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Designing technology for spatial needs: Routines, control and social competences of people with autism

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Abstract. Over the years, the relationship between technology and people with autism has been framed mainly in a medical model, where technology is primarily aimed at mitigating deficits and providing helps to overcome limitations. This has yielded a variety of Human-Computer Interaction designs addressed to improve the autistic individuals' daily tasks and behavior. In this article, we want to explore a different approach, by proposing a phenomenological take on the autistic lived experience, which could integrate the results achieved by the medical model, and offer a "first person perspective" on autism. More precisely, by adopting a cognitive approach to urbanism we want to explore how autistic individuals conceptualize and experience the spaces they inhabit. To this aim, we interviewed 12 adults with a diagnosis of autism asking them to recount their everyday movements and city living activities. Building on the study findings, we identified three kinds of spaces that characterize their life and outlined a series of design considerations to support technology interventions for satisfying their spatial needs. Then, during a design session, we developed our conceptualization as well as our design suggestions, yielding a more nuanced picture of how space is subjectively constructed by autistic people.

Keywords: autism; design; semi-structured interviews; orientation; space; interactive maps

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1 INTRODUCTION

Autism is characterized by peculiarities in domains as diverse as social interaction, communication, attention, and practical skills (Hobson, 1993; Silberman, 2015), as well as emotional features like a propensity to become anxious. All of these may occur in different forms, ranging from severe intellectual and language impairments to high-functioning autistic/Asperger syndrome, sometimes with an IQ above the average. The latter may often remain invisible to society (Hobson, 1993; Luciano et al.; 2014, Keller et al., 2016). Since autism is marked by a tendency to withdrawal from social relationships as well as oftentimes a preference for the mechanical and formal over the biological and psychological, technology-based interventions appear to be successful when used by affected individuals: interactive technologies typically are more predictable than humans, do not require direct social interaction, and can provide routines as explicit, present, and clear expectations, as well as feed back consistent rewards or consequences for responses (Kientz, Goodwin, Hayes, & Abowd, 2013).

Designing technology for people with autism, however, implies the willingness to understand their “neurodiversity”[1], if we want to go beyond the idea that a unique mode of existence and experience is legitimate in our society. For a long time, neurodiverse conditions have been framed within a medical model, “defining being disabled by people’s physical or cognitive differences and the resulting functional limitations” (Frauenberger, 2015, 58). Likewise, the relationship between technology and people with disabilities has been framed within the medical model, because it has proven to be pragmatically useful in providing requirements for design (Frauenberger, 2015). This

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[1] Neurodiversity is a movement advocating different cognitive and perceptual capabilities than what is normative, in other words, neurotypical (Çorlu et al., 2017). The term was coined in 1999 (Singer, 1999), and has been used to advocate autistic people’s rights, whereas neurotypical started indicating all those individuals not belonging to the autism spectrum. Over time, populations with other neurological conditions, such as ADHD (Attention Deficit Hyperactivity Disorder) (Dalton, 2013), joined the movement by using the term to refer to their community as well.

surely has to be applauded, as Mankoff, Hayes, and Kasnitz (2010) noted: however, they also pointed out that a different take, coming, for instance, from disability studies, could integrate the medical approach helping us produce a nuanced understanding of these people's needs. In the 1980s, the disability rights movement proposed a reconceptualization of disability (the so-called social model), being seen as a social construct resulting in impaired people being disadvantaged (Barnes, 2012). Recently, Frauenberger, Good and Parés (2016) claimed that we need to capture the complexities of the disabled experience, suggesting that we should explore novel theoretical approaches. If we want to be able to respond to needs and desires that go beyond mitigating deficit, this requires us to understand what is meaningful in the autistic people's lives and develop solutions that are situated in their lifeworlds (Frauenberger, 2015).

Building on top of these insights, in this article we aim at exploring how people with autism experience the spaces they live, since their spatial needs, i.e. what they seek when they inhabit a place, or move across different environments, seem to be still underexplored in both the autism and Human-Computer Interaction (HCI) literature. We further propose to adopt a phenomenological perspective, in order to account for the lived experience of this neurodiverse population. This could integrate the medical perspective, by offering an alternate take on the autistic lived experience.

The philosophical and psychological paradigm of phenomenology has its roots in the works of Hussler (1962, 1976), Merleau-Ponty (1962), and Heidegger (1982). This theoretical approach sees reality as the product of a "view from within" (in contrast with the "view from nowhere" criticized by Nagel, 1986) and conceives the mind as subjectivity, which actively "constructs" the world by ascribing subjective meanings to it (Clancey, 1997; Brizio & Tirassa, 2016). Within HCI, phenomenology has been used to promote a tool-based approach to design (Ehn, 1988), ground a theory of embodied interaction (Svanæs, 2013), and inform the design of Personal Informatics systems (Rapp & Tirassa, 2017). Phenomenology offers a rich and diverse range of orientations providing a useful framework for understanding how people make sense of existence in and toward the world (Frauenberger, Good, Keay-Bright, 2010). Therefore, it may be useful to understand the autistic people's experience, looking at their world from a first person point of view.

To explore autistic spatiality, we moved from studies on cognitive urbanism (Lynch, 1960), which investigates how the features of human cognition and the characteristics of urban environments interact to produce a subjective spatial representation of city places, paths, and landmarks. This approach focuses on how people experience and subjectively construct urban environments, thus encompassing the phenomenological perspective we want to follow.

In sum, our work aims to explore how adults with autism live their cities, what kind of spatial needs they have, and how they can be supported in their daily routines by technology. We look for an answer to the following questions: How do individuals with autism perceive and represent the urban spaces in which they live? What do they mean for them? What kinds of barriers do they encounter when moving across urban environments? How might HCI technologies support people with autism living their city and during their transfers?

We interviewed 12 adults with autism asking them to recount their everyday movements and city living activities. Our contribution to HCI is twofold: i) we investigate autistic persons focusing on their lived spatial experience, and ii) we provide implications for the design of interactive systems capable of supporting their situated needs in urban environments.

The article is structured as follows. Section 2 outlines the relevant related literature and our theoretical background. Section 3 describes the method used in this research. Section 4 exposes its results. Section 5 discusses the main features of the "autistic space" and presents a few considerations for design. Section 6 reports the outcome of a design session with high-functioning/Asperger individuals, developing our conceptualization of the autistic space, along with the proposed design suggestions. Section 7 describes the limitations of our study and Section 8 concludes the article.

2 BACKGROUND

In this Section, we will first introduce relevant literature with reference to autism and technology. In doing so, we will try to highlight current literature trends. Then, we will briefly outline the theoretical background that informed our study.

2.1 Autism and adult individuals

The clinical investigation of adolescents and adults with autism has not been developed as extensively as that of children (Kientz et al., 2013). This may be a function of the medical model that promotes early intervention in the home and school targeting school-aged individuals, because that is where the service provisions have been focused. The clinical focus on the autistic children's first years of life has also been translated into a privileged attention of the HCI community to designing technologies suitable for them (Boucenna et al., 2014). Frauenberger et al. (2016), for example, involved four autistic children in participatory design sessions to develop smart objects designed from and for their idiosyncratic perspective. Hirano et al. (2010) developed vSked, an interactive and collaborative visual scheduling system aimed at supporting primary school classroom activities for children with autism. Suzuki, Hachisu, & Iida (2016) created EnhancedTouch, a bracelet-type wearable device that can measure human-human touch events and provide visual feedback to augment touch interaction, in order to facilitate physical contact between children with autism. Spiel, Malinverni, Good, and Frauenberger (2017) developed an approach for participatory evaluation called PEACE (Participatory Evaluation with Autistic ChildrEn) to include autistic children in dedicated evaluation phases through the co-definition of goals and methods, joint processes of data gathering and co-interpretation of findings. Boucenna et al. (2014) provided a detailed picture of how technology has been used for supporting autistic children.

More recently, HCI has begun to explore design for adults with autism as well. For example, Hong, Kim, Abowd, & Arriaga (2012) implemented SocialMirror, a device connected to an online social network that allows autistic adults to seek advice from a trusted network of family, friends and professionals. Simm, Ferrario, Gradinar, & Whittle (2014) prototyped Clasp, a tactile anxiety management, communication and peer support tool developed with, by and for adults diagnosed with high functioning autism. Boyd et al. (2016) designed SayWAT, a wearable assistive technology that provides feedback to adults with autism about their prosody during face-to-face conversations. Simm et al. (2016) created Snap, a digital stretch wristband that collects interaction for later reflection and the self-management of anxiety, through a three-month co-development process with and for adults diagnosed with high-functioning autism.

Most of these interventions have been addressed to social communication skills like language production, emotion management, and social interaction, as these are the core features of autism in clinical terms. Exceptions are Hara & Bigham's work (2017), who developed the Assistive Task Queue, a crowd labor platform to facilitate image transcription tasks. They suggested that people with autism are likely to be able to accomplish this kind of assignment, and that a platform of that kind might help them find appropriate tasks to work on. HygieneHelper (Hayes & Hosaflook, 2013) supports teens and young adults in developing skills for independent living by tracking and monitoring progress on hygiene routines, and prompting feedback through a virtual coach.

We aim at exploring technology opportunities for autistic adults, focusing on the domain of spatiality: daily movements in the urban environment, as well as modes of living city spaces, represent an important aspect of the everyday life, which appears to be still underexplored in autistic people.

2.2 Autism and spatial needs

Autism is marked by an atypical social functioning, with a need of withdrawal from social interaction, which can grow into the preference for non-socially intensive activities and environments. Moreover, autism is characterized by weak central coherence (Happé & Frith, 2006), namely a difficulty in the perception of Gestalts as opposed to a collection of unrelated details: in other words, individuals with autism tend to see the trees and not the forest. Emotionally, they are particularly prone to become anxious and to find relief in behavioral routines. This may be due to attempts to provide a reassuring sense of predictive success in a world otherwise filled with error, since it has been noted that individuals with autism have scarce flexibility in dealing with violations to their expectations (Van de Cruys et al., 2014). These characteristics may lead to peculiar modes of representing and using space as well as to the need of tailored supports for movements in the city. Despite several studies hint to a superior performance of persons with autism on visuospatial tasks, reporting for example a higher than control accuracy in graphic cued recall of a path (Caron, Mottron, Rainville, Chouinard, 2004), "many anecdotal reports from people with ASD [Autism Spectrum Disorder] and their carers actually attest to a difficulty with daily navigation and there are myriad accounts on internet forums of people with ASD being unable to find where they parked their car, or becoming lost in their hometown because a familiar route was blocked" (Smith, 2015: 2).

While these problems may impact on the quality of daily life, as well as create anxiety, they received a limited attention in psychology and HCI. In a critical review of spatial navigation in autism, Smith (2015) emphasized that autistic individuals may demonstrate better perceptual distance matching, better cued recall of routes on a map, and better encoding of route information from a map than neurotypical control groups. However, they are slower at learning spatial regularities, less capable of learning locations based on allocentric representations, less likely to sufficiently explore an environment, and more likely to revisit locations that they have already explored. Given these apparent strengths and weaknesses and the still limited knowledge we have on the topic, Smith argued for a more nuanced and comprehensive approach to the understanding of spatial behavior in autism.

In the HCI domain, Bozgeyikli, Raij, Katkoori, & Dubei (2016) explored different locomotion techniques in Virtual Reality with autistic individuals, recommending using joystick, point & teleport, redirected walking or walking in place; however, their proposal is only relevant to virtual environments. Boyd, Jiang, and Hayes (2017) designed ProCom, a prototype system for measuring proximity without requiring instrumentation of the environment or another person, in order to improve the awareness of physical proximity in social settings: therefore, their work paid more attention to proxemics and social interactions than to orientation and movements. Carmien et al. (2005) used a distributed cognition framework to derive requirements for design human-centered transportation systems that are universally accessible, by analyzing “how things are” for individuals with cognitive disabilities who learn and use public transports. Although they did not specifically target people with autism, and mainly involved caregivers and specialists in their design research, their work aimed at supporting people with cognitive disabilities in moving across the city.

