Charting the path towards rehabilitation: a compensatory approach to navigation impairments

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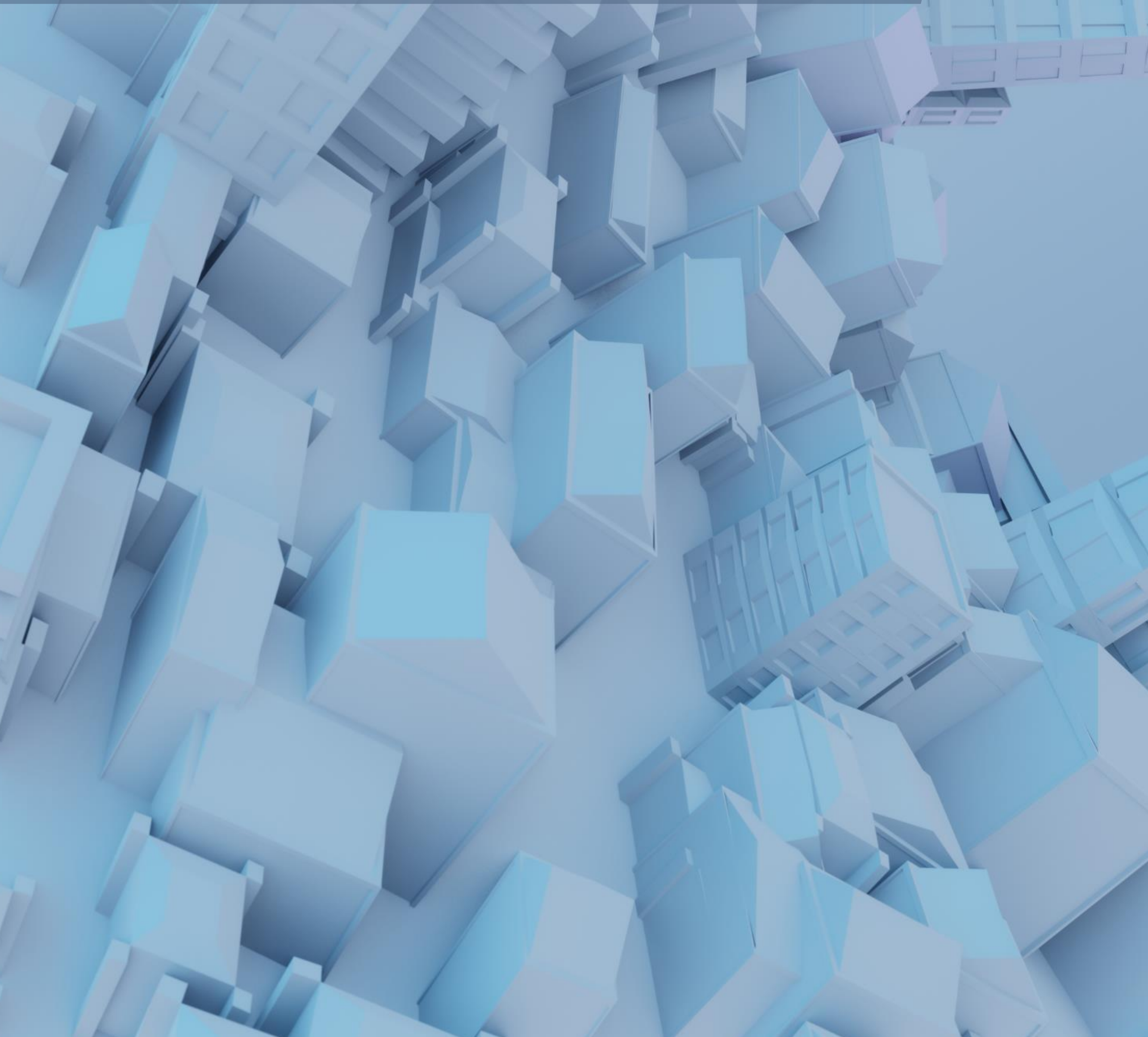
Chapter 4

