMDR therapy and her psychological needs, particularly regarding her driving fears, mood swings, anxiety, and contamination concerns affecting public transportation use. Adaptation challenges included difficulties with solitude, adjusting to change, managing trauma, excessive rumination, and family relationships. V.G. also reported sleep disorders, nightmares about being lost, and frequent headaches.

We examined both traumatic and positive events to gain insight into V.G.'s past. With the help of the *Top Ten list* (TTL: Shapiro, 2017), a grid collects the ten most negative and positive memories experienced by her. For each memory, V.G. was asked to indicate the year it happened and to express on the Subjective Units of Distress Scale (SUDs) (Wolpe, 1969; Kim et al., 2008), a self-rated scale assessing the subjective intensity of distress currently experienced by a person between "a state of absolute calmness" (0) and "the worst anxiety" (10). The TTL was modified and adapted to the DTD condition to collect a list of negative and positive navigational memories. The modified instructions are: "Please try to compile a list of your top 10 most distressing memories related to your difficulties in environmental orientation. Arrange them in order of their level of negativity, starting from the most intense and ending with the least severe. These memories can include past and present events, minor traumatic encounters with adults, physical challenges, experiences with other therapies, instances of humiliation, unsuccessful efforts to obtain a driving license, school-related experiences, and more. To gauge the disturbance associated with each negative memory, we ask you to rate your current emotional state on SUDs. V.G. was also asked to compile a list of 10 positive memories from her life when discussing pleasant experiences. We systematically searched for any additional negative memories linked to DTD, driving-related traumatic experiences, or driving anxiety. We also asked V.G. to indicate the year of each negative event and its impact on the SUDs.
To address V.G.'s dysfunctional avoidance response triggers effectively, we identified prevalent factors such as "I don't drive," "I don't take public transport," and "I get disoriented." We then discussed potential future scenarios and goals to foster adaptive behavioral patterns (i.e., Solomon & Shapiro, 2008).
Therapeutic goals. V.G. and the therapist together established the treatment goals that included (a) reducing the anxiety associated with driving; (b) increasing confidence and clarity while driving, as well as improving awareness of location; (c) developing a stronger sense of orientation; (d) learning useful techniques and strategies to improve orientation (e) learning helpful techniques and strategies to manage driving anxiety.

Phase 2:Before the reworking phase, to achieve the necessary good therapeutic relationship with V.G., we explained the EMDR treatment and the RDI protocols. Additionally, we conducted a psychoeducation session to discuss the possible implications on both psychological and behavioral levels of being a "bad navigator" or being affected by DTD.
The therapy preparation phase focused on establishing a framework and setting realistic expectations for V.G., aimed at improving her emotional management and addressing trauma. Initially, V.G. learned to perform the "Butterfly Hug" and maintain a comfortable posture and diaphragmatic breathing for the resource installation phase. The "safe place" technique was also introduced for future trauma processing. The RDI protocol, integrated into EMDR, used positive memories to boost V.G.'s self-efficacy in daily challenges, especially in driving and navigation, emphasizing qualities like concentration, route memorization, and confidence.

. To overcome her challenges, V.G. held onto positive self-beliefs like "I am capable," "I can do it" and "I can manage it." The installation of the resources led to the dissolution of bodily sensations linked to tension and the emergence of more adaptive positive cognitions: "I am proud of myself,"; "I feel like going on the highway and testing myself,"; "Now I want to try to take public transportation"; "I did not give up, and I can get involved." As the installation session progressed, V.G. was able to overcome the travel-related anxiety and face the challenge with confidence, where she previously felt tremendous fear.

Phase 3-7 After the application of the RDI protocol, in agreement with V.G., it was decided to work on a traumatic memory with the maximum SUDs scoring (10/10) that was related to V.G.'s risk of being involved in a car accident, that happened a few months earlier.
In the remaining sessions, we continued to install positive cognition (phase 5) and the "body scan"[2] (phase 6). In the remaining phases of re-evaluation of the memory, the SUDs value remained stable (0/10), and therefore, some sets of BLS were applied to reinforce positive sensations.

Phase 8 The installation of the resources allowed V.G. to experience less anxiety while driving and to use public transport more often. V.G. reported that she was calmer while driving, felt less anxious, and was able to control and manage driving-related fear. V.G. also reported that since she started the EMDR and RDI protocols, she has been feeling a change in her navigation approach. She also reported being able to give the "right weight" to things. During the last session, V.G. reported that she was maintaining the improvements achieved and that she could now drive without anxiety, even when her family was in her car. She also felt capable of recognizing driving anxiety and knows how to deal with it.

Post-treatment neuropsychological assessment

---

[2] In body scan clients are required to observe their physical responses while thinking about the traumatic events and the positive cognition

Two weeks after completion of the treatment, V.G. underwent another assessment for DTD and any psychological disorders related to it. V.G. performed a parallel version of LBS (see Figure 1b) and completed the MIA, ACQ, and SAQ questionnaires again. For the post-treatment confrontation of LBS, we collected an ad-hoc sample (N = 16) matched for age (M = 23.19; SD = 3.64), gender and education (M = 14.5; SD = 2.10) and performed a single-case Bayesian analysis (Crawford & Garthwaite, 2002). Results show significant differences between V.G. and control group scores in the accuracy of the landmark knowledge, survey knowledge, and landmark ordering subtests. No significant differences were found regarding the accuracy of the route knowledge subtest (see Table 2). Regarding response times, no significant differences were found between V.G. and control scores. However, we observed a remarkable reduction in V.G. response times concerning those obtained pre-treatment (see Table 2).