Following this line of research, we wanted to address autistic individuals’ spatial needs, exploring how they perceive and understand the spaces they inhabit.

2.3 Autism and ecological interventions

A final element worth considering is the effectiveness of the technological aids provided. Most current solutions for autism treatment are based on behavioral interventions (Dawson & Burner, 2013). Despite their therapeutic successes on the specific problems to which they are addressed (Dawson & Burner, 2013), they treat the condition in artificial contexts, removed from the natural contexts of everyday life where the skills supported should be enacted. This success thus risks to be hardly transferable to the difficulties that the subjects face in the real world, and in general to be irrelevant to the overall improvement of their quality of life (Voss et al., 2016). As Voss et al. (2016) noted, technologies for autism often translate behavioral interventions: this may lead to pay less attention to the study of how technologies may be tailored to autistic individuals’ daily routines, addressed to favor generalization of the newly learnt skills to real-life situations, and appropriate to real contexts of use. This trend may be also due to difficulties that academic research faces in deploying robust systems in the wild, as researchers are often pressured to create novel and frequent contributions rather than producing incremental work.

Nonetheless, there actually is research aimed to address these points. Escobedo et al. (2012), for example, designed MOSOCO, a mobile assistive application aimed to help autistic children practice social skills in real-life situations in a public school, also exploring how they might generalize their newly learned skills to situations outside the classroom. The Autism Glass Project (Voss et al., 2016) is a system for automatic facial expression recognition that runs on wearable glasses and delivers real time social cues to individuals with autism in their natural environments.

Our work embraces an ecological take on autism as well, investigating how autistic people perceive the spaces they live, in order to outline design suggestions that may satisfy their situated needs and create solutions integrated into their daily routines. In doing so, we propose a cognitive approach to urbanism, which focuses on the autistic people's lived experience through a phenomenological lens.

2.4 A cognitive approach to urbanism

In his book "The Image of the City", Kevin A. Lynch recounted the results of several interviews with citizens of Boston, Los Angeles, and Jersey City in order to understand how people account for the urban spaces they live in. He asked them to describe the distinctive elements of their city and to sketch a map of it. From his exploration, Lynch concluded that people in urban situations perceive a city as a cognitively built image, namely a subjective, "phenomenological", representation of space: "In the process of way-finding, the strategic link is the environmental image, the generalized mental picture of the exterior physical world that is held by an individual. The image is the product both of immediate sensation and of the memory of past experience, and it is used to interpret information and to guide action" (Lynch, 1960, p.4). Lynch further highlighted that while each individual creates and bears his own image of the city, there is substantial agreement among members of the same group in terms e.g., of social classes. Belonging to specific communities, participating in certain social practices, as well as having certain cognitive and emotional functioning, can inform the representations of the city and consequently the ways in which the city is lived.

Lynch's empirical study of how people perceive the landscape of a city has become a classic in urban planning (Hospers, 2010), being widely referenced in the academic literature and having a profound effect on the teaching and practice of the discipline worldwide (Pearce & Fagence, 1996; Carmona et al., 2003). Lynch's work has influenced not only planners but also psychologists, geographers and other social scientists allowing them to carry out "map-in-the-head"-research (Hospers, 2010). Pearce and Fagence (1996) and Šiđanin (2007) provide reviews of research inspired by Lynch's study. Lynch's book has also inspired planners to propose more meaningful environments in contemporary society (Southworth, 1985; Ford, 1999; Sieverts, 2003), and has been used to plan cities as different as San Francisco, Cairo and Havana (Hospers, 2010). Within HCI, Lynch's analysis has been employed to model cities in virtual reality, yielding a digital image of the city (Morello & Ratti, 2009), as well as to inform a crowdsourcing project aiming to investigate what visual aspects of London neighborhoods make them appear beautiful, quiet, and/or happy (Quercia, O'Hare, & Cramer, 2014).

By grounding our research in Lynch's work, we aim to understand how neurodiverse individuals represent and experience urban spaces, in order to find insights for technology aimed at satisfying their spatial needs. This implies accounting for the subjective meanings and perceptions through which they see and understand the world, producing an informed design that strives for developing tools through their eyes. This might be called a *cognitive urbanism approach*, aiming to study how the characteristics of human cognition on the one hand, and the structure of the city spaces on the other, interact in building the subjective spatial representation of urban areas, paths, and landmarks. As a consequence, our focus is no longer on what an individual can or cannot do, nor on designing to “help”: this might create a power relation that represents others with disabilities as worse off in some way when compared with the researchers themselves (Rogers & Marsden, 2013). Instead, we emphasize what it means to “be-in-the-world” as a neurodiverse individual, shifting the attention from helping to empowering “the other”.

3 METHOD

To explore the representation that autistic adults have of the urban environment and their ways of using it and moving within it, we interviewed 12 persons with a diagnosis of autism. Then, in a subsequent design session, we recalled five participants to further develop the outcome of the interviews (Section 6).

3.1 Sample

We interviewed 12 participants with a diagnosis of autism. We split the sample into two groups. The first (average age=28,7; SD=8,8; females=0; IQ min=37; IQ max=97) was comprised of 6 mid-functioning individuals with autism level 1 and 2 according to DSM-5 (American Psychiatric Association, 2013). They were slightly or moderately below normal mental functioning. They had difficulties in social emotional reciprocity (e.g. in showing interest in the interaction with another individual, or in recognizing her emotional states). They showed almost no nonverbal behavior during social interactions. All of them had extremely narrow interests. Some of them had motor stereotypies like touching surfaces or smelling objects while talking. Five of them did not work and one worked part-time.

The second group (average age=34,8; SD=13,6; females=2; IQ min=88; IQ max=145) comprised 6 high-functioning/Asperger individuals with autism level 1 according to DSM-5 (American Psychiatric Association, 2013). This group included one international translator, one manager, one artist, one unemployed person, one part-time office worker, and one student. They had some difficulties in decoding information during social interactions (e.g., some of them did not understand metaphors or double meanings); they tended to focus on details losing the overall view. They had an average to high IQ, which, when applied to interests (which were narrow, even at a lower level than the first group) led them to develop high competences in diverse domains (e.g. in art, mathematics, music). Almost all of them excelled in their work.

Another inclusion criterion was the possession and routine use of a smartphone with mobile internet access. This was needed for the research (see below). Exclusion criteria included other known neurological or neuropsychological conditions, a history of substance abuse, and physical or motor conditions which could hamper the subject's potentiality for autonomous movement in the city space.

We involved two distinct groups because we wanted to investigate whether there were differences in the spatial experience of people that are differently categorized in the clinical practice of autism, and are reported as having correspondingly different characteristics in the relevant literature. Autism widely varies in terms of severity and we wanted to understand whether one of the two groups could benefit more from spatial technology support. We also aimed at obtaining a more nuanced understanding of the phenomenon under study through a comparison between the two groups.

In accordance with Glaser and Strauss's (1967) theoretical saturation principle, the decision to settle for 12 participants was made when we realized that additional interviews would not have produced substantial new results for the aims of our research, following a data saturation criterion (Bowen, 2008). In this sampling strategy, the researcher does not seek generalizability, focusing less on sample size and more on sampling adequacy: an appropriate sample is composed of participants who best represent the research topic (Bowen, 2008). To recognize the data saturation point we considered data replication and redundancy: experiences reported by participants were quite uniform with reference to the underlying spatial needs they expressed. The psychologist involved in the research also confirmed the “typicality” of the recruited participants, ensuring that sufficient data to account for the phenomenon had been obtained. Further, other studies with similar design in HCI have adopted a similar sample size (e.g. Zolyomi et al., 2018).

The participants were screened and recruited by the staff of the Adult Autism Centre, Department of Mental Health, ASL City of Torino, Italy - (Piemonte Region pilot center), following DSM-5 criteria (American Psychiatric Association, 2013).

3.2 Procedure

The interviews were semi-structured and were carried out jointly by a HCI researcher and a clinical psychologist specializing in autism. We chose the interview method as it is commonly used for gathering requirements in HCI studies with autistic people (Çorlu et al., 2017). None of our participants had problems in language production, so that explicitly asking them to express their perspective about their daily routines and transfers was considered the best method to grasp their subjectively lived experience, as well as the meanings they ascribe to the spaces in which they live. Although individuals with autism may have the tendency to withdraw from social interaction, this need is less pressing when they have clear in mind what they can expect from the ongoing social interaction. We then paid attention to explaining the scope of our research and the kinds of questions we would have asked during the interview. The climate was friendly and participants showed to be at ease in reporting their experience and explaining their perspective to us.

Participants were first asked to sketch a map of the center of the city in which they lived, as well as of their home neighborhood, highlighting important landmarks and describing the routes that they habitually travelled. The latter kind of task is a spatial problem-solving method, aimed at exploring how people translate their environment into cognitive maps (Lynch, 1960; Mohsenin & Sevtsuk, 2013). It is a psychological process by which individuals internalize, recall, reason upon, and externalize a subjective representation of their environment: a person's cognitive maps embed that person's knowledge of routes, places, and key environmental features (Sanoff 1991). Participants had all the time they wanted to elaborate their drawings. They stopped when they thought they had finished. We did not seek an accurate representation of their spaces, instead aiming to understand how they subjectively represented these spaces in their mind. We also used the maps during the interviews to elicit further comments, by indicating buildings and spaces depicted in them and asking participants to describe the meanings and the feelings they connected to them (e.g. *Can you describe this place? What does it mean for you?*).

The interviewees were asked to describe their daily habits in terms of movements, use of means of transportation, daily task management (i.e., *Can you describe your typical day? How do you organize your day? What are your typical transfers? What kind of path do you prefer? Why? Are there any paths that you avoid? Why? What kinds of public or private transportation means do you use? Which of them do you prefer and why? And which do you avoid and why? What do you do in your spare time and in the days when you do not work, for example during holidays or week-ends? Do you ever travel to other cities or abroad? What are your favorite places? Why? And what are the places that you do not like? Why? When you move across your city, are there situations that may make you feel more comfortable? And situations in which you do not feel at ease? If you have to choose a place to spend some time comfortably what kind of features would you consider?*). However, the participants were free to explore themes not foreseen in the initial list of questions: they were prompted to clarify their recounts when needed by providing examples coming from their personal histories. The participants were not rewarded. Each interview lasted about 1 hour. The interviewees were invited to the Adult Autism Center to perform the interview. No one apart from the HCI researcher and the psychologist was present during the interviews.

Interviews were audio-recorded and then transcribed verbatim. The data analysis followed open and axial coding techniques (Strauss & Corbin, 1990) to identify and link the data collected to the research questions. The findings were then coded separately by the first and the second author, who produced initial codes: the data were broken down by taking apart sentences and labeling them, with labels like "problems in public transportations" or "anxiety". Then, the same researchers reviewed the results segment by segment to assess consistency between them in defining the beginning and end of segments and the application of codes (MacQueen et al. 2008). The intercoder reliability (Miles & Huberman, 1994) at this stage was 68%. Then, all inconsistencies were resolved. Inconsistencies were mainly related to the differences in labeling the same concepts (e.g., "anxiety" for the first coder and "stressful situation" for the second one, which turned out in the decision of keeping the former as the best label describing the underlying concept). The resulting codes were finally grouped independently by the two researchers, labeled and then compared again to solve inconsistencies. This yielded 13 learned abstracted categories, two of which were discharged as not directly related to the participants' spatial needs. Axial coding categories from open coding were amalgamated to create a more defined hierarchy forming key related categories. The resultant three axial categories are the central themes formed from the participants' recounts: spatial routines, controlled environments, and social competences. From these key categories a "core" category can be developed using selective coding that integrates and connects to all others: the central theme of "coping about uncertainty" can be seen as an overarching concern.