Modules of the navigation training software



Designing training modules

The training was composed of a face-to-face psychoeducation session and a software package. The psychoeducation session served to teach patients the fundamentals of navigation as understood within the field of spatial cognition. This information was then related to the impairment of each patient and a compensatory strategy was introduced. Accompanying the psychoeducation session, was a software package that included exercises and additional information and instructions regarding the use of the strategy that was to be trained. Patients had access to either an allocentric or egocentric version of the software. Within the versions, three modules were designed that each trained a subcomponent of the strategy. A navigational skill was introduced, trained and an explanation was given on how to integrate this into real life situations. Each module was inspired by experimental paradigms used the in spatial cognition literature. Key concepts of these paradigms were taken and designed as a serious game, with varying levels of difficulty. Importantly, the environments in which the exercises took place were constructed in a modular fashion, consisting of separate geographical features such a corridors, rooms and landmarks. These environmental elements were connected to each other using scripts that allowed for randomization. Every time a module was started, a novel environment was generated in which the exercise took place, thus avoiding undesired learning effects. The design of the modules, their theoretical background and intended learning component are described in this chapter.

Egocentric version

Spatial-temporal sequence memory

The core principle of this egocentric module was the adoption of a sequential egocentric strategy (Igloi, Zaoui, Berthoz, & Rondi-Reig, 2009; Rondi-Reig et al., 2006). This strategy comprises a rudimentary form of route-based navigation. The module was inspired by the classic T-maze paradigm (d'Isa, Comi, & Leocani, 2021), although multiple connected Y-shaped junctions were used (Fig 4.1). Patients were trained to remember routes through an environment by learning an array of bodily turns. No landmarks were present in the environment, so that sequence memory of body turns was trained rather than stimulus-response associations. The resulting spatiotemporal organization was at least partly reliant on episodic memory.

Within this module, patients discovered a basic navigation strategy that was not reliant on landmarks or geometric cues. This strategy could be used when the use landmarks in an environment is difficult or impaired. Furthermore, the module potentially strengthened sequence memory for navigational tasks, by forcing patients to pay attention to this component of navigation ability.

In each trial, a modular maze was generated that consisted out interlocking Y-junctions. The number of junctions determined the difficulty level for this module.

Patients watched a demonstration route through the maze. Patients were insturcted to focus on the order of turns.

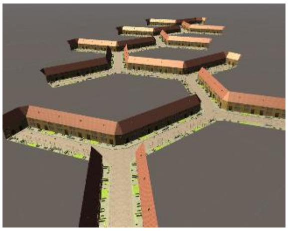
Patients were placed in starting area and were tasked to find their way to the end location. While traveling the correct path, stars were earned. Heading into an wrong corridoor resulted in the loss of a star

Fig 4.1 Description of the spatial-temporal sequence memory module

Landmark -direction associations

In this egocentric module, patients were trained to adopt a landmark-response-based strategy. This module trained a compartmentalized aspect of route-based navigation. The module was inspired by the T-maze paradigm, although Y-shaped junctions were used and landmarks were included at choice point (Baker & Holroyd, 2009). Participants observed a demonstration route, in which left or right turns were taken at landmarks (**Fig 4.2**). Participants would then replicate the actions of the demonstration route to reach an end location. Importantly, the order in which the landmarks were encountered was randomized after the demonstration, ensuring that participants focussed on forming landmark-response associations, rather than sequence memory. In this module, landmarks were used in a non-geometric manner, serving as anchor points along a route.

This module emphasized the use of landmarks along a route in an egocentric context. Patients were trained to pay attention to the identity of landmarks and the action required at the location to follow route. This strategy could be used in environments with prominent landmarks. The module rewarded patients that payed strong attention to landmarks and developed methods to remember the directional association with each landmark.



The modular maze was set up similar to **Fig 4.1**. In this module, easilt distinguisable landmarks were place in the middle of each junction points

Patients watched a demonstration route through the maze. Patients were insturcted to focus on the actions taken at landmarks. Following the demonstration, the order of the junction points was shuffled. The relation between the landmark and the correct direction remained intact.