While no clinical condition was assessed by the questionnaires used for the initial and final assessment, it must be noted that no scoring showed a reliable change, except a specific item on the MIA avoidance scale (both when accompanied by someone or alone) concerning car driving experiences. While V.G.'s score on such scale was 3.2, after treatment during re-testing, the score lowered to 2.5 (change is considered reliable when greater than 0.73). For the MIA scores, we calculate the effectiveness, a useful tool for quantifying the effect of rehabilitation, as follows:

$$Eff. = \left| \frac{(PostTreatment\ Score - PreTreatement\ Score)}{(Maximum\ Score\ Test - \ Pre\ Treatment\ Score)} * 100 \right|$$

We computed the absolute value to avoid negative values.

Discussion

V.G. suffers from driving-related fear and DTD. When she addressed us, her concern was related to the fact that she could not remember any roads while driving. However, V.G.'s fear of driving emerged strongly after the assessment. She reported that feeling stemmed from a recent traumatic experience and from being hyper-attentive to the danger of the road, which was passed on in her family.

However, since DRF is present in individuals who do not show signs of DTD and most DTD individuals do not show any sign of DRF, it was possible that these two types of disorders were not related. Indeed, individuals who suffer from a cognitive developmental disorder (DTD, developmental prosopagnosia, dyslexia, etc.) may easily become anxious when obliged to face their difficulties in daily life, even if they are not affected by a generalized anxiety disorder or may develop a fear strictly related with challenging situations concerning their developmental cognitive disorder.

On the other hand, the co-presence of DTD and DRF could also be explained by some key neurobiological systems, particularly the hippocampus and parahippocampal regions, including the parahippocampal place area. These brain regionsare crucial for spatial navigation and constructing cognitive maps of our environment. DTD often has dysfunction in these regions, particularly in processing and integrating spatial information (e.g., Iaria et al., 2009; Kim et al., 2015; Sokolowski and Levine, 2023). Conversely, in individuals with DRF, these regions may exhibit hyperactivity when processing spatial information related to vehicle movement and environmental navigation. When examining DRF, it is essential to recognize the involvement of various brain structures, particularly the amygdala and its associated fear circuitry (e.g. Garfinkel and Critchley, 2014; Shin and Liberzon, 2010). These components are pivotal in processing fear and likely hold a significant role in DRF and DTD. In the case of DRF, the amygdala may become hyperresponsive to driving-related cues. Conversely, in DTD, the anxiety associated with the fear of getting lost could trigger increased amygdala activity, leading to a feedback loop that further disrupts spatial processing. Thus, a potential shared mechanism between DRF and DTD is the disrupted integration of these systems. The amygdala-driven anxiety response may hinder effective spatial processing, which relies on hippocampal formation. This results in a self-reinforcing cycle characterized by several dynamics: spatial uncertainty triggers anxiety, anxiety compromises spatial processing, amplifies uncertainty, and exacerbates anxiety.

Recent studies about the effect of COVID-19 on young adults underline the presence of poorer mental health in college students (Leaune et al., 2022), and the rise of anxiety in young women (Wilzer, 2024), suggesting that since V.G. has just started to drive when COVD-19 pandemic started, therefore driving anxiety and DRF could derive from the addition of difficulties in wayfinding due to DTD and the rise of anxiety due to COVID-19 pandemic. To test this hypothesis, we decided to address the DRF before dealing with the DTD, by applying RDI-EMDR treatment protocol.

Indeed, current literature suggests that anxiety may worsen navigational skills so that less proficient navigators would show difficulties in learning novel routes or recalling familiar ones (Geer et al., 2024). Thus, if underlying psychological disorders caused her DTD, RDI-EMDR treatment would result in a drastic reduction of deficits in environmental orientation and navigation. On the other hand, individuals who are affected by DTD, especially if they are also more prone to develop anxious behaviors, would develop psychological disorders because of the daily difficulties they experience in environmental orientation and navigation. If DTD were an independent disorder, EMDR treatment would just alleviate the symptoms of distress and driving issues without affecting navigational skills; in this case, the reduction of her psychological symptomatology would help in treating DTD in a second treatment phase.

Two weeks after the end of RDI-EMDR, in the post-treatment evaluation, V.G. had increased confidence in her capabilities; she managed to drive with less anxiety and started to remember some very familiar roads. However, the evaluation of navigational skills did not evidence any significant improvement, and V.G. still showed persistent poor SOD and DTD, even if the increased self-esteem allowed her to perform the tests in a shorter time. This speed-accuracy trade-off suggests that while V.G.'s anxiety reduction led to greater confidence and faster responses, the underlying spatial processing deficits remained unaddressed. The increasing number of errors, even with faster task completion, indicates that cognitive skills have not enhanced significantly, despite reduced emotional barriers. Therefore, we believe that the RDI-EMDR addressed psychological symptoms but did not fundamentally resolve the spatial orientation disorder.