4 RESULTS

As we have seen, the analysis resulted in three main themes, which all relate to the overarching theme of uncertainty. Spatial routines, i.e., the tendency to stick to rigid paths during daily transfers, may be interpreted as a compensatory strategy that participants enact to cope with uncertainty, which otherwise may yield anxiety and consequently disorientation. Controlled environments, which point to all those places that are considered "secure" by our participants, can be seen as another way to cope via rigidity, in order to maintain control upon unexpected situations, which may happen in the world "out there". The management of the social competencies, expressed by the third theme, is another example of dealing with the uncertainty, this time that which comes from interacting with new people. The importance of uncertainty is not a new finding about autism, as it has been noted that neurodiverse people have scarce flexibility in dealing with violations to their expectations (Van de Cruys et al., 2014). Our study, thus, confirms this general knowledge. But it is interesting and novel way to explore the impact anxiety about uncertainty plays out in an autistic adult's navigation of a city, as well as in her perceptions of the spaces she inhabits. In this perspective, space is the context wherein uncertainty can be encountered and anxiety can be experienced. We will now move to the in-depth description of the three identified themes.

4.1 Spatial Routines

Spatial routines describe the fixed paths that participants have set to "tame" the uncertainty of novel environments. Both mid-functioning and high-functioning/Asperger participants recount travelling a very limited range of routes during their daily living. Mid-functioning participants (5 out of 6) report great limitations to their movements, being capable of autonomous travel only between home and close or well-known places (e.g. specific shops, the gym). For any transfer other than these, they have to rely on their caregivers or tutors. This attitude is due to the *anxiety* yielded by breakdowns in spatial routines, to the difficulties they find in orienting and to the incapability of managing unexpected events. A1 reports: "*I count the bus stops to go to work and back. One time the bus happened to change its route so I got off in the wrong place… I was in panic. After a long time I called my mom, and I don't know how I found the way*". All of these six interviewees show scarce to no interest in visiting new places, traveling alternative routes, or exiting from their city boundaries: they frequent always the same cafes, libraries, and parks located next to their home.

High-functioning/Asperger participants, instead, are able to move wherever they want, but they also report difficulties with orienting and a tendency to always hang out in the same places, due to the anxiety engendered by unexpected situations and novel environments: for example, they always travel the very same path when going to work, since even the slightest variation in the route due to external conditions (e.g. a closed road) may make them feel overwhelmed by anxiety and bewilderment. H2, for example, reports that "*I don't have a good sense of direction so I tend to get easily lost. But once I have learned what streets bring to a certain place I always use them. It's a matter of habits*". Although accustomed to travelling for work, when H3 is in her city "*I always go the same paths. I never change them. When I go to the gym I always pass through via San Domenico, keeping on the right side... I've never kept the other side, even if there is a scaffolding. It can be sunny or it can be rainy, that's the way. If I don't do this way, I can't find the gym, I become anxious, because I don't have my landmarks anymore*". Rigidity of their spatial routines, therefore, is a means to cope with the uncertainty of the world, and a tool for preventing the possibility of experiencing anxiety.

This also shows in that most of the high-functioning/Asperger individuals (4 out of 6) are completely uninterested in wandering around their city. They rarely "go for a walk"; when they go out it is always for a precise reason, to accomplish a certain task. H1 stresses that "*I don't go outside if I don't have a goal. I may go to an exhibition, but then I return home, I see no reason for hanging around*". Rather than a preference, again, this is a need that may provoke an anxious reaction when unsatisfied. This disposition shows even in their attitude toward travelling for tourism. Travelling to them (4 out of 6) is a struggle, something that they have to do, that they have learned to do, but that they often do not yearn to do. H3 emphasizes that when she travels she is not curious at all toward the places she is visiting: "*Being at the hotel of the airport, or in the city center, is the same for me. I hate travelling. I have to do that, and I'm capable of doing it, but, if I can, I stay in my hotel working the whole day. I never travel for tourism".* Technology here helps the participants by allowing them to organize their travel without having to engage in social interactions: *"through the internet* – H2 says – *I can easily book everything relevant to my travels without exchanging a word. This has been a great improvement for me*".

High-functioning/Asperger individuals, then, have developed skills to cope with transfers to novel places, and in general with unknown situations, by also relying on technology. This differentiates them from mid-functioning participants. The latter rarely use location-based services due to the difficulties in managing digital maps, whose high level of detail typically distracts them: mid-functioning participants have a simplified mental representation of their city, as it emerges from their cognitive maps, and they tend to focus on specific details, becoming prone to losing vision of the whole.

Instead, high-functioning/Asperger (4 out of 6) participants frequently use applications like Google Maps. H2, for instance, describes that "*When I get lost, now I use Google Maps or Google Earth. If I have to go to a new place, I look at the satellite images, I seek points of reference, for example a park or a fountain that can help me memorize the path. I can't handle the names of the streets very well, so I look for something visual, an image rather than a name*". In this case, technology proves useful to support and enhance a strategy that H2 has developed to memorize routes and develop spatial routines. Four other high-functioning/Asperger participants confirm the dominance of the visual channel over the verbal one, reporting difficulties in handling street names, or, like H3, in following verbal instructions when she asks for directions.

4.2 Controlled environments

"Controlled environments" are all those spaces that participants consider secure, because they allow them to exert control upon unexpected events, encounters, and sensory stimulations. In this perspective, for participants *home* is the controlled environment par excellence. To both the mid-functioning and high-functioning/Asperger participants, this is the most important space of their life. In the cognitive maps they drew (Figure 1 and 2 and Figures in Appendix), for example, when asked to sketch the neighborhood where they live, most of them (9 out of 12) either depicted only their house, or at least gave it centrality and dominance upon the surrounding spaces. The main difference between the two groups is that the mid-functioning participants stay home most of the day since the assistance they need to go out is not always available, whereas all the high-functioning/Asperger ones go out for accomplishing their daily tasks but actively yearn to spend most of their time in their home. H3, for instance, recounts that "*I bought a house in the city center, because I have everything I need nearby. So everything is under control. When I go out I know that home is always within reach, so if something happens I can go back… If I've got more than a single errand, I always return to home: for example, I buy the water at the supermarket, then I go back home, then I go out again, even if the other place that I need to reach was close to the supermarket*". Returning at home, in this case, is a means for finding reassurance against a world that is seen as unpredictable.

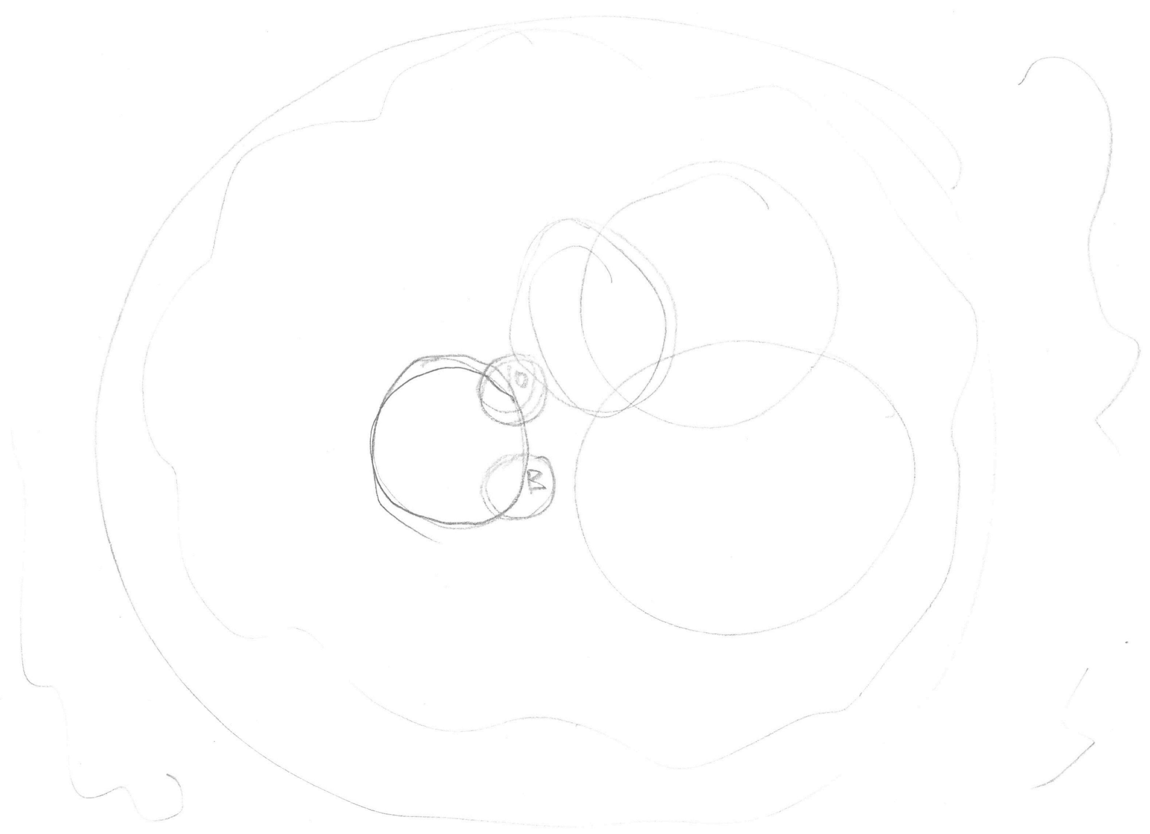

Figure 1. The house is the central circle which intersects two small circles that point to the private spaces of the participant and her husband.

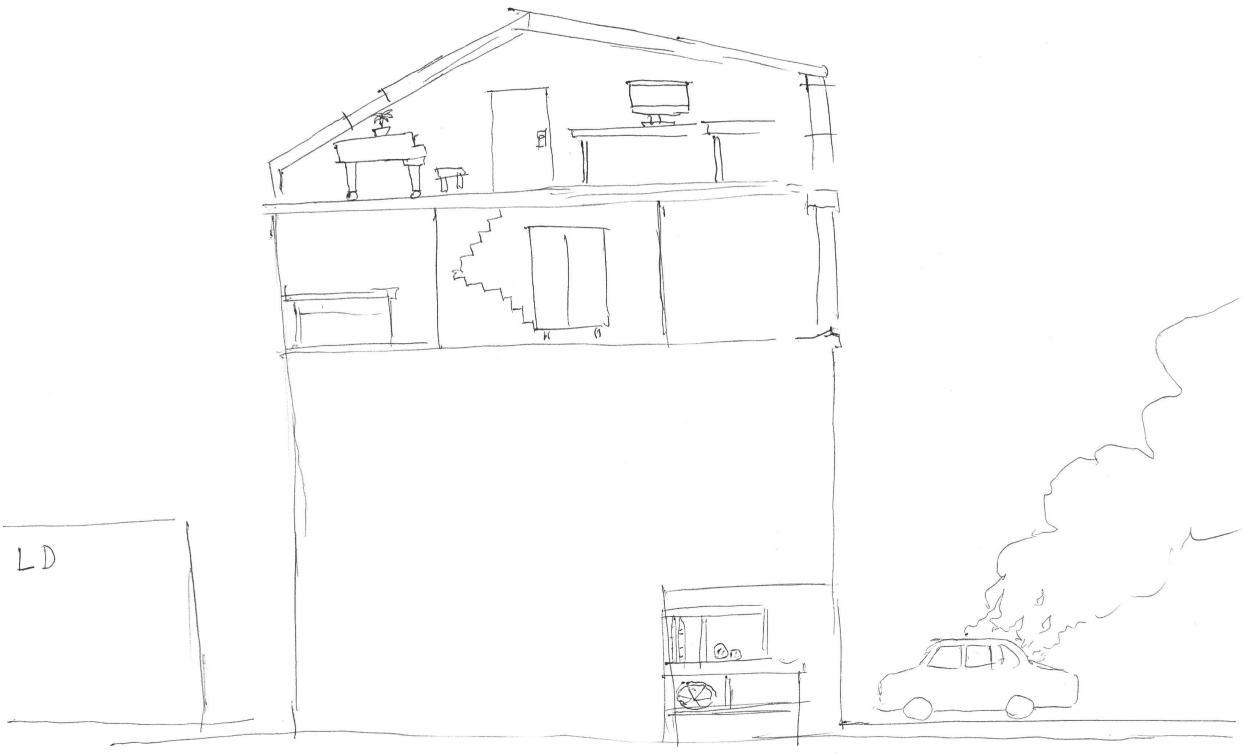

Figure 2. The participant drew only his house and a supermarket next to it.