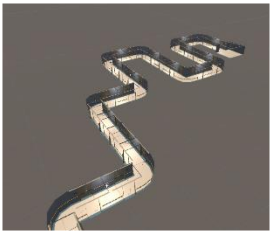
Patients were placed in starting area and were tasked to find their way to the end location. While traveling the correct path, stars were earned. Heading into an wrong corridoor resulted in the loss of a star

Fig 4.2 Description of the Landmark-direction association module

Egocentric updating

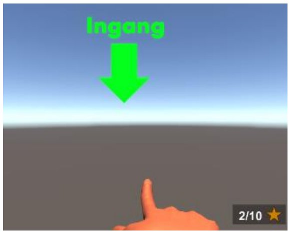
This egocentric module trained spatial updating ability as part of more general egocentric navigation strategy. When using egocentric updating, the navigator continuously updates self-to-object relations towards a specific location whilst moving through an environment (Zhong & Kozhevnikov, 2016). This process relies on idiothetic signals and allothetic cues. When tracking a specific starting location in an environment, this process is often referred to as path integration. Egocentric updating can be regarded as an egocentric form of survey knowledge, as metric information regarding one's position and a location is processed. The module was inspired by scene depended perceptual pointing tasks frequently used in human navigation studies (Hodgson & Waller, 2006; Waller & Hodgson, 2006; Zhang, Copara, & Ekstrom, 2012). In this module, patients were placed in a starting room and were tasked to walk through a corridor that contained a number of turns (Fig 4.3). After a set amount of turns, patients were tasked to point to their starting position. The walls became transparent and gave feedback regarding their pointing accuracy.

This module emphasized and promoted the use spatial updating during navigation. Spatial updating can be used when landmarks are difficult to use or when forming sequence memory is to taxing. For example, when navigating a dense city, patients can attempt to maintain their orientation towards the location of a train station (or parking place) to be able to travel back home.



In each trial, a modular corridor was constructed consisting of straight, and turn segments. The number of turn segments present in the maze determined the difficult of the trial as well as intensity in which the maze spiralled around the starting location

Patients were tasked to remain focussed on the start location whilst traveling along the corridoor. At set intervals, patient's movement became locked. At this point were asked to point toward the starting location by rotating the camera.



After confirming their pointing direciton, the walls of the corridoor became transparent and the correct location was shown. The deviation in pointing angle determined the performance. Patients then continued through the corridoor towards the ending location.

Fig 4.3 Description of the Egocentric updating module

Allocentric version

Map use

In this allocentric module, patients were trained to use GPS-like map systems. Three types of maps were used in this module. In one set of exercises, a map was shown in which the current location of the navigator was continuously updated (GPS trial). In the second set of exercises, a map was shown that only indicated the starting location (traditional map). In the third set of exercises, a map was only shown before the trial started (temporary map). A key component of the module was the focus on switching between egocentric and allocentric perspectives (Colombo et al., 2017). The module was inspired by a variety of studies that concerned map learning and GPS-based navigation (Lobben, 2007; Munzer, Zimmer, Schwalm, Baus, & Aslan, 2006; Thorndyke & Hayes-Roth, 1982). Participants were placed in an environment with several rooms (**Fig 4.4**). Each room was marked with on a map. Participants were tasked to find the shortest route to an ending location. In the GPS trials, allocentric information could be readily obtained from the map and could be easily transferred to the egocentric perspective. In the traditional map trial, the switch between perspectives required patient comparing environmental elements obtained in the egocentric perspective and match those to information on the map. In the final trial, allocentric information was stored in memory and accessed when traveling the environment from an egocentric perspective.

The goal of this module was to train effective map use during and prior to navigation. In addition, the trials in this module were designed to make switched between allocentric and egocentric perspectives increasingly difficult. This module emphasized the use of allocentric information that is available using navigation systems on GPS and mobile devices.