Based on our current understanding, it seems that driving anxiety and DRF are not the direct causes of DTD. However, future studies should investigate this comorbidity more thoroughly. Indeed, Nori et al. (2020) suggest that navigational strategies and different sense of direction skills affect driving behavior. In fact, bad navigators make more mistakes than skilled navigators. Skilled navigators may be characterized as "careful drivers" (Lucidi et al., 2010) or characterized as Cluster 1 (Ulleberg, 2001). They exhibit traits such as calmness, emotional stability, and responsibility, significantly reducing their risk of accidents. This is reflected in their positive attitudes towards traffic safety, alongside fewer violations, errors, and lapses during driving. According to the study by Nori et al. (2020), drivers who employ a high spatial strategy commit fewer errors, experience fewer lapses, and exhibit safer driving behaviours.

On the other hand, it is more likely that the presence of DTD leads to psychological disorders such as spatial anxiety, while, in V.G.'s case, DRF is a negative outcome resulting from personal traumatic experiences and a family environment that exacerbates the symptoms.

For this reason, two months later, we scheduled a new interview with V.G. to set the start date for the treatment of DTD. During the interview, she mentioned that she decided to relocate to the city where she studied. In addition, she had begun to apply tactics to enhance her sense of direction. For instance, she always asked her friends to help her memorize the route efficiently by leading her to where they had been before until she learned the route. She no longer feels ashamed to discuss with others, her navigational challenges, which has created a more empathetic environment for her. She even drives on roads that she previously avoided, even when alone. To face a challenging journey, she prefers having someone she trusts to accompany her.

Despite driving with her family in the car was still stressful, she was now able to manage it. The patient initiated discussions with her family regarding their behavior during car rides, which contributed to her stress. As a consequence, she succeeded in driving more safely and with greater focus. As a result of her assertiveness, the family members stopped expressing their fears while she was driving.

After considering the strategies VG had already implemented on her own, her new course of study (she had been admitted to an international course in the meantime), and her new life commitments, we came to the mutual agreement that we would allow her to proceed independently, remaining available if she needed further assistance.

In V.G.'s case, prioritizing psychological treatment was the most effective approach. Undoubtedly, VG's ideal intake would have been continued treatment with exercises to develop alternative strategies and access to cognitive resources to improve the DTD. The two treatments are not mutually exclusive but are a continuation of each other; sometimes, it is more convenient to treat the psychological aspects first, and sometimes, to treat the DTD first. Evaluating which disorder to treat first is a delicate and important step in the assessment process.

Generally speaking, when an individual suffers from DTD, it needs to create an empathetic environment around his/her condition, helping the person to be open to navigational challenges and minimize psychological distress. From a cognitive point of view, it could be useful to structure environmental learning exercises, including gradual, systematic training in route memorization, using visual aids and landmarks, and breaking down complex spatial information into manageable components. It is also useful to implement mental imagery-based training (IBT) like that used by Boccia et al. (2019), as well as to teach the person to effectively use GPS and mapping technologies to the point of developing personalized navigation support systems for the more severe cases. The key is a personalized, multi-faceted approach that addresses DTD's cognitive and psychological aspects . Specifically, VG would have benefited from a treatment program similar to that described in Boccia et al. (2019). Indeed, IBT likely engages a vast network of regions responsible for creating a mental representation of our environment, which encompasses the hippocampus, the retrosplenial cortex and the parahippocampal place area (Boccia et al., 2015a, 2017). According to Boccia et al. (2019), the IBT may play a crucial role in restoring the mechanisms of environmental navigation due to the redundant spatial coding present within this network (Boccia et al., 2019). Moreover, IBT would act on the very brain network that seems to share biological mechanisms underlying both DTD and DRF and spatial anxiety.

In a recent study, Zafar et al. (2023) found no correlation between anxiety and depression traits in 1,237 participants without DTD and their ability to form cognitive maps. This suggests that the daily struggle of navigating through the environment or the inability to find an alternative route when necessary can lead to low self-esteem and a perceived lack of self-efficacy, even in individuals not affected by DTD but who have low-level spatial orientation skills.

DTD is a specific developmental disability that may cause severe psychological distress. The more severe the DTD, the greater the risk of developing severe psychological discomfort. Those who suffer from DTD often experience discomfort, worry, shame, and depression, feeling alone in their struggle since DTD is a little-known developmental disorder and the di difficulties it causes are not well understood. However, many people with DTD feel relieved knowing that they are not alone in their suffering. It is important to raise awareness about this disorder so that the general population can understand

the problems DTD causes in daily life and the individuals suffering from the disorder can better comprehend their condition and seek help from specialists who may provide appropriate care. Furthermore, the increased awareness about DTD will decrease incidents in which the problems of individuals with DTD are ridiculed and underestimated. It will also produce a climate of greater empathy that will make it easier for a DTD individual to cope with the daily challenges of moving around in the environment.
This highlights the need for a campaign to raise awareness about DTD, involving schools, psychologists, GPs, and the public to help individuals with such difficulties get the appropriate treatment so that DTD individuals do not feel isolated in their struggles and can still take advantage of opportunities for employment, travel, and cultural exchange. In rare cases, a combination of travel-related anxiety and DRF with DTD can restrict one's ability to explore the surroundings. However, with proper treatment and relief from psychological symptoms, patients can develop strategies to improve their autonomous mobility. An accurate diagnosis is crucial and pivotal to determining the most suitable treatment plan for each specific patient. The clinician can decide when intervening in psychological distress and when addressing navigational deficits.
Identifying the best treatment for DTD based on its primary manifestation is crucial, and V.G.'s case highlights the complexity of DTD when it is intertwined with psychological disorders, providing useful tips for clinicians.