Home is a shelter where the individual feels at ease: it is perceived almost as an extension of her self. H4 actually detests the city in which she lives, perceiving it as hostile both aesthetically and socially. However, she says "*If I listened to my instincts I wouldn't go out… I keep living in this city only for my house. It's my kingdom, everything in it is shaped around me. There are all of my stories in that house, the products of my special interests, my books, and that delicious garden... This morning I spent one hour looking at an owl on a tree. I share my house with my husband and* *it's our little world… But each of us has his or her own private place, and then we share other environments*". Autistic individuals feel safe at home because they feel they have control of the environment. All the participants report to be very sensitive and susceptible to external influences like light, sounds, smells, and people. This confirms research about the unusual sensorial experiences of autistic individuals (Robertson & Simmons, 2015). Autistic individuals exhibit a strong sensitivity toward *physical sensations*: H1, for example, emphasizes how he barely bears the odors he smells when aboard a train; both A5 and H1 report their intolerance of high and low temperatures, which lead them to avoid air conditioned places as well as hot environments. A3 recounts how he loves quiet, almost isolated, places, where the noises of the city leave place to the sounds of nature. H5 hates people when he walks in the street, because they walk too fast or too slow, in either way interrupting his rhythms. All the participants describe ideal places offering what they would consider *secure* characteristics. However, such characteristics depend heavily on individual preferences, since each participant shows idiosyncratic "passions" for specific kinds of place. H4 stresses how important it is to find these kinds of places is when she is traveling far from home.

The tendency to withdraw from crowded places is dominant, albeit not unanimous, among the interviewees (8 out of 12). Even more important is the chance to remain ignored, or invisible. H3, for example, remembers how she loved to live in New York when she was young, because no one cared about her. She further explains "*Sometimes I invite people to my house for dinner. I am accustomed to invite even thirty, forty people… This is not a problem, because I can leave the conversations whenever I want, I can observe them from a distance, becoming engaged and then rapidly disengaged, and nobody cares*". Being ignored, again, is a means for withdrawing from uncertainty in the form of unexpected encounters.

Home, therefore, is a place where the situation can be finely tuned according to one's needs and perceptions, the access of other people may be controlled, and one's interests may be projected upon the environment. *Interests* play an important role, since high-functioning/Asperger participants show to be motivated to go out only when they can be pursued and satisfied. To be immersed in an exhibition, a concert, a book, or even in work is a means to isolate themselves from the outside world, recovering that sort of "control" they have on their private place.

4.3 Social competences

The theme of social competences points to the connection that participants see between spaces and the social skills required in those spaces. Our participants relate the urban environments where they live to their capability of being engaged in social interactions. As we have seen above, almost all of them report either the need to withdraw from crowded places or the desire of being ignored whenever desired. However, this does not mean that they want no interaction with other persons at all. Actually, most of them (8 out of 12) strive for social contact. Especially high-functioning/Asperger individuals are aware of their weak competence in conducting "proper" social interactions, due to their difficulties with understanding the others' intention, their word games, or their real feelings. H6 explains: "*I want to encounter other people, but at the same time I find it difficult to interact with them... that is, they don't understand that it's impossible for me to know what they are thinking and their emotions... often I'm uncomfortable, I make a bad impression... because I don't know how to properly interact with them, when it's appropriate to say something, and what is out of context*".

This weakness in empathy and Theory of Mind (Baron-Cohen, 1989), as the faculty of understanding and reasoning upon mental states is most commonly called, leads participants to tie each place they visit to the social competences needed to interact with others there. This, in turn, allows them to form a series of *expectations* about how much they will "fit into" that situation and, consequently, how much they will feel comfortable in there. For example, H5 actively searches for new acquaintances when he is hanging out with his friends, e.g. going to bars at night. However, he explicitly admits that he is not able to carry out a conversation with strangers properly, so that he generally feels uneasy in there, and forecasting such a situation makes him a bit anxious. Not knowing how the interaction could proceed is again a source of great uncertainty, which can be coped with only when the individual has learnt to foresee its typical development. H3 explains how going to places like banks is a nightmare for her: "*I'm annoyed because I don't know how to handle the interaction. I cannot understand what they want and how I should behave. I get nervous… The interactions in which I am engaged at work, instead, are different, because they have a clear objective, there is nothing personal, and I know exactly what I must talk about*". As H5 further explains, organizing tasks and conversations in a series of consequential steps in a given place is a major issue for autistic individuals. This problem is more relevant for mid-functioning participants, as A2 stresses. However, also high-functioning/Asperger people are weak in recognizing the "correct" sequence of social actions to be performed in order to accomplish a goal, turning a place into something unexpected and unknown from the social point of view: "*When I go to the post office, I don't know what to do first, how to approach the employee, and what kind of actions are needed to send a package. For me, going to the post office means to go in a place where I don't know what to do and what to say*".

These interviewees, therefore, embed "sociality" in the urban environments which they traverse during the day, appraising them based on the abilities they require in terms of "how to" and social rules. The constant feeling of being out of place, which often brings with itself the desire to stay away, can be traced in the *social gaze* with which the interviewees look at the city spaces. H4, however, describes how Asperger individuals have a high degree of sociality among them and technology might represent a means for increasing the social connections of autistic persons, by putting them in contact with similar others. However, from H4's point of view, this jeopardizes Asperger individuals' integration into "the wider world": "*We commonly talk about us and them, it is we who first draw a line between what we are and the rest of the world*".

5 DISCUSSION AND CONSIDERATIONS FOR DESIGN

High-functioning/Asperger participants encounter more or less the same barriers faced by mid-functioning ones, albeit to a lesser extent. This is likely due to their greater intellectual abilities, which makes them substantially self-sufficient in daily living. However, their need of moving around the city is far more pressing than that of the mid-functioning individuals, since their everyday routines and work require frequent transfers: as a consequence, they face “uncertainty barriers” more often than the other group. Despite these differences, the ways the two groups conceptualize and appraise the spaces they live present similar characteristics. We want now to try to distill the findings outlined above so as to list the main features of the “autistic space”. Despite the diversity of experiences reported by our participants, there are several common threads worth identifying.

We will describe three different kinds of spaces characterizing the autistic individuals’ spatial representations: the *crystallized space*, the *safe space*, and the *social space*. These spaces relate to the core characteristic areas of autism we found in our study: the crystallized space is connected with the fixed routines that participants enact to cope with uncertainty; the safe space is tied to the sensory preferences of autistic individuals and their attempts to control the environment; and the social space relates to the social competences participants see embedded in the spaces they encounter. We will discuss the main features of these spaces, also suggesting design considerations specifically addressed to them, aiming at supporting autistic persons in their daily movements and city living. As such suggestions are not implemented yet, they are design hypotheses, in need of further testing to prove their validity (Hekler et al., 2013).

5.1 The crystallized space

Autistic individuals tend to perceive the environments in which they live as fixed, crystallized spaces, where their everyday routines trace permanent lines that they have to follow, and the spaces which are not included in their usual routes shift to the background. These representations of space are extremely schematic and rigid, which hampers adaptivity in the face of unexpected events. The crystallized space is built through the memorization of precise landmarks like fountains and parks, allowing autistic individuals to develop a mental visual path that can be followed step by step, landmark after landmark. This representation is strengthened through repeated passages, as they learn to match the representation of the path they have "in the head" with the slight variability they find in the real environment (e.g., due to weather conditions). However, this space is extremely fragile, as even a minor change, such as walking on the other side of the road, may disrupt the fixed lines they have built over time. Consequently, whereas their capability of navigation is preserved if precise landmarks are provided, their ability of wayfinding is limited. Wayfinding is the behavior of finding one's way from an origin to one or more destinations, relying on the current understanding of an environment's spatial characteristics and on mental models of the environment itself based on previous experience (Taylor, Brunyé, & Taylor, 2008). Navigation, on the contrary, only needs understanding of how a memorized motor sequence or a particular navigational aid (e.g. a map) should be used (Hartley, Maguire, Spiers, & Burgess, 2003). In other words, navigating consists in following a fixed route, wayfinding consists in deriving it (Taylor et al., 2008). Autistic individuals are capable of travelling their habitual routes by sticking to action-based sequences (i.e. sequences like "When you see the library, turn right") (Taylor et al., 2008) which are mainly based on visual landmarks, but find it difficult to construct "maps in the head" in the form of abstract spatial representations (O'Keefe & Nadel, 1978), or to make them "actionable".

As a result, they have their own way of getting lost, different from that of individuals with other cognitive disabilities like memory damage or dementia. In the former case, anxiety triggered by uncertainty yields disorientation and incapability of managing the unexpected change: as long as the autistic person remains in an unknown space her emotional reaction prevents the possibility of recovering the lost path. In the latter cases, loss of memory produces a “scattered space”: the individual can lose her situation awareness, then moving abruptly from a familiar space to a unfamiliar one. For instance, working memory, which is dramatically affected in Alzheimer's Disease (AD), is heavily involved when a person refocuses on more relevant situational aspects after being distracted by unimportant details: this skill may be severely impaired in AD, leading to bewilderment and wrong spatial decisions (Passini, Rainville, Marchand, & Joanette, 1995).

To support the situation awareness of persons with dementia, Koldrack, Henkel, Krüger, Teipel, & Kirste, (2015) proposed to design systems capable of observing a patient, recognizing her disorientation, and offering help based on what activity was interrupted by the disorientation. Home Compass (Rassmus-Gröhn, & Magnusson, 2014) provides a compass that continuously points to a “home” location and thus supports exploratory wayfinding: it is specifically addressed to persons with memory impairments, allowing them to always locate home when they get lost, without the need or the offer of a predefined route. These kinds of aids do not appear as suitable to autistic individuals because they could jeopardize their spatial routines by potentially redirecting them to novel routes and thus becoming less a solution than a problem to them.

The disruption of the crystallized spaces may generate anxiety and panic in autistic individuals: navigational aids should rather help them preserve the integrity of the “fixed lines” that characterize such spaces than propose alternative routes. To them, the primary need is to recover the habitual path when something unexpected happens, rather than reaching the final destination as fast as possible.

Design suggestions. Design could support the autistic persons’ daily transfers (e.g. home-work, home-gym etc.) by memorizing the relevant routes in a spatial agenda. For instance, a user might insert her habitual routes onto a map: if she gets lost, the system could provide suggestions for recovery, e.g. by prompting the shortest route to the nearest point memorized in the map. The system might also give personalized information to cope with routine breakdowns: for example, by providing information on alternative transportation means if the subway is on strike, and thus enhancing the user's sense of control over the unexpected event and preventing or reducing anxiety. Still another possibility, especially for mid-functioning individuals, could be to put the user in communication with a significant other (e.g. one of her parents or caregivers or a friend) who may direct her out of the impasse.

Allowing the user to attach visual landmarks to the routes on the map, whether habitual or novel, might further help her to both plan her travels in advance and recover her sense of direction when she gets lost. A similar feature has been implemented in NevMem (Popping, Heuten, & Boll, 2014), which decomposes complex navigation tasks into several simpler ones, and prompts landmarks in forms of photographs to support the orientation of people with mild cognitive impairment. Landmarks could instead be made available to autistic users by providing a sort of "route composer" based on images, which may enhance the spatial agenda with pictorial elements better recognizable by autistic individuals.

