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Mapping Autistic Wayfinding in Urban Environments

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Abstract: Needs and preferences in wayfinding tasks of people with autism spectrum disorders (ASD) have been a topic of ongoing discussion in the scientific literature over the last decades. While different tasks have revealed both autistic strengths (e.g., encoding and recall of route information) and weaknesses (e.g., understanding allocentric representations), ASD spatial behaviour is not fully understood yet. In this paper we focus on spatial uncertainty, which is the discrepancy between a-priori expectation and in-situ experience and thus a constant factor in ASD wayfinding tasks. As a matter of course, spatial uncertainty is inevitable, always resulting from a dynamic interaction of situational qualities (e.g., noise or smell). Nevertheless, mapping uncertainty and the underlying spatial patterns in an organized way might help users from the ASD spectrum to better prepare for the different levels of expectable uncertainty in route. We propose a framework of conceptualizing, measuring, and mapping spatial uncertainty from an autistic viewpoint. The discussion of this framework is based on a qualitative analysis of the spatial behaviour of B, a five-year-old child with ASD and nonverbal communication, in an urban environment. We compare the level of spatial uncertainty of the routes developed by B against the routes indicated by ourselves.

Keywords: spatial uncertainty, wayfinding, navigation, autism

1. Introduction

For centuries, cartographers have been working on the visualization of both tangible and intangible spatial phenomena (Kraak & Fabrikant, 2017). The defining criteria of these ongoing efforts (e.g., generalization, symbolization, and scale; cf. Robinson et al., 1995), also shape the design of geodatabases, mapmaking software and resulting geovisualization products. However, cartography has usually been conceptualized from a rather neurotypical than neurodiverse perspective on space and map makers have shown just sporadic interest in different cognitive and perceptual capabilities (Çorlu, et al., 2017; Hounting, 2019).

In this paper, our particular focus is on the limitations, needs and preferences in wayfinding tasks of people with autism spectrum disorders (ASD), especially in urban environments (DeSalle, 2018; Meneghetti, et al, 2020). In accordance with the American Psychiatric Association (2013), “Autism spectrum disorder (ASD) is a complex developmental condition that involves persistent challenges in social interaction, speech and nonverbal communication, and restricted/repetitive behaviors”. Statistics on the prevalence of ASD on a global level differ, but the World Health Organization (WHO) estimates that 1 in 160 children is part of the ASD spectrum (2021).

2. ASD and spatial navigation

Over the last decades, significant research has been done on spatial cognition and human wayfinding (Barker, 2019; Golledge, et al, 2000; Montello & Sas, 2006; Rapp, 2018). This work allows us to understand navigation and wayfinding as tasks of constant and concurrent processing of stimuli, which can be interpretated and framed in physical, behavioural, and cognitive spaces (Bacastow (2014).

For the purpose of this paper, cognitive spaces are of particular interest as they focus “on concepts and objects that are not themselves necessarily spatial, but the nature of the space is defined by the particular problem” (Slater et al., 2018), for instance in the form of a mental map, imbued with abstraction and significations.

In accordance with Klatzky (1998), spatial cognition and mental maps develop within the two reference frameworks of egocentric (object-to-self) and allocentric (object-to-object) relationships and representations (cf. Meilinger y Vosgerau, 2010). Egocentric representation is important for navigation via specific sequences of landmarks, thus relying on both motoric and executive skills, which are closely linked to procedural memory (Lederman & Klatzky, 2009). On the other hand, allocentric representations rather use declarative memory functions e.g.: scene construction and generation of detailed and coherent mental representations (Meneghetti, et al, 2020).

For people with ASD, research has shown particular difficulties in allocentric representation and navigation, while egocentric spatial skills remain intact and comparable to neurotypical individuals (Ring, et al. 2018).

Especially in urban environments, orientation in open space is a challenge in ASD. Compounding the problem, wandering from a supervised place by children with ASD is common (Rice, et al, 2016), be it for the joy of running or rather escaping an uncomfortable situation (e.g., noise), (Rapp, et al, 2018; Rice, et al, 2016). As a consequence of these spatial disorientation issues, the risk of death by accident in ASD is three times that of the neurotypical population (Guan & Li, 2017).

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3. The present study

While most research on autistic navigational skills is done in controlled laboratory conditions, we built our experiment in a real-world urban environment with uncontrolled multi-sensorial input. Our particular interest lied in the homing strategies of a child with ASD, i.e., the ability to find one's way home (Golledge, et. al, 2000; Dorado, et al, 2019)

3.1 Test person

In this study, we worked with B, a five-year-old child with ASD. At the time of the experiment, B could answer requests in Spanish, e.g., "¡Ven!" (Come!), "¡Alto!" (Stop!), "¡Espera!" (Wait!). B's caregiver watched out for him during the whole study, and B was not exposed to any risks from the experiment. Regarding the condition of B within the spectrum, he has not developed spoken language nor reading or drawing abilities, which are common characteristics in many cases of ASD.