In each trial a 3x3, 4x4 or 5x5 gridlike maze was generated containing landmarks and road blocks. Patients were tasked to find the shortest route the ending location whilst avoiding roadbloacks. Each room visited lead to a star beeing lost, whilst visiting a roadblock lead to two stars being lost

In the lower difficulty setting, A map was always present during navigation. Participants could track their current location on the map. In the intermediary difficulty setting, the map would only show that starting en ending locations, not the current location.

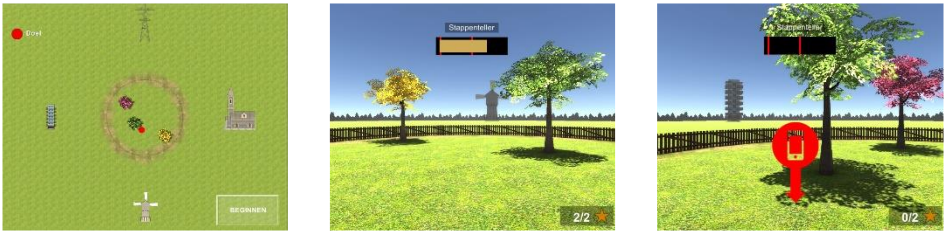
In the high difficulty setting, a map was only shown before the trial started. Patients had to plan a route before navigating.

Fig 4.4 Description of the Map-use module

Place learning

The key principle of this allocentric module was the adoption of an allocentric strategy in which geometrical information of landmarks was used to determine locations in an environment. The module trained map and place learning abilities as well as cognitive mapping. The design of the trials in the module were inspired by the Moris Water Maze paradigms (Vorhees & Williams, 2006). Landmarks in the environment were first presented on a map which included a marker for the goal location (Fig 4.5). Patients were then placed somewhere in the environment and were tasked to find the goal location. Starting and goal locations could only be determined by using the configuration of objects in the environment.

Within this module, patients practised with the use of geometric information during navigation. Both local and distal landmarks were used as markers in the module, so patient were trained to use landmarks that gave information regarding cardinal directions and more locally placed landmarks that could be used as anchor points in a coordinate frame. The module emphasized the use of geometric landmark information for navigation rather than route-based navigation strategies.



In each trial, a circular map was shown. On the map a goal location was shown and a set of landmarks. Landmarks could be local, within the circle, or global, far in the distance. The size of the circle and the number of landmarks present varied with the difficulty of the module.

Patients were task to use the landmarks to find the shortest route to the goal location, which was hidden during navigation. A steptracker measured how much distance was traversed. As this bar depleted, starts were lost.

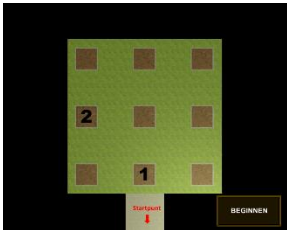
If patients found the goal location with a limited amount of steps, stars were earned. Is too many steps were taken, the goal location would be revealed.

Fig 4.5 Description of the Place learning module

Place and order learning from maps

The principle of this module was to train map learning in combination with route order and place learning. The inspiration for this module was the Walking Corsi Test, which in turn is a variation of the Corsi Block Tapping Task (Piccardi et al., 2013). A map depicted nine cubes, which contained numbers that indicated in what order they should be visited (Fig 4.6). After encoding the map, patients were placed in a 3D environment and were tasked to visit the locations in the correct order.

Patient were presented with spatiotemporal information was presented in an allocentric reference frame. This module mimics situations in which a route should be planned and remembered by studying the map of an environment.



In each trial, a map of a garden was shown contained 9 allotments. Patients were tasked to water these allotments in the order indicated by the numbers on the map. The difficulty of the trial was determined by the number of allontments that needed to be visited.

Patients were placed in the garden and were instructed to travel to the allotments in the correct order. The map was not shown again during this phase.

Watering the correct allotment yielded a star, whilst watering the incorrect allotment lead to the loss of a star.

Fig 4.6 Description of the Place and order map-learning module