5.2 The safe space

People with autism view home as an enclosure, sheltering them from the outside world. The safe space is an environment where an individual can control the surrounding context and project herself onto it. It reflects her identity and actually constitutes an extension of herself. Humphreys (2005) highlighted how comfortable the homes of autistic children are when they are capable to convey a sense of calm, order and simplicity, lit up by natural light, and designed for reducing noises. Ahrentzen & Steele (2009) claimed that the main goals in designing residential buildings for autistic people should be to ensure psychological safety, to maximize familiarity, to minimize sensory overload, and to allow control over social interactions. Sánchez, Vázquez and Serrano (2011) provided a detailed overview of design guidelines to build places that feel secure to autistic individuals. Most of our interviewees have similar needs for safety, calm and sensory comfort. The meanings that they attach to their secure places reflect their interests, personal histories, and past experiences. Whereas the crystallized space is an instrumental space "used" to go from one location to another, the safe space is a "place" (meant as a space which is enriched with meanings and valued (Harrison and Dourish (1998)) where people with autism feel comfortable, and want to spend their time and live. In these places they have the opportunity of exerting control over the environment and of finding a sort of mirror of their perceptions and meanings.

Design suggestions. Systems that aim at providing a spatial support to autistic individuals may then signal "partially safe spaces" available in the cities where they live or where they have to travel for work or for other reasons. This could not substitute for home, of course, but could allow them to find a shelter in contexts whose novelty they might perceive as hostile. This could be based on crowdsourcing populating urban maps with positive (and possibly negative) highlights and reviews specifically addressed to autistic individuals. Such a "safe" map might include uncrowded, quiet places as well as locations and events where autistic persons may encounter like-minded people. This would enlarge their safe space outside the boundaries of their homes, albeit with different degrees of emotional comfort.

The active involvement of autistic persons in this collective endeavor might be a way to empower their sense of individual and social agency. They could feel like protagonists in the improvement of their city, for example by making it more accessible to the member of their community. This would make their voice more heard, their views on the opportunities offered by the city spaces more visible.

5.3 The social space

Autistic individuals connect the spaces they traverse during their daily activities with the social competence needed to interact with others there. Far from being neutral, spaces are intrinsically social, in that they embed a set of the autistic person's social expectations.

The notion of *script* (Schank & Abelson, 1977) may be useful for dealing with this third nature of the autistic space. Scripts are knowledge structures that describe stereotypical sequences of events, possibly with adjustable parameters, allowing an agent to anticipate and understand what will happen in a certain social interaction. While neurotypical individuals generate these structures during the early childhood, but add further layers of complexity as they grow up (Trillingsgaard, 1999), autistic ones appear to develop fewer and less flexible scripts (Trillingsgaard, 1999) and to find it hard to abandon them in favor of more sophisticated representations. They appear to assess their comfort within a certain social space based on the kind of script it embeds and on their degree of confidence in mastering it: our participants pointed out that when they do not know how to interact in a certain place or context they become anxious, whereas when they are perfectly aware of what they can expect from a social interaction (for example in the office at work, as reported by H3) they feel more comfortable.

In this perspective, scripts may be useful for autistic individuals as they may provide a means to reduce the uncertainty of the social interaction. As they tend to be bewildered by the impossibility of decoding what is socially happening in a specific place, technology could give them means for dealing with uncertain social situations by making them aware of what they may "socially" expect within a specific place.

Design suggestions. Scripts and scenarios describing social interactions and how they typically proceed within a certain context could be embedded in the map, creating a geo-localized handbook that allows the user to explore the sociality of a place. When a user is localized in a specific place thanks to the mobile phone GPS, the relevant scenarios would be loaded, possibly letting the user select those that fit more into her current objectives. This would provide the user with contextual knowledge that could decrease the possibility of bumping into unexpected social situations, thus reducing the anxiety derived from the lack of understanding and perceived control. Such knowledge could empower the user, making her more self-confident and at the same time leaving her free to act and express as she wants and feels. This would enable a more aware and comfortable interaction with the "neurotypical world", preserving the way of living of the neurodiverse population.

6 DESIGN SESSION

In order to have a feedback on our conceptualization, as well as on the defined design considerations, we recalled the interviewees to collectively discuss them. At this stage, we decided to focus on the high-functioning/Asperger individuals, since the frequency, variety, and magnitude of their everyday movements (most of them travel for work and/or are involved in mundane activities requiring regular transfers) pointed to a more pressing desire to use technology for spatial support. Moreover, they are already accustomed to use technology to cope with the uncertainty barriers they encounter (e.g. by using Google Earth to check a novel path and make it more familiar), making the integration of technology into their everyday life easier and more natural. Mid-functioning individuals, instead, spend most of their time at home and do not have the need of going outside. When they go for a walk they are often accompanied by a caregiver. Given the frame of our research, aimed at addressing the autistic individuals' spatial needs, we believe that technology for spatial support would fit better into the high-functioning/Asperger people's lives. For this, we decided to deepen and discuss design opportunities with them. However, some of the insights coming from this discussion could also be used to design for mid-functioning individuals since, as discussed above, the kinds of barriers encountered by these two populations with reference to daily movements are similar.

Researchers have recently started involving autistic people more fully in the design process. Millen, Cobb, and Patel (2011), for instance, engaged autistic children and their teachers in the design of a collaborative virtual environment for supporting learning. Benton et al. (2012) developed IDEAS, a method to support autistic children to collaborate within a design team. This presents diverse challenges, from managing narrow interests to coping with social anxiety that may be triggered by group interaction, leading to preferring the involvement of high-functioning autistic children rather than low of mid-functioning ones in research studies (Frauenberger et al., 2017). Examples of involving autistic adults in technology design, instead, include Simm et al.'s (2014, 2016) works. Bossavit & Parsons's (2016) also developed a serious game with a natural user interface to improve academic skills in geography, via a participatory design approach with two adolescents with high-functioning autism.

Building on top of these attempts of involving autistic users in design sessions, we decided to form one group, composed of five high-functioning/Asperger individuals previously interviewed (all the interviewees accepted, except H2), a human-computer interaction researcher and a psychologist specializing in autism, who had previously participated in the research. Participants were invited again in a room of the Adult Autism Center and no other person apart them and the two researchers was present during the discussion. Recalling participants to develop the findings of our empirical study evokes the practice of "backtalk" in ethnographic research (Cataldi, 2014), where the ethnographer interviews the natives and then asks them whether the interpretations she developed are correct from their perspective. Likewise, we discussed the three kinds of space we defined, and we collaboratively elaborated on our design suggestions. Having the same researchers conducting the interviews and the design session proved important in establishing a climate of trust and cooperation, where researchers and participants could work together toward a common aim. In order to mitigate the social desirability effect, we informed the participants that every criticism would have been welcome, making it clear that the session was going to be an opportunity to contribute to the design of technology that could be used by themselves in the near future, as well as by other autistic persons.

First, we asked the participants to think of their daily routines and the difficulties encountered during their everyday movements. Each participant had to work individually: they had 20 minutes to develop as much as possible "design ideas" they might use to overcome such difficulties. Afterwards, everyone presented her ideas to the rest of the group that could constructively criticize them. Then, we explained our conceptualization of the autistic space and the design suggestions we had defined. Participants discussed how their concepts could integrate into, revise, or substitute ours. The session lasted about three hours and was entirely audio recorded and then transcribed verbatim.

In the following, we report the outcome of the session. We analyzed the data by using the same techniques of coding and thematic analysis employed in the interviews phase. The analysis resulted in six categories which led to three main themes. "Spatial routines are tied to everyday activities" develops the idea of the crystallized space, specifying that such space is strictly tied to the sequence of activities that autistic individuals carry out in their daily life. "Bounded spaces might separate 'us' from 'them'" elaborates on the idea of the safe space, specifying that it can turn into a secluded space, where autistic individuals may isolate themselves. Finally, "From social competences to social relations" highlights that the social space expresses not only a need to understand the social proceedings in there, but also a desire to develop social relations.

By and large, participants positively responded to the three spaces we proposed, as well as to our design concepts, enriching them with more nuanced features, and often proposing further aids.

6.1 The crystallized space: Spatial routines are tied to everyday activities

All the participants confirmed the features of what we defined the crystallized space, emphasizing its "rigidity" and "pervasiveness": it erases the "adjacent spaces", making the alternatives shift out of sight. The participants stressed that this kind of spatiality is intertwined with their daily activities. H3 said that "*When I have to travel, I usually stick to a series of tasks and places that I have been defined well in advance... When I was in Naples two weeks ago, a business meeting that I had to attend was postponed for three hours. I was literally paralyzed in the train station, I didn't know what to do, where to go... I stayed there for three hours. I was unable to consider other possibilities, to go somewhere else, to visit an exhibition. I would have liked to, maybe, but I wasn't able to change my destination and reorganize my tasks*". This problem is shared by other three participants, who highlighted how the fixity of the crystallized space is reflected in the steadiness of their daily schedule: the places they go during the day are connected with the activities they have to perform. On the one hand, such activities cannot be easily modified; on the other hand, they might obscure other relevant needs and goals. H4 confirmed that she is unable to see her plans and routines "*from the outside*", so that even a slight variation of her schedule impacts her whole day. H6 further explained that "*I carefully plan my day by defining what I have to do, but then I practically forget everything else, to do the grocery shopping, for example, even to drink. Yes, I forget to drink and this is a problem for me, it's not the first time that I have to go to the hospital*". Participants elaborated on the need of recovering from breakdowns in routines reestablishing the integrity of the crystallized space: they feel the desire to occasionally crack its surface by being supported in considering "opportunities for actions" when immersed in a "predetermined flow", or when something unexpected happens.

Returning to the issue of drinking described by H6, H4 envisioned an application capable of reminding common tasks that could be easily forgotten, such as eating, cleaning home, having a shower, and so on: in fact, despite their importance, such tasks do not fit easily into the participants' daily schedules. This kind of technology has been already developed within the HCI community: for instance, Shahid et al. (2016) designed a mobile application to support autistic students in reminding their activities. The remaining participants agreed with H4, further specifying how such an application should be less invasive as possible. H1 explained that most of the reminders available on a mobile phone are barely bearable for an autistic individual: sounds, vibrations, even tactile feedback might hurt their "sensorial sensitivity", in H4's words. An opportunity for designing these reminders, then, would be to rely on glanceable (Consolvo et al., 2008; Goueveia et al, 2016) or peripheral (Bauer et al., 2012) displays, which might convey important information, as well as instructions and recommendations, in a glance. Participants promoted this kind of solution, specifying that displays should not call for attention, but simply visualize that a state has changed, or that a certain lapse of time has passed since a specific action.

By being asked to respond to the spatial agenda we defined, participants expressed their enthusiasm for the concept; at the same time, they proposed novel features to enrich it. These primarily concerned the aforementioned desire to occasionally shake the crystallized space, without being overwhelmed by the anxiety that is brought on by novel situations. Participants proposed to merge the spatial agenda with a "task agenda", listing the activities that they have to perform during the day. In other words, each space should be connected with the tasks that have to be accomplished in there, allowing the user to easily configure her daily program. While a breakdown in the spatial routines might be addressed by recommending an alternative path that allows for a quick recovery of the usual route, breakdowns in activity routines should suggest alternatives that open possibilities for action. H3, for instance, stressed that "*If I had had a tool prompting something to do in the environs, based on my interests and tastes, exactly specifying how to reach that place, how to reschedule my day, and how to join the meeting afterwards, I would haven't been there for all that time*".

A spatial-task agenda, therefore, may propose location-based opportunities when something unexpected happens, on the basis of the user's daily plan, interests, and current location, as well as instructions to rearrange her daily schedule: the precision and meticulousness of the provided instructions (literally step-by-step) could, in the participants' opinion, reduce the anxiety of diverting from their prearranged plans. For example, it would recommend an exhibition to H3, clearly specifying the transportation means to be taken, the travelling time, the time available for the visit, and the path to joining the meeting from there.