Limitations and Future Directions

The current study has several limitations that warrant attention. Our two-week post-treatment evaluation showed positive results, but the short follow-up limits our ability to assess the long-term stability of improvements in driving-related fear due to the long-life span of DTD. Future research should incorporate longer follow-up periods, such as 3, 6, and 12 months to enhance the understanding of the sustainability of therapeutic outcomes.
Second, as with all single-case studies, the generalizability of our findings is inherently limited. While this methodology allowed for a detailed analysis of the relationship between DTD and driving-related fear, larger-scale studies are needed to validate these findings across diverse populations. Future research should explore this comorbidity in larger samples and investigate potential interactions between DTD and other anxiety disorders, such as generalized anxiety disorder or post-traumatic stress disorder. Such investigations could provide valuable insights into the broader relationship between spatial processing deficits and anxiety disorders. Additionally, neuroimaging studies could help elucidate the neural mechanisms underlying the interaction between navigation difficulties and anxiety, potentially informing more targeted therapeutic approaches. Finally, comparative studies examining different treatment protocols would be valuable in determining the most effective interventions for this specific comorbidity.

Conclusions

Summing up, here we reported the case of V.G., a young woman who suffers from DTD and driving-related fear. In her case, since DTD was especially severe when she was driving, alleviating her psychological disorders by EMDR also resulted in an improvement in her autonomy in navigation. Indeed, after RDI-EMDR treatment, despite her navigational deficits remaining unchanged, she felt more confident and able to face DTD. Controlling DRF allowed V.G. to access her cognitive resources. It gave her the drive to access the most functional strategies for living with her deficit, such as speaking without shame of her DTD with her friends. This created a friendly network of solidarity around her that helped her not only to allow V.G. to feel accepted but also to develop further strategies for increasing her navigational autonomy, such as asking her friends for help learning novel routes.
From a clinical point of view, the present case represents an important advancement in facing psychological disorders related to navigational deficits since it highlights the fact that spatial orientation deficit may coexist as a comorbidity with psychological disorders, such as travel-related anxiety and fear of driving, having both these aspects very similar relevance on daily autonomy. It also underlines the importance of correctly identifying the comorbidities and evaluating their relative weight concerning the client's daily difficulties for developing a really effective plan of treatment and deciding if the two aspects (the cognitive deficit of DTD and the psychological disorders) could be treated at the same time or if one of the two should be treated first.
To our knowledge, this is the first case where psychological disorders completely hindered the possibility of working on the inherent part of spatial orientation deficits. Despite the psychological therapy per se did not resolve V.G.'s spatial navigation deficits, it allowed her to face her DTD and develop effective compensatory strategies.
The current case highlights the importance of evaluating the occurrence of DTD in individuals with spatial anxiety disorder, agoraphobia, fear of driving, and travel-related anxiety. Depending on the severity of each condition, clinicians must determine whether to prioritize treating DTD or anxiety disorder for successful and effective treatment.

References

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

Alvarez-Vargas, D., Abad, C. & Pruden, S.M. (2020). Spatial anxiety mediates the sex difference in adult mental rotation test performance. *Cognitive Research*, 5, 31 https://doi.org/10.1186/s41235-020-00231-8

Andreescu C, Mennin D, Tudorascu D, Sheu LK, Walker S, Banihashemi L, Aizenstein H. (2015). The many faces of anxiety-neurobiological correlates of anxiety phenotypes. Psychiatry Res. 30;234(1):96-105. doi: 10.1016/j.pscychresns.2015.08.013.

Barclay, S.F., Burles, F., Potocki, K., Rancourt, K.M., Nicolson, M.L., Bech-Hansen, N.T. & Iaria, G. (2016). Familial aggregation in developmental topographical disorientation (DTD). *Cognitive Neuropsychology*, 33, 388–397. DOI: 10.1080/02643294.2016.1262835

Bianchini, F., Palermo, L., Piccardi, L., Incoccia, C., Nemmi, F., Sabatini, U., & Guariglia, C. (2014). Where am I? A new case of developmental topographical disorientation. *Journal of Neuropsychology*, 8, 107–124. DOI: 10.1111/jnp.12007

Bianchini, F., Incoccia, C., Palermo, L., Piccardi, L., Zompanti, L., Sabatini, U., Peran, P. & Guariglia, C. (2010) Developmental topographical disorientation in a healthy subject. *Neuropsychologia* 48, 1563–1573. https://doi.org/10.1016/j.neuropsychologia.2010.01.025

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

Boccia, M., Guariglia, C., Sabatini, U., & Nemmi, F. (2015). Navigating toward a novel environment from a route or survey perspective: neural correlates and context-dependent connectivity. *Brain Structure and Function*, 221(4), 2005–2021. https://doi.org/10.1007/s00429-015-1021-z

Boccia, M., Piccardi, L., Palermo, L., Nemmi, F., Sulpizio, V., Galati, G., et al. (2015a). A penny for your thoughts! patterns of fMRI activity reveal the content and the spatial topography of visual mental images. Hum. Brain Mapp. 36, 945–958. doi: 10.1002/hbm.22678

Boccia, M., Sulpizio, V., Palermo, L., Piccardi, L., Guariglia, C., and Galati, G. (2017). I can see where you would be: patterns of fMRI activity reveal imagined landmarks. Neuroimage 144, 174–182. doi: 10.1016/j.neuroimage.2016. 08.034