3.2 Analysing & mapping spatial uncertainty

During the trips undertaken within the experiment, we noticed B showing different levels of spatial uncertainty caused by stimuli like flashing lights, sound, smell, shadows or even street morphology, and leading to anxiety and disorientation (Van de Cruys, et al, 2014).

In accordance with our own observations with B, spatial uncertainty can be understood as the "surprise" over information and stimulus input received in a given situation (Friston, 2010). This feeling of surprise, in terms a of disorganized sensorial processing, results in an incomplete mental representation and, thus, in an inexact spatial reference frame (Montello & Sas, 2006; Klatzky, et al, 1990).

Two elements of wayfinding were particularly affected during the trips with B, namely path integration (also known as dead-reckoning) processes (Montello & Sas, 2006) and piloting. In path-integration "subjects maintain track of their movement based on self-motion cues" (Dorado, et al. 2019, p1), e.g. optic flow, vestibular, proprioceptive or sensorimotor information. In piloting, "subjects create a mental representation of the path based on external references and their spatial relationships" (ibid.).

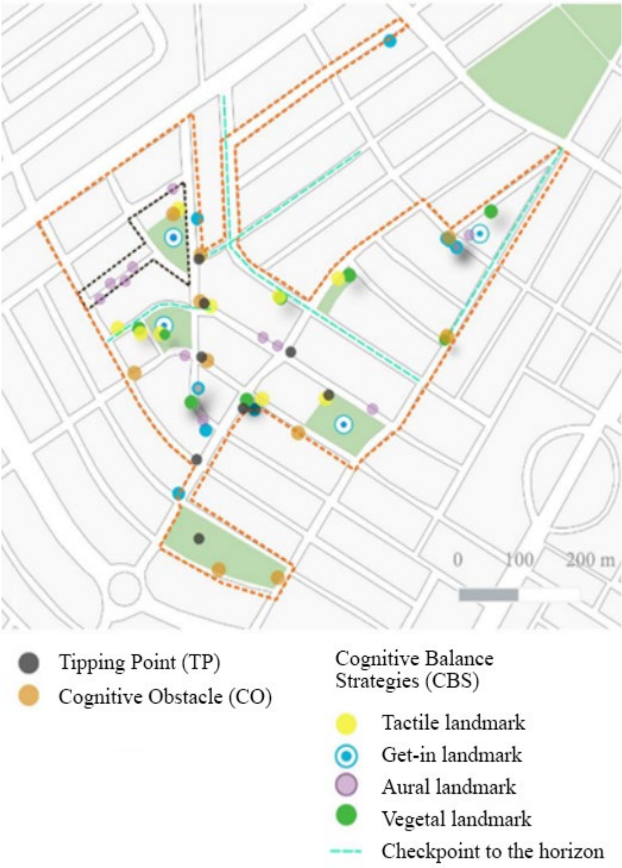
Map 1. Indicated route (in blue) from B's home (A) to a local grocery store (B); B's homing route (in red) from January 5th; nodes are indicated by numbers form ① to ⑨

Path integration processes during the homing task were concerned by the decisions B made on tipping points (TP), where the flow of self-motion cues is interrupted. Hence, tipping points and path integration are rather associated with an egocentric perspective. On the other hand, the spatial images created by B during piloting are rather allocentric representations (Dorado, et al. 2019; Montello & Sas, 2006).

Those allocentric references (e.g., winding streets, tall buildings) that hinder B's orientation are referred to as cognitive obstacles (CO) subsequently. Despite the aforementioned obstacles and limitations, B started to make his own decisions and construct his own routes over the course of several trips (cf. map 1&2).

We evaluate B's navigation strategy based on the four levels of spatial behaviour established by Marchionini (1997): patterns, strategies, tactics and moves.

From week three on, B began to identify landmarks, detected patterns and implemented movement and strategies like touching the texture of walls and plants. We will label these approaches of problem solving as cognitive balance strategies (CBS).



Map 2. The study area with all TP, CO and CBS referenced by January 12th

TP, CO and CBS allow us to estimate levels of spatial uncertainty along the routes taken by B, thus integrating physical, existential and cognitive space (cf. map 2). In doing so, we can integrate both the tangible (e.g., groups of trees, details of buildings, power lines, paving patterns, etc.) and the intangible (e.g., shadows, smells, bark, temperature, etc.) features B used for guidance.

3.3 Test procedure

Excursions with B took place between October 12th, 2020 and January 12th, 2021 in Guadalajara, Mexico. Over the first two weeks, walks were made twice weekly without any particular destination in order to test, if B showed interest and tolerated these activities.