6.2 The safe space: Bounded spaces might separate "us" from "them"

All the participants reaffirmed the importance of the safe space, confirming home as the secure place par excellence. However, during the group discussion, they provided a nuanced picture of this kind of spatiality, pointing to its drawbacks, as well as its positive characteristics. H4 well explained how the attachment to a secure place may conceal potentially negative side-effects: "*Most of us have a tendency to withdraw in our homes, because we find them reassuring. But this is not always a good thing... It's the only place where I really feel safe, where I'm completely comfortable, but... I can stay for days in there without going out, and sometimes it seems to me more a prison than a shelter*". H1 agreed with H4's words adding that: "*I could stay at home for weeks without having the need of seeing someone or going out, and the more I stay in there the more I'd like to remain. I think that this isn't positive for us, sometimes we have to go out, even if we don't want to*". During the discussion, the majority of the participants (4 out of 5) became aware of how "home" has multiple meanings and may elicit ambivalent attitudes, unveiling that the safe space might become a "bounded space" that separates autistic individuals from the rest of the world, risking to confine them to a "*completely predictable and isolated place*", as H5 emphasized.

The "second nature" of the safe space yielded the desire to design instruments capable of "pulling" autistic people out of their houses. To this aim, participants agreed that technology should act upon motivational mechanisms, without using coercion. Among the different concepts discussed during the session, they believed that a game frame could have the most effective outcomes. H1 recalled the Pokémon GO phenomenon, envisioning a similar design to help autistic individuals search for places "out there". The others affirmed the importance of blending the game into real life situations, without separating it from everyday activities.

Serious games have been used to deliver interventions for autistic individuals (for a review see Zakari, Ma, & Simmons, 2014). However, this kind of game is separated from people's daily tasks, creating a confined environment where players may experiment and learn something that could be transferred to real world situations only afterwards. Gamification techniques, instead, defined as the use of game elements in non-game contexts (Deterding et al., 2011), match better with the participants' concept of embedding the gameplay within daily living. Gamified systems have been designed for a variety of purposes, e.g. to change the users' behavior (Rapp, 2017b, 2017c), but have rarely been employed in autism. Actually, gamification might foster a person's intrinsic motivation (Rapp, 2017a) and thus can be used for stimulating her to go "into the world". For example, as H3 emphasized, a "reward system" could motivate them to go to certain places at specific moments of the day: however, participants agrred that this kind of applications should carefully select such places, as to not jeopardize their sense of safety.

Since this suggestion paralleled our design concept of a system addressed at recommending safe spaces, we introduced it to them, highlighting how such secure places could be mapped through crowdsourcing. All the participants welcomed the design, and reaffirmed the importance of the sensorial component of the suggested places. Sensitivity to sensorial stimuli widely varies from individual to individual, they emphasized, and this "map" should rely on a large array of "reviews" to satisfy the autistic people's idiosyncrasies. For example, a user might rate her idiosyncratic sensorial aversions and preferences with reference to the physical characteristics of places (e.g., in terms of temperature, brightness, noise). Then, the map could allow people to rate places along these dimensions as well, so that they can be matched with the sensorial preferences of each user, and then prompted as geo-localized suggestions.

However, the idea of solely relying on autistic individuals' efforts to populate this kind of map encountered a skeptical reaction. First, as H1 noticed, autistic individuals' endeavors might not be sufficient to overcome the "cold start" of a crowdsourcing application. Second, the theme of "social inclusion", which had already been pointed out by H4 during the interviews, re-emerged here. From H5's point of view, to rely exclusively on the autistic people's endeavors might increase their desire to retreat in their communities: "*we exclude the others by believing that we are something special*", H5 said. H6 and H3 agreed, emphasizing the closure of the Asperger's community.

This hints to how inclusion dynamics are a matter not only of not being viewed by neurotypical individuals as different, but also of perceiving themselves as integrated into the wider world. Using a crowdsourcing system exclusively addressed to autistic people could strengthen the separation between "us" and "the rest of the world", as participants noticed. A "social safe space", that of the autistic community, might then have its dark side as well: it can produce a bounded space, separating instead of safeguarding, like a physically safe space might isolate rather than protect. All the participants agreed that the involvement of people not directly belonging to the "autistic circle" could instead provide a useful contribution in reducing the distance between "us" and "them", by making all the crowd workers contribute toward a common goal. This could create a neuro-shared space where people with autism and neurotypical individuals may collaborate (Bertilsdotter Rosqvist , Brownlow & O'Dell, 2013).

Hong, Gilbert, Abowd, and Arriaga (2015) showed that crowdsourcing can generate extremely fast and direct answers from a diverse set of "out-group" responders, who might provide advice at least as good as that by members of a dedicated autism community. They stressed that autistic individuals can benefit from obtaining diverse perspectives from neurotypical responders like friends, relatives, friends of their parents, and volunteers. While Hong et al.'s (2015) work used crowdsourcing mainly as a way to provide informational or emotional support for specific on-thefly problems (e.g. schedule planning, physical or mental health habits, school, work and professional life), here the suggestion is to exploit it as a means to permanently map places suitable for the autistic individuals' needs of safety and comfort.

To summarize, whereas a game logic could motivate autistic individuals to leave their safe space, an open crowdsourcing process could ensure that the suggested places would meet their expectations of safety and comfort, without enclosing them in a bounded space.

6.3 The social space: From social competences to social relations

When we described our notion of social space, all participants agreed that dealing with social competences is paramount in their everyday life. They confirmed that this need actually emerges in the proximity of specific places where social interactions are required. Nevertheless, three participants pinpointed that our conceptualization looks at this phenomenon through an excessively instrumental lens. It is true that the lack of social skills undermines their capability of acting in the world, and that a support for accomplishing their "social tasks", as the scripts in our design concept did, would greatly improve their life. But it is also worth noticing that this "incapability" jeopardizes their social networks, reducing their opportunities to know new persons and develop relationships. In the participants' perspective, places are not only tied to the social competences needed to deal with mundane activities, but also to the interpersonal connections they would like to establish.

H1 expressed the need of social interaction with other people: "*Sometimes I pass by a cinema, and later I'd like to see that movie, but I can't find anyone to go with me, I don't know how to approach people, how to ask someone out*". H5, instead, has a deep aversion towards other persons, but she explained that "*Knowing that someone else is visiting a particular exhibition could push me to go there... I mean, I can do a lot of things alone, but sometimes I don't want to, or there are things that you cannot do alone, for example, dining in a Michelin Star restaurant: I can dine alone in a fast* *food or a pub, but not in there*". The social space, therefore, does not only point to the need of acquiring social skills to accomplish a momentary task, like interacting with an employee to send a mail in a post office, but also embeds a desire for connectedness.

Talking about the social space the participants envisioned features that could allow to seek suitable companions to satisfy interests and share experience. They further stressed the idiosyncratic nature of autistic condition, emphasizing that each individual has her "social preferences", which are meant more as compelling needs than arbitrary tastes. H5, for instance, specified that she can't stand a "talkative profile": therefore she should be able to choose only "*those that meet my requirements*". Whereas participants like H1 reported a preference for Asperger persons, sharing the same difficulties and therefore capable of better understanding how he feels, others (3 out of 5) reaffirmed the need to break the barriers that separate the autistic community from neurotypical people. H3 mentioned the idea to rate and review the users to be encountered in order to know whether they can meet her expectations. This would also reduce the uncertainty yielded by a novel encounter.

As a result, participants proposed a design capable of putting users in contact with "similar" individuals, when they are close to places in which they might satisfy their interests, whereby the concept of similarity was referred to like-mindedness rather than to the autistic condition. To this aim, designers might look at techniques employed in social matching systems: these systems build user profiles, compute the matches, and recommend individuals to one another (Terveen & McDonald, 2005). Burke, Kraut and Williams (2010) suggested employing reputation systems to deal with issues of trust when autistic people meet online. These could also be used to rate or describe potential "friends" with whom to share interests and experience.

6.4 Reflecting on autistic spatiality

Our conceptualizations based on the interviews' findings, and further enriched by the insights emerged during the design session, attempt to describe the features of the autistic subjective space. This space seems permeated by overwhelming sensory stimuli and perceived as potentially dangerous: the autistic space narrows the "comfort zones" to circumscribed well-known areas, forcing the autistic individual to stick to rigid spatial routines. The fixity and narrowness of this kind of spatiality, nevertheless, are perceived as limitations: autistic people sometimes yearn to slightly divert from their habits and plans in order to satisfy momentary needs and interests, provided that such changes do not jeopardize their sense of safeness. Moreover, the autistic persons' space appears to incorporate their social expectations concerning the skills required to both accomplish everyday tasks and establish interpersonal relationships, being further characterized by a sense of inadequacy that undermines their opportunities for action. These elements all relate to the difficulty in dealing with the uncertainty that autistic individuals experience in their daily living. Table 1 provides a summary of the results of the two studies, as well as of the design suggestions developed.

Interviews			
Themes	*Findings*	*Autistic spaces*	*Design suggestions*
Spatial routines	Participants stick to rigid spatial routines to cope with anxiety yielded by uncertain "spatial situations". High functioning / Asperger participants use technology to cope with anxiety generated by	The crystallized space is characterized by fixed lines corresponding to the autistic people's spatial routines. The disruption of the crystallized spaces may generate anxiety and panic in autistic individuals. Technology may help them preserve	A spatial agenda in which the user might insert her habitual routes onto a map and which helps her recover the habitual path when she gets lost. A route composer based on images to plan travels,

	traveling to unknown places.	the integrity of its “fixed lines”.	favoring the recollection of the pre-planned path.
Controlled environments	Participants consider secure the environments where they can exert control. Participants exhibit a strong sensitivity toward physical sensations, which nonetheless is highly idiosyncratic. At home participants can exert total control and project their interests upon the environment.	The safe space is an environment where an individual can control the surrounding context and project herself onto it. The space is safe when the sensorial stimulations match the idiosyncratic preferences and aversions of the autistic person and when it reflects her interests, personal histories, and past experiences	Crowdsourcing populating urban maps with highlights, and reviews, specifically addressed to autistic individuals, signaling “safe places” in the city.
Social competences	Participants have difficulties in understanding others intentions. They tie each place they visit to the social competences needed to interact with others there.	The social space is the space where social competences are intertwined with the environment.	Geo-localized scripts and scenarios describing social interactions and how they typically proceed within a certain place, in order to mitigate the uncertainty about the social interactions that happen in that place.
Design session			
Themes	*Findings*	*Autistic Spaces*	*Design suggestions*
Spatial routines are tied to everyday activities	Participants have difficulties in planning their daily tasks. The places participants visit during the day are connected to the activities they have to perform, and such activities are not easily modified.	The crystallized space is strictly intertwined with the activities performed in there.	A spatial-task agenda that proposes location-based opportunities when something unexpected happens, on the basis of the user’s daily plans, interests, and current location, as well as suggestions to rearrange

			her daily schedule.
Bounded spaces might separate “us” from “them”	Participants tend to remaining at home the whole day: this attitude can persist for days. Participants claim that their own feeling of being special may lead them to exclude neurotypical individuals.	The safe space may be a “cage”. The safe space may be represented by the autistic community as well, which can separate itself from the neurotypical world.	Gamified applications capable of pulling autistic people out of home. “Open” crowdsourcing processes allowing for the creation of maps that are safe from the sensorial point of view.
From social competences to social relations	Participants want to establish and develop social relations.	The social space is also tied to the interpersonal connections autistic people would like to establish.	A social matching system that favors the encounters among autistic individuals.

Table 1. Summary of the main findings, spaces' features, and design suggestions of the interviews and the design session

Building on top of these findings and fully embracing the phenomenological take on autism that we decided to adopt, we want now to move to outline further, and more general, design considerations: the suggestions described below could then be used to guide the design of any tool addressed to autistic individuals, even beyond the spatial domain, opening opportunities for future research.

First, technology should reinforce autistic people's perception of safety and, at the same time, reduce the sense of inadequacy, which, as we noticed in our study, affects their interpretation of reality. Design might give the perception that everything can be recovered at any time, no matter what unexpected events may occur, both in the real and in the digital world: this would allow the autistic individual to act with a higher degree of freedom, pursuing her interests and adventuring out of her fixed routines. This goes along with the idea of empowering autistic individuals, rather than substituting or compensating for their alleged lack of skills.