Bonavita, A., Teghil, A., Pesola, M.C., Guariglia, C., D'Antonio, F., Di Vita, A. & Boccia M (2022). Overcoming navigational challenges: A novel approach to the study and assessment of topographical orientation. Behavior Research Methods https://doi.org/10.3758/s13428-021-01666-7

Burles, F., & Iaria, G. (2020). Behavioural and cognitive mechanisms of Developmental Topographical Disorientation. *Scientific Report* 10, 20932. https://doi.org/10.1038/s41598-020-77759-8

Chambless, D.L., Caputo, G.C., Jasin, S.E., Gracely, E.J. & Williams, C. (1985). The Mobility Inventory for Agoraphobia. *Behavior Research and Therapy* 23, 35–44. https://doi.org/10.1016/0005-7967(85)90140-8

Chambless, D. L., Caputo, G. C., Bright, P., & Gallagher, R. (1984). Assessment of fear of fear in agoraphobics: the body sensations questionnaire and the agoraphobic cognitions questionnaire. *Journal of Consulting and Clinical Psychology*, 52(6), 1090. https://doi.org/10.1037/0022-006X.52.6.1090

Crawford, J. R., & Howell, D. C. (1998). Comparing an individual's test score against norms derived from small samples. *Clinical Neuropsychologist*, 12(4), 482–486. https://doi.org/10.1076/clin.12.4.482.7241

Crawford, J. R. & Garthwaite, P.H. (2002). Investigation of the single case in neuropsychology: confidence limits on the abnormality of test scores and test score differences. *Neuropsychologia* 40, 1196-1208. https://doi.org/10.1016/s0028-3932(01)00224-x.

Crawford, J. R., & Garthwaite, P. H. (2005). Testing for suspected impairments and dissociations in single-case studies in neuropsychology: Evaluation of alternatives using Monte Carlo simulations and revised tests for dissociations. *Neuropsychology*, 19, 318-331.
Epstein, R., Parker, W., & Feiler, A. (2007). Where am I now? Distinct roles for parahippocampal and retrosplenial cortices in place recognition. Journal of Neuroscience, 27, 6141–6149. doi:10.1523/JNEUROSCI.0799-07.2007

Epstein, R. A., Higgins, J. S., & Thompson-Schill, S. L. (2005). Learning places from views: Variation in scene processing as a function of experience and navigational ability. *Journal of Cognitive Neuroscience*, 17, 73–83. doi:10.1162/ 0898929052879987

Fiani, F., Russo, S., & Napoli, C. (2023). An Advanced Solution Based on Machine Learning for Remote EMDR Therapy. *Technologies*, 11(6), 172. **https://doi.org/10.3390/technologies11060172**

Fisher, N. (2021). Using EMDR therapy to treat clients remotely. *Journal of EMDR Practice & Research*, 15(1): 73-84.

Garfinkel, S. N., & Critchley, H. D. (2014). Neural correlates of fear: insights from neuroimaging. *Neuroscience and Neuroeconomics*, *3*, 111–125. https://doi.org/10.2147/NAN.S35915

Geer, E. A., Barroso, C., Conlon, R. A., Dasher, J. M., & Ganley, C. M. (2024). A meta-analytic review of the relation between spatial anxiety and spatial skills. *Psychological Bulletin* . https://doi.org/10.1037/bul0000420

Habib, M., & Sirigu, A. (1987). Pure topographical disorientation: A definition and anatomical basis. Cortex, 23, 73–85. doi:10.1016/S0010-9452(87)80020-5.

Hornsveld, H. K., Houtveen, J. H., Vroomen, M., Kapteijn, I., Aalbers, D., & van den Hout, M. A. (2011). Evaluating the effect of eye movements on positive memories such as those used in resource development and installation. *Journal of EMDR Practice and Research*, 5(4), 146-155. https://doi.org/10.1891/1933-3196.5.4.146

Iaria, G. (2013). Developmental Topographical Disorientation: lost every day. *The Lancet Neurology*, 12, 745. https://doi.org/10.1016/S1474-4422(13)70133-9

Iaria, G. Bogod, N. Fox, C.J. & Barton, J.J. (2009). Developmental topographic disorientation: Case one. *Neuropsychologia* 47, 30–40. DOI: 10.1016/j.neuropsychologia.2008.08.021

Iaria, G. & Barton, J.J. (2010). Developmental topographical disorientation: A newly discovered cognitive disorder. *Experimental Brain Research*, 206: 189–196. https://doi.org/10.1007/s00221-010-2256-9 PMID: 20431873
Iaria, G., Incoccia, C., Piccardi, L., Nico, D., Sabatini, U. & Guariglia, C. (2005). Lack of orientation due to a congenital brain malformation: A Case Study. *Neurocase* 11, 463–474. DOI: 10.1080/13554790500423602

Jones, R.B., Humphris, G. & Lewis, T. (1996). Do agoraphobics interpret the environment in large shops and supermarkets differently? *British Journal of Clinical Psychology*, 35, 635–637. doi: 10.1111/j.2044-8260.1996.tb01220.x.