In week 3, B was shown a nearby grocery store. After shopping, B decided his way home so that we could analyse how his homing strategies developed (cf. map 1).

On January 5th, B was able to complete the homing task for the first time. Afterwards, he started to discover other nearby streets, which he had not considered.

3.4 Assessing spatial uncertainty

To assess spatial uncertainty, we drew upon Lynch's (1960) concept of nodes as those parts of the route offering to B "multiple perspectives of the other core elements" (ibid.; cf. Zmudzinska-Nowak, 2003).

In the present study, and also considering the rather rectangular grid pattern of the Guadalajara road network, we established all corners of houses/building blocks along the routes as nodes, i.e., as decision points for the path to be taken (map 1).

We grouped and tagged all results obtained from the trips with B by four categories (continuity, ruptures/distractors, proximity, delimitation), resulting in a measure of cognitive morphology when considered together. Each node was then evaluated in accordance with the four categories mentioned above, and levels of spatial uncertainty (*su*) were calculated as follows.

The existence of no CO or TP was rated with a value of 10, one CO or TP with a value of 20, two CP or TP with a value of 30, etc. (cf. tab. 2). Additional, distances d^s of segments between neighbouring nodes (one start-node n^a and one end-node n^b per segment) and the averaged spatial uncertainty $\overline{su}^s$ for each segment were calculated. We then integrated these measures into a segment-based index of spatial uncertainty, calculating $d^s * \overline{su}^s$ (cf. tab. 3).

3.5 Results

Once we had documented the routes designed by B, we measured and compared distances between guided outward and non-guided return trip. In absolute numbers, B's route was not just longer than the standard route we had showed to him, but also contained more CO and TP. However, analysing this data in relative terms, averaged *su* scores per metre were lower on B's route (26.66), which indicates that B designed his route rather for spatial-uncertainty optimization that distance optimization (cf. tab. 1 and 2).

4. Conclusions

In this paper, we tried to shed some light on the homing process and the underlying construction of space developed by B, a child with ASD. However, there are at least three different types of reasoning documented in ASD, namely spatial, verbal, and visual thinkers (Grandin & Panek, 2019).

Given B's ability of landmark and pattern recognition we consider him falling into the first category. Future research shall, thus, also analyse representatives of verbal and visual thinkers regarding their strategies of dealing with spatial uncertainty.

Our preliminary findings indicate the importance of encouraging people with ASD to solve wayfinding tasks on their own. In the case of B, challenging his resistance to sources of irritation turned out to be an interesting and stimulating game for B. After the excursions made in this study, he seems to better tolerate stress factors like

n^a	*su* at n^a	n^b	*su* at n^b	$\overline{su}^s$	d^s	SU / segment
A	20	1	20	20	29.7	594.0
1	20	2	20	20	59.0	1180.0
2	20	3	60	40	58.0	2320.0
3	60	4	20	40	107.0	4280.0
4	20	5	30	25	108.0	2700.0
5	30	6	20	25	280.0	7000.0
6	20	7	20	20	90.2	1804.0
7	20	8	10	15	74.7	1120.2
8	10	9	40	25	61.3	1532.5
9	40	B	30	35	73.0	2555.0
$\overline{su}$= 26.66						

Table 1. Node- and segment-based measures of spatial uncertainty for B's final homing route

n^a	*su* at n^a	n^b	*su* at n^b	$\overline{su}^s$	d^s	SU / segment
A	20	1	60	40	28.7	1148.0
1	60	2	30	45	130.3	5863.5
2	30	3	40	35	103.0	3605.0
3	40	4	30	35	30.0	1050.0
4	30	5	30	30	50.0	1500.0
5	30	6	30	30	162.0	4860.0
6	30	7	20	25	81.0	2025.0
7	20	8	40	30	69.0	2070.0
8	40	9	20	30	79.0	2370.0
9	20	B	20	20	60.0	1200.0
$\overline{su}$= 32.40						

Table 2. Node- and segment-based measures of spatial uncertainty for the outgoing route shown to B

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barking, engine noise or the glare of the sun. From a social perspective, the homing strategies learned, as well as interacting with salespersons, strengthened B's independence and lead to a "natural" process of inclusion. The main achievement of this study, however, is that our pre-verbal proband gave us an insight into how he experiences and maps his urban environments. B solved the wayfinding task we assigned to him with a multisensory approach, integrating vision, sound, smell and touch. And, not less important, he explored the city around him with obvious pleasure.
Finally, we cannot deny that the insights shared by B raise more issues than answers. Although the viewpoint of people with ASD has been widely ignored in the realm of urban planning, mapmakers can help to make landmarks and obstacles visible and collect relevant data more systematically. Hence, with this paper we also hope to provide a preliminary work for a more inclusive cartography.

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