Second, design should reduce the sensorial overabundance that may increase autistic individuals' sense of discomfort. Mottron and Burack (2001) described autism as characterized by an enhancement of sensorial and perceptual performances resulting in the capture of attentional resources. This might yield a fragmented perception of the world, since autistic individuals seem to have difficulties in integrating more than a single type of perceptual attributes into a meaningful perception (Bertone, Mottron, Jelenic, & Faubert, 2003). The overwhelming sensorial space might have consequences on how interfaces are designed, since, as we found in our study, different autistic individuals might prefer specific modes of interaction in accordance to their specific modes of perception; otherwise, they may be disturbed and confused by different design elements (e.g. sound or tactile alerts, colorful maps, etc.). This also stresses the role of the body in shaping autistic cognition, suggesting the need to further investigate how sensorial capabilities affect the autistic person's body schemata, i.e., how she perceives and represents her body and how this is connected to the world. In fact, HCI research highlighted that body experience is crucial to how we construct meaning (Dourish, 2001; Kirsh, 2013), an issue which is also discussed in the cognitive sciences (e.g. Johnson, 1987; Brizio & Tirassa, 2016) as well as in artificial intelligence (e.g., Harnad, 1993; Agre, 1995). In this perspective, autistic people who are more sensitive to tactile stimulations could understand their body and the world differently from others, more sensitive to the visual channel. However, despite the body of work that has explored how people with cognitive disabilities interact meaningfully through the way the body moves, e.g. in severe dementia (Kontos, 2005; Lazar et al., 2017), there is still a lack of research on embodiment and autism, e.g., on how bodily features like the variable sensitivity of the different sensorial pathways may impact on the autistic representation of the body and the environment.

Third, despite the autistic people's tendency to withdrawal from social relationships, design should offer possibilities to socially connect. The autistic space is often characterized by a sense of isolation. Technology might help autistic persons break the boundaries that separate the neurotypical world from the neurodiverse one, which often rejects the former similarly to how “normal individuals” distance themselves from “the others”. This rapprochement could be achieved by using technology to support cooperation between the two worlds, e.g. through shared tasks and common goals, or to provide opportunities for people to meet. Furthermore, a phenomenological perspective investigates how different sensorial and interpretative experiences may contribute to design. Cooperation between individuals with and without autism might be fostered by inserting them in a world that both can share, for instance by creating drawing activities where they might communicate without relying on strict social rules. Framing design in a perspective where technology is used to value a diversity of subjective experiences, instead of forcing users to participate to structured activities requiring specific skills and social competences proper to the neurotypical world, might increase autistic people’s participation in shaping the instruments they use and the world they live.

6.5 Reflecting on designing with autistic individuals

As a conclusion, we want to highlight some reflections about designing with autistic people. One of the challenges we faced during the interview and the design session was to make the participants comfortable. As Çorlu et al. (2017) noted, participants with autism may act hesitant, distressed and anxious behavior when immersed into unfamiliar, unexpected contexts, environments, and materials in HCI studies. We tried to tune the external environment where the interview and the design session took place according to the participants’ preference in terms e.g., of brightness. The design session was more difficult in this regard because a compromise had to be found between different needs which, as we have seen, could be highly idiosyncratic. On the other hand, the interactions between the researchers and participants during this session were eased by the fact that participants already knew both the researchers and the goal of the research, which allowed for a friendly and informal climate. We think that it is important to develop a relationship of trust between the autistic participants and the researchers: as long as such relationship develops autistic people become keener on exposing themselves. Another point is that all the steps of the work should be made clear in advance. This allows participants to reduce the anxiety that results from the uncertainty of the context and the interaction. We also specified that they could leave the interview and the design session whenever they wanted, so to make them feel free and unconstrained by the ongoing social situation. In sum, we found that autistic participants benefitted from a "preparatory stage" whereby they could become familiar with both the researchers and the environment: a suggestion, therefore, is that researchers should not start the interview or design session abruptly, but give the participants all the time they need to acclimatize (and this may vary widely depending on the participant).

Still another point is related to the conduction of the interview, and the extent to which it should be structured. Again, this greatly depends on the specific participant. A minority of our participants tended to stop immediately after having precisely responded to our question, never wandering off and only describing topics directly hinging on the original question. With them, it was useful to carefully specify all the information we wanted to gain, possibly asking for further clarification of some details of their responses. Other participants, instead, tended to lose the focus of the answer, apparently unaware of the researchers' verbal and non-verbal attempts to refocus the discussion on the topics of interest. In this case, it was helpful to be completely explicit about what was or was not interesting to the scope of the research, articulating what kind of information we expected from the participant.

Finally, during the design session, it was difficult to make all the participants participate equally. This is a common issue of any design or focus groups, but we discovered that dealing with autistic people requires a special attention in the management of turn taking. We found benefits in structuring the conversation with (smooth) rules for expressing opinion, e.g. asking the participants to raise a hand when they wanted to intervene, or making the order of the contributions explicit, so to let everyone express their opinion about the topic at hand. The idea of making the participants work alone at first and then starting the collective discussion immediately afterward worked well, as this allowed everyone to present her ideas and to comment upon those of the other participants, thus giving a clear and predictable structure to the interaction and anchoring the discussion to clear starting points.

7 LIMITATIONS

One limitation of our work is that we did not involve a group of neurotypical individuals to compare the experience of autistic participants with those of others to highlight the unique aspects of autism. This somehow undermines the possibility of claiming that what we outlined in this work represents unique and idiosyncratic needs of the autistic population. However, this can be mitigated by the fact that the need we found underlying all the themes we described, namely that of coping with uncertainty, is well documented in the autistic literature, which highlights its idiosyncratic nature in reference to the normotypical population (Van de Cruys et al., 2014). An interesting result of this study is that this compelling need, which may yield anxiety and bewilderment if unsatisfied, takes place within a spatial context and is explicated in the autistic individuals' spatial routines as well as in how they appraise the environments they inhabit. Another point is that all the participants affirmed the idiosyncratic nature of their ways to live spatiality. This may be due to their "pride" in belonging to a "special" community, as we have seen above. However, all the participants showed to have reflected upon their condition and how it differs from that of the neurotypical population, developing an awareness of its weaknesses and strengths. Thus, the emphasis we put on the peculiar nature of certain spatial needs comes directly from the participants' perspective, which stressed how the "degree" of certain aspects of their experience was different to that of neurotypical individuals (e.g. the higher fixity of their routines, of their anxiety when something unexpected happens, of their willingness to stay at home, and so on).

Another big challenge for us was to do justice to the richness and complexity of the participants' spatial experience with the methodological tools we employed. We relied on their verbal reports and their cognitive representations of the space they inhabited, but we were unable to interview them "in situ", e.g. by using shadowing techniques (Gill, Barbour, & Dean, 2014). This would have allowed them to account for their spatial practices in their original context, yielding a more ecological approach. However, this would have had other problems, e.g. about privacy, or a feeling to be constrained into a continuous social interaction (with the researcher), which would have made them uncomfortable. In fact, most of them reported suffering from being observed in what they do, because this makes them feel caged within a situation that continuously demands unforeseeable social competences.

8 CONCLUSION

In this article we explored the representations that autistic individuals have of home and of the urban spaces, and the ways and needs they have to live and move within them. The interviews and the design session helped us understand how these persons conceptualize the spaces in which they live as well as the barriers they encounter in the urban environments. This allowed us to identify three kinds of spaces that characterize their life.

The *safe space* practically identifies with home, a place where autistic individuals are sheltered from the social and sensorial overload of the external world and of which they feel they have control: this space, however, can turn into a bounded space, isolating the person and separating her from the rest of the world. The *crystallized space* consists of the spatial routines that autistic people have, from which they find it anxiogenic to divert: such routines are intertwined with their everyday tasks, which may become unmanageable when something unexpected occurs. The *social space* lets emerge the social competences that are inscribed in each space of our everyday living, which can be managed by autistic individuals only with enormous efforts, to reduce which they devise suitable, albeit comparatively rigid, strategies; this space exposes their need of connectedness as well, making visible their desire to share experiences and interests.

As a final point, we want to stress the qualitative nature of our research and the value that a phenomenological approach may bring to the research community. Rather than seeking generalizations and allegedly objective validations of our study findings, we aimed at conveying the participants' experience through a first-person perspective, as well as developing our conceptualizations in collaboration with them. We hope that the findings we have outlined in our work could represent a useful integration to those that can be achieved by adopting the more classical medical model, offering an additional perspective grasping the autistic individuals' lived experience.

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APPENDIX

In this appendix we provide all the drawings made by participants. Figure 5 lacks a map because one participant sketched his home neighborhood and the city center in a unique drawing (No. 6 in Figure 3, the home neighborhood is represented by the house on the left, whereas the city center is represented by the other buildings on the right).

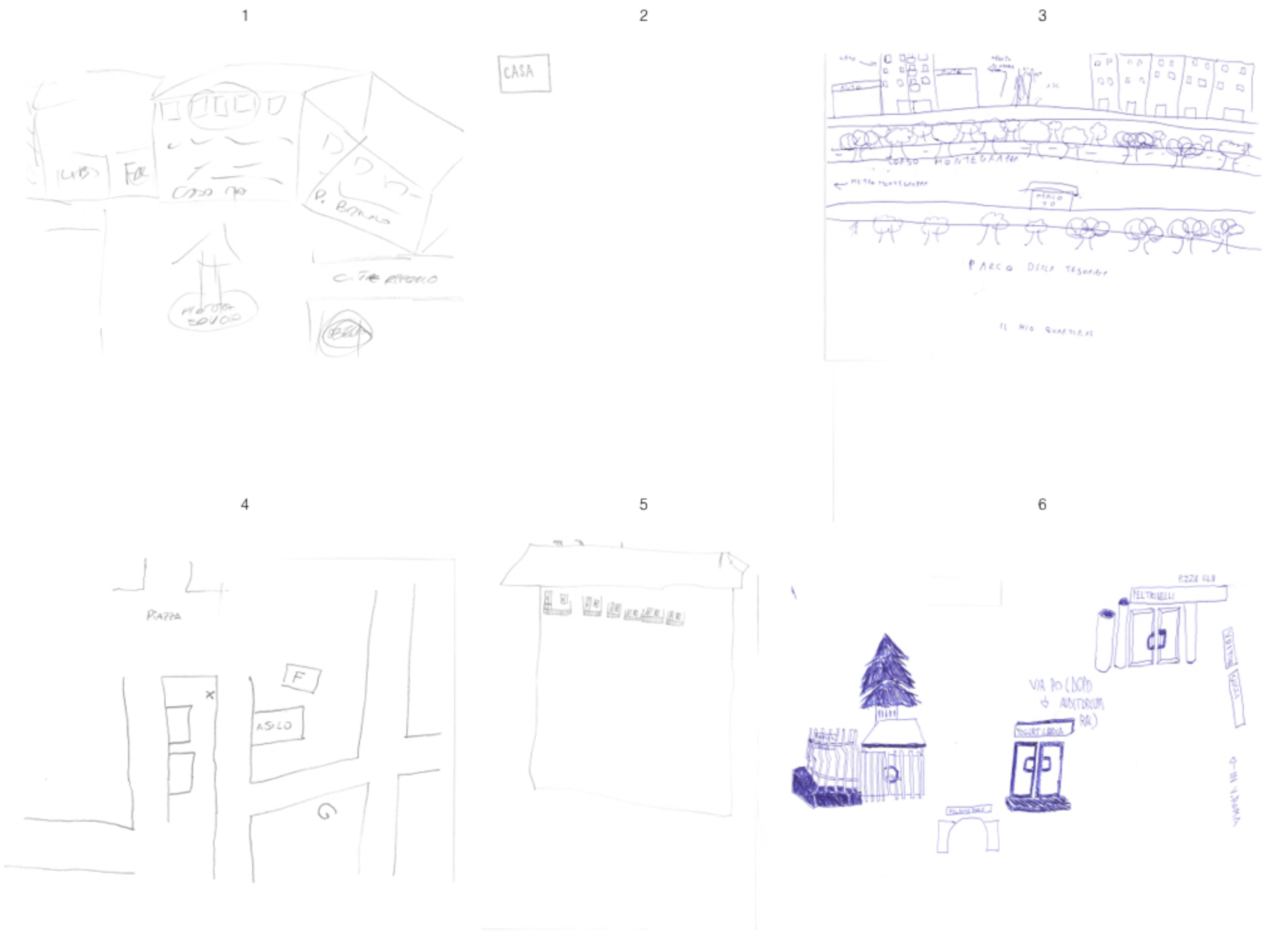

Figure 3. Maps of the home neighborhood of mid-functioning participants (group 1)