Kállai, J., Kóczán, G., Szabó, I., Molnar, P. & Varga, J. (1995). An Experimental Study to Operationally Define and Measure Spatial Orientation in Panic Agoraphobic Subjects, Generalized Anxiety and Healthy Control Groups. *Behavioural and Cognitive Psychotherapy* , 23 , 145 – 152 DOI: https://doi.org/10.1017/S1352465800014399

Kállai, J., Karádi, K., Bereczkei, T., Rózsa, S., Jacobs, W.J. & Nadel, L. (2007). Spatial exploration behaviour in an extended labyrinth in patients with panic disorder and agoraphobia. *Psychiatry Research,* 149 223–230. DOI: 10.1016/j.psychres.2003.12.032

Kaplan, S.K., Kaya, Z.M., & Akan, A. (2024). Addressing mental health need after COVID-19: a systematic review of remote EMDR therapy studies as an emerging option. *Frontiers in Psychiatry*. 14, 1336569. https://doi.org/10.3389/fpsyt.2023.1336569

Kim, J.G., Aminoff, E.M., Kastner, S., & Behrmann, M. A (2015). Neural Basis for Developmental Topographic Disorientation. *The Journal of Neuroscience*, 16;35(37):12954-69. doi: 10.1523/JNEUROSCI.0640-15.2015.

Kober, S. E., Witte, M., Ninaus, M., Neuper, C., & Wood, G. (2013). Learning to modulate one's own brain activity: The effect of spontaneous mental strategies. *Frontiers in Human Neuroscience*, *7*, 53097. https://doi.org/10.3389/fnhum.2013.00695

Korn, D. L., & Leeds, A. M. (2002). Preliminary evidence of efficacy for EMDR resource development and installation in the stabilization phase of treatment of complex posttraumatic stress disorder. *Journal of Clinical Psychology*, 58 (12), 1465-1487. DOI: 10.1002/jclp.10099

Lawton, C. A. (1994). Gender differences in way-finding strategies: Relationship to spatial ability and spatial anxiety. *Sex Roles, 30*, 765–779. https://doi.org/10.1007/ BF01544230

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

Leaune, E., Vieux, M., Marchal, M., Combes, C., Crandall, S., Haesebaert, J. & Poulet, E. (2022). Self-reported mental health symptoms, quality of life and coping strategies in French health sciences students during the early stage of the COVID-19 pandemic: An online survey. *Encephale*. 48(6):607-614. doi: 10.1016/j.encep.2021.09.002.

Leeds, A. M. (2009). A guide to the standard EMDR protocols for clinicians, supervisors, and consultants. Springer Publishing Company.

Leeds, A. M., & Shapiro, F. (2000). EMDR and resource installation: Principles and procedures for enhancing current functioning and resolving traumatic experiences. In J. Carlson & L. Sperry (Eds.), *Brief therapy with individuals & couples* (pp. 469–534). Zeig, Tucker & Theisen.

Lucidi, F., Giannini, A. M., Sgalla, R., Mallia, L., Devoto, A., & Reichmann, S. (2010). Young novice driver subtypes: Relationship to driving violations, errors and lapses. Accident Analysis and Prevention, 42, 1689–1696. https://doi.org/10.1016/j.aap.2010.04.008.

Marialuisa Martelli, Gloria Di Filippo, Donatella Spinelli, Pierluigi Zoccolotti; Crowding, reading, and developmental dyslexia. *Journal of Vision* 2009;9(4):14. https://doi.org/10.1167/9.4.14.

Nemmi, F., Boccia, M., & Guariglia, C. (2017). Does aging affect the formation of new topographical memories? Evidence from an extensive spatial training. *Aging, Neuropsychology, and Cognition*, 24(1), 29–44. https://doi.org/10.1080/13825585.2016.1167162

Nemmi, F., Bianchini, F., Piras, F., Péran, P., Palermo, L., Piccardi, L., Sabatini, U., Guariglia, C. (2015). Finding my own way: an fMRI single case study of a subject with developmental topographical disorientation. *Neurocase*, 21, 5, 573–583, http://dx.doi.org/10.1080/13554794.2014.960424

Nori, R. & Piccardi, L. (2012) Il senso dell'orientamento: Quanto conta la familiarità con l'ambiente? *Giornale Italiano di Psicologia*, 39, 343–368.

R. Nori, M. Palmiero, A. Bocchi, A.M. Giannini, & L. Piccardi (2020) The specific role of spatial orientation skills in predicting driving behaviour. Transportation Research Part F, 71, 259-271. https://doi.org/10.1016/j.trf.2020.04.009

Nori, R., Zucchelli, M.M., Palmiero, M., & Piccardi, L. (2023). Environmental cognitive load and spatial anxiety: What matters in navigation? *Journal of Environmental Psychology,* 88, 102032. https://doi.org/10.1016/j.jenvp.2023.102032

Oliver, A., Wildschut, T., Parker, M.O., Wood, A.P. & Redhead, E.S. (2023). Induction of spatial anxiety in a virtual navigation environment. *Behavior Research Methods*, 55, 3621–3628 https://doi.org/10.3758/s13428-022-01979-1

Palermo, L., Boccia, M., Piccardi, L. & Nori, R. (2022). Congenital lack and extraordinary ability in object and spatial imagery: An investigation on sub-types of aphantasia and hyperphantasia. *Consciousness and Cognition,* 103, 103360. https://doi.org/10.1016/j.concog.2022.103360

Palermo, L., Piccardi, L., Nori, R., Giusberti, F., & Guariglia, C. (2016). The impact of ageing and gender on visual mental imagery processes: A study of performance on tasks from the Complete Visual Mental Imagery Battery (CVMIB). *Journal of Clinical and Experimental Neuropsychology*, 38(7), 752–763. doi: 10.1080/13803395.2016.1161735.