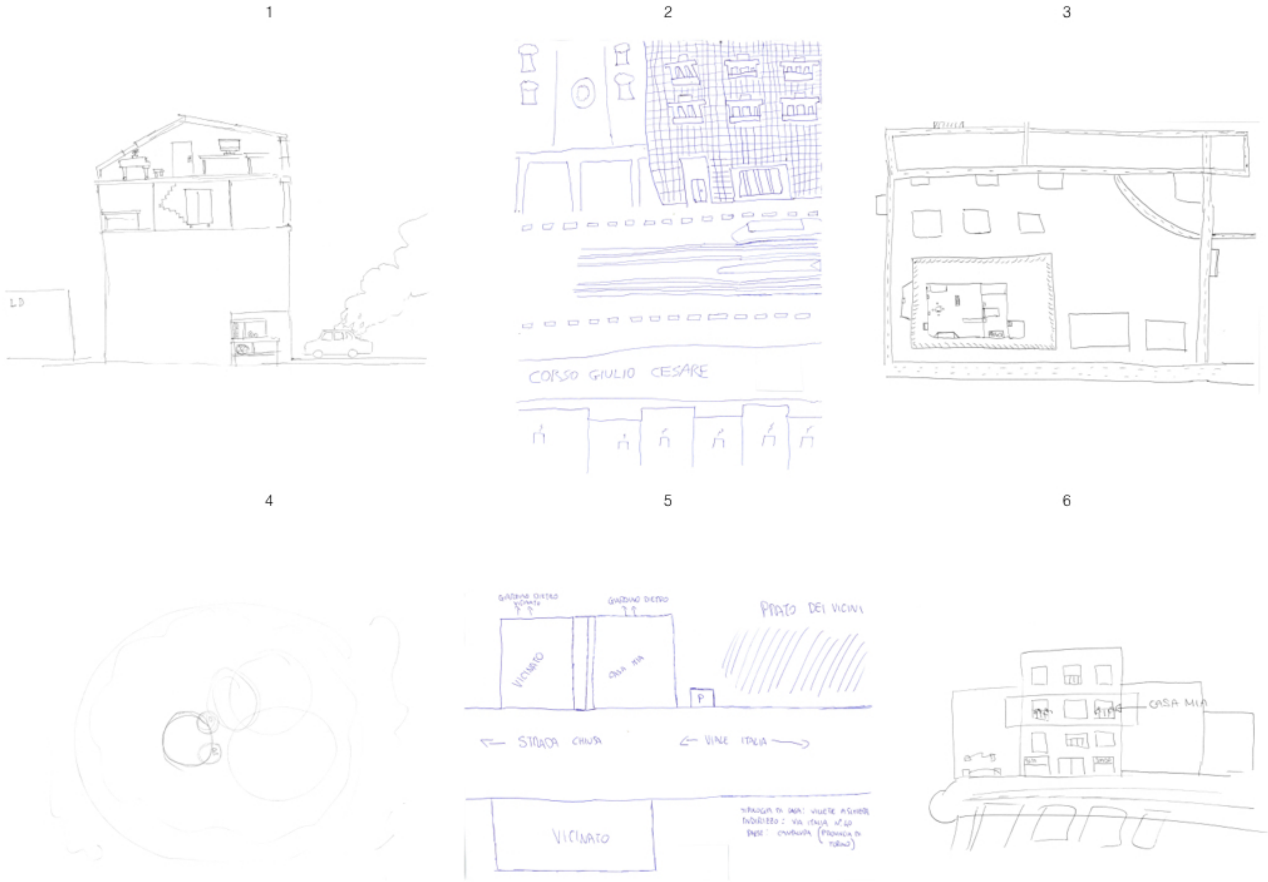

Figure 4. Maps of the home neighborhood of high-functioning/Asperger participants (group 2)

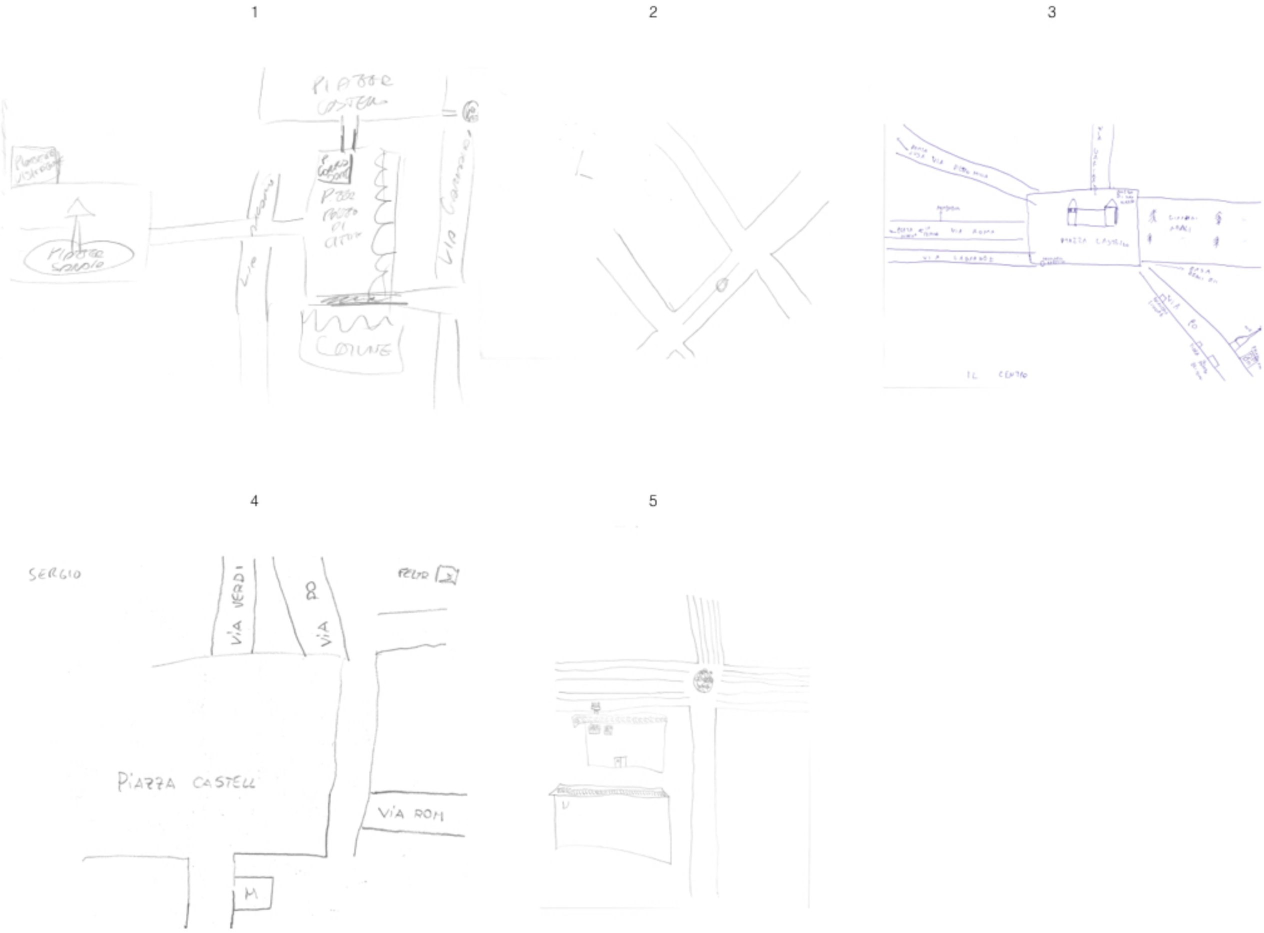

Figure 5. Maps of the city center of mid-functioning participants (group 1).

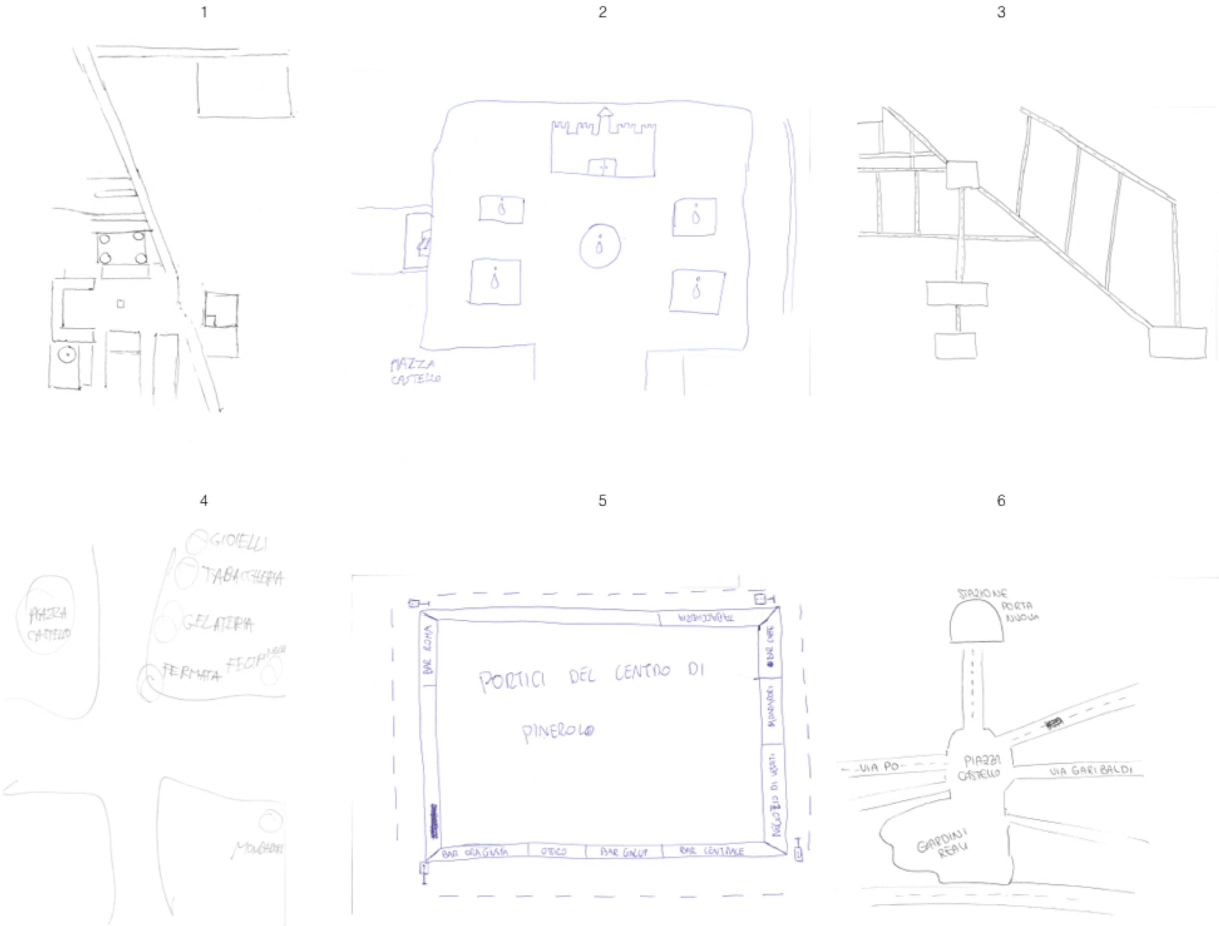

Figure 6. Maps of the city center of high-functioning/Asperger participants (group 2).