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 topographical disorientation: A behavioral and neuroimaging study. *Journal of Clinical and Experimental Neuropsychology*. 36, 464–481. https://doi.org/10.1037/neu0000021

Palermo, L., Nori, R., Piccardi, L., Zeri, F., Babino, A., Giusberti, F., & Guariglia, C. (2013). Refractive errors affect the vividness of visual mental images. PLoS One, 8 (6), e65161. https://doi.org/10.1371/journal.pone.0065161

Piccardi, L., Palmiero, M., Cofini, V., Verde, P., Boccia, M., Palermo, L., Guariglia, C. & Nori, R. (2022) "Where am I?" A snapshot of the Developmental Topographical Disorientation among young Italian adults. *PLoS ONE*, 17, e0271334.

Piccardi, L., Cofini, V., Palmiero, M., Verde, P., Boccia, M., Palermo, L., Guariglia, C. & Nori, R. (2022a). Where Am I? Searching for the Tangle in the Developmental Topographical Disorientation. *Neurology International*,, 14, 824–838. https://doi.org/10.3390/ neurolint14040067

Piccardi, L., De Luca, M., Di Vita, A., Palermo, L., Tanzilli, A., Dacquino, C. & Pizzamiglio, M.R. (2019). Evidence of taxonomy for Developmental Topographical Disorientation: Developmental Landmark Agnosia Case 1. *Applied Neuropsychology: Child.* 8(2):187–198. https://doi.org/10.1080/21622965.2017.1401477 PMID: 29192795

Piccardi, L., Risetti, M. & Nori, R. (2011). How well do you know your city? Effects of familiarity on environmental representations: A self-report study. *Psychology Report*, 109, 309–326.

Shapiro, F. (2017). *Eye movement desensitization and reprocessing (EMDR): Basic principles, protocols, and procedures*.3rd Edition, Guilford Press.

Shapiro, F. (2007). EMDR and case conceptualization from an adaptive information processing perspective. *Handbook of EMDR and family therapy processes*, 1-34.

Shin, L., & Liberzon, I. (2010). The Neurocircuitry of Fear, Stress, and Anxiety Disorders. *Neuropsychopharmacol* **35**, 169–191. https://doi.org/10.1038/npp.2009.83

Sokolowski, H.M., & Levine, B. (2023). Common neural substrates of diverse neurodevelopmental disorders, *Brain*, 146, 2, 438–447, https://doi.org/10.1093/brain/awac387

Solomon, R. M., & Shapiro, F. (2008). EMDR and the adaptive information processing model potential mechanisms of change. *Journal of EMDR Practice and Research*, 2(4), 315-325. https://doi.org/10.1891/1933-3196.2.4.315

Stephens, A.N., Collette, B, Hidalgo-Munoz, A. Fort, A., Evennou, M. & Jallais, C. (2022). The quiet passenger: Cognitions, avoidance, and onset among people with driving anxiety, *Transportation Research Part F: Traffic Psychology and Behaviour*, 87, 30-41, https://doi.org/10.1016/j.trf.2022.03.017.

Stoll, J., Müller, J. A., & Trachsel, M. (2020). Ethical issues in online psychotherapy: A narrative review. *Frontiers in Psychiatry*, 10, 993. https://doi.org/10.3389/fpsyt.2019.00993

Taylor, J., Deane, F. & Podd, J. (2002). Driving-related Fear: A Review. *Clinical Psychology Review*. 22 (5): 631–645. doi:10.1016/s0272-7358(01)00114-3. PMID 12113199.

Teghil, A., Boccia, M., Bonavita, A., & Guariglia, C. (2019). Temporal features of spatial knowledge: Representing order and duration of topographical information. *Behavioural Brain Research*, 376, 112218. https://doi.org/10.1016/j.bbr.2019.112218

Ulleberg, P. (2001). Personality subtypes of young drivers. Relationship to risk-taking preferences, accident involvement, and response to a traffic safety campaign. Transportation Research Part F: Traffic Psychology and Behaviour, 4, 279-297. https://dx.doi.org/10.1016/S1369-8478(01)00029-8.

Vannucci, M., Cioli, L., Chiorri, C., Grazi, A., & Kozhevnikov, M. (2006). Individual differences in visuo-spatial imagery: Further evidence for the distinction between object and spatial imagers. Cognitive Processing, 7(Suppl. 1), 144–145. DOI 10.1007/s10339-006-0108-0.

Waterman, L. Z., & Cooper, M. (2020). Self-administered EMDR therapy: potential solution for expanding the availability of psychotherapy for PTSD or unregulated recipe for disaster? *British Journal of Psychiatry Open*, 6(6), e115. DOI: 10.1192/bjo.2020.92

Wetzels, R., Matzke, D., Lee, M. D., Rouder, J. N., Iverson, G. J., & Wagenmakers, E.-J. (2011). Statistical Evidence in Experimental Psychology: An Empirical Comparison Using 855 t Tests. *Perspectives on Psychological Science*, 6(3), 291–298. https://doi.org/10.1177/1745691611406923

Wilzer E., Zeisel A., Roessner V. & Ring M. (2024). Association between anxiety, depression and quality of life in male and female German students during the COVID-19 pandemic. *BMC Psychiatry*, 24 (1), art. no. 212. DOI: 10.1186/s12888-024-05611-8

Wolpe, J. (1969). The Practice of Behavior Therapy; Pergamon Press: New York, NY, USA.

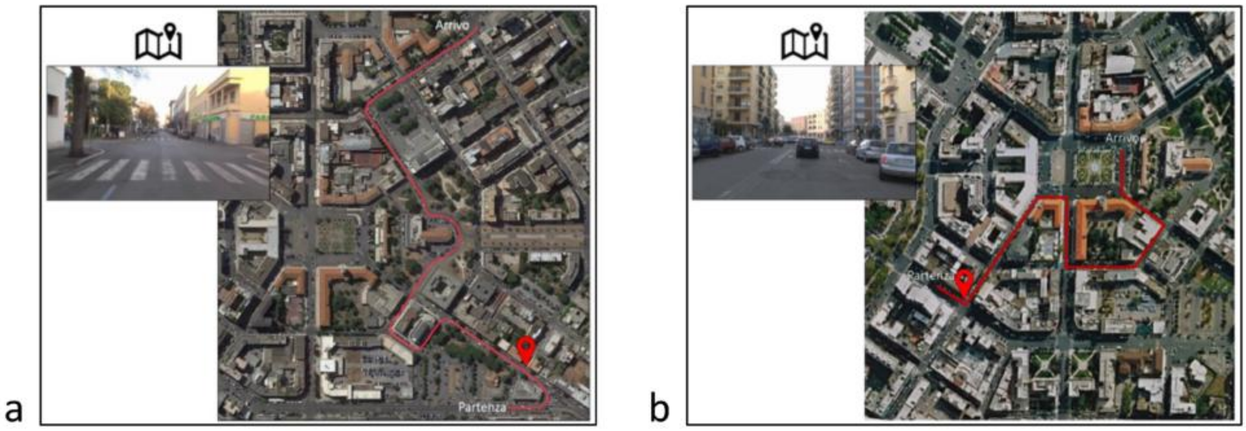
Kim, D., Bae, H., & Park, Y.C. (2008). Validity of the Subjective Units of Disturbance Scale in EMDR. Journal of EMDR Practice and Research,, 2, 57–62. DOI: 10.1891/1933-3196.2.1.57

Zafar, I., Burles, F., Berger, L., McLaren-Gradinaru, M., David, A.L., Dhillon, I. & Iaria, G. (2023). Anxiety and Depressive Traits in the Healthy Population Does Not Affect Spatial Orientation and Navigation. *Brain Sciences*. 13(12):1638. https://doi.org/10.3390/brainsci13121638

Zucchelli, M.M., Piccardi, L. & Nori, R. (2021). The Fear to Move in a Crowded Environment. Poor Spatial Memory Related to Agoraphobic Disorder. *Brain Sciences*, 11, 796. https://doi.org/10.3390/ brainsci11060796

Figures:

Figure 1. Figure shows the item presented to V.G. in the survey knowledge subtest of the LBS in the parallel versions used to assess the spatial ability pre (a) and post (b) treatment.



Tables:

Table 1. The scores on the questionnaires and tests administered to V.G. before (pre) and after (post) the treatment are reported.

	Scores			
Test	**Pre**	**Post**	**Cutoff**	**Eff. (%)**
FSCS				
SOD	1.45*	–	2.1	
MIA				
Avoidance accompanied	1.21*	1.21*		
Avoidance alone	1.43*	1.56*	1.61	16.667
ACQ	1.13*	1.40*	1.52	
SAS	16	17	9.40	
MIQ				
Single items	6	–		
Events	2	–		
Spatial	5	–		
SVT				
Self-evaluation	33	–		
Multiple-choice	9	–		
OSIQ				
Object	55	–		
Spatial	27	–		
CIT	9	–		

*mean score; FSCS: Familiarity and spatial cognitive style scale; SOD: Sense of Direction; MIA: Mobility Inventory for Agoraphobia; ACQ: Agoraphobic Cognitions Questionnaire; SAS: The Spatial Anxiety Scale; MIQ: Mental Imagery Questions; SVT: Short Vividness Task; OSIQ: Object and Spatial Imagery Questionnaire; CIT: Color Imagery Task.

Table 2. For each LBS subtest at baseline and post-treatment V.G.'s raw score is reported, along with the result of the Crawford analysis.

	Baseline			**Post treatment**		
		Crawford analysis			**Crawford analysis**	
	V.G.'s score	**t**	**p**	**V.G.'s score**	**t**	**P**
RK_2_acc	4	−1.27	0.15	6	−1.60	0.09
RK_3_acc	7	−0.38	0.37	8	−1.91	0.06
RK_2_rt	1088.25			1478.33	0.48	0.34
RK_3_rt	1494.14	1.25	0.15	989.12		
LK_acc	15	−2.48	**0.02**	15	−2.22	**0.04**
LK_rt	3293.4	0.63	0.30	1363.93		
SK_acc	12	−1.47	0.12	9	−3.70	**<.01**
SK_rt	4456.91			2321.11		
LO_acc	32	−2.01	0.05	29	−4.17	**<.01**
LO_rt	1376.12			1038.62		

Significative results are reported in bold. RK: route knowledge; LK: landmark knowledge; SK: survey knowledge; LO: landmark ordering; acc: accuracy; rt: response time.