

State of the art

Technology at the service of a more inclusive society: innovative solutions dedicated to the mobility of ASD people

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Introduction

Nowadays, with the increasing growth of populations, mobility has become a constant axis of development. Cities put more and more effort in expanding their public transportation networks in order to serve the consistent flow of users and avoid traffic jams. Additionally, mobility must adapt to the challenges of the 21st century, like ecology, hence the development of alternate ways to get about.

However, mobility still fails to address the issue of inclusivity. An increasing population means an increasing number of people with disabilities or disorders, and some infrastructures are still not adapted to the special needs they may have. Modern constructions have started to evolve, specifically to be more accessible for deaf people, blind people, or wheelchair users.

But one of the disorders that stays under the radar when it comes to public transportation policies is Autism Spectrum Disorder (ASD). Given that it is an invisible disability, it usually goes unnoticed, even though it may cause numerous issues when using vehicles or public transportation. These issues should be investigated in order to provide solutions for the mobility of autistic people.

This document aims to understand the challenges regarding the mobility of the autistic community. First, we define what ASD is and what problems this community faces. Next, we focus on the specific issues regarding their mobility. Then, we take a detailed look at the existing solutions for autistic people. Finally, we analyze their limits and explore how future efforts should address these shortcomings.

1 Autism, a complex condition

As defined by the DSM-5, autism spectrum disorder is a complex neurodevelopmental condition that manifests itself in a wide range of challenges related to social interaction, communication, repetitive behaviors, and often, restrictive interests.

The World Health Organization estimates that approximately 1 in 100 children worldwide has ASD. However, this figure may not capture the full extent of ASD prevalence due to underdiagnoses, which we will further explain in the report. It's important to note that an observed increase in ASD prevalence over time may be attributed, at least in part, to factors such as improved awareness, expanded diagnostic criteria, and increased access to services rather than a true rise in the prevalence of the condition.

Concerning the official diagnosis, there are several recurring themes. First and foremost, autistic individuals often struggle with social interactions. They may find it difficult to initiate or sustain conversations, understand non-verbal cues like facial expressions and body language, and may have trouble forming and maintaining relationships. This comes hand in hand with communication challenges, which can vary widely. Some individuals may have delayed speech development or may never develop spoken language. Others may have a rich vocabulary but struggle with pragmatic aspects of communication, such as understanding sarcasm or maintaining appropriate eye contact.

Routine is of great importance to a lot of autistic individuals. It helps maintain a sense of safety in a constantly unsafe world. Furthermore, many engage in what is known as stimming, or self-stimulatory behavior (like rocking, hand-flapping, and nail-biting), that helps them soothe emotional and/or sensory overloads. On that note, autistic individuals may be hypersensitive or hyposensitive to sensory stimuli. They may find certain sounds, textures, or lights overwhelming, while others may not register sensory input as much as expected.

Another behavior that characterizes ASD is special interests, referring to a particular topic, subject, or activity that captures someone's attention and enthusiasm to a significant degree. The number of such interests varies from person to person. Some may stay engrossed by the same topic for years, while others may jump from special interest to special interest every few months. These special interests often involve periods of hyper-focus, which result in a great expertise on said domain from the part of the autistic individual.

The autistic experience is not a monolith. It depends on many factors beyond the mere criteria of the diagnosis itself. To live as an autistic person is, before anything else, a personal experience that cannot be reduced to a series of symptoms.

1.1 Co-occurring Conditions and Mental Health Challenges

Over time, the diagnostic criteria for Autism Spectrum Disorder have evolved. The introduction of the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) in 2013 marked a significant shift, consolidating previous separate diagnoses like autistic disorder and Asperger's syndrome into a unified diagnosis of ASD. This transition has had notable effects on prevalence rates and diagnostic approaches. Despite progress, research on ASD remains relatively recent, indicating that much remains to be discovered about the intricacies of this condition.

Autism is not classified as a mental health disorder, yet a significant proportion of individuals on the autism spectrum grapple with mental health challenges. Elevated rates of anxiety and depression among individuals with autism have been linked to various adverse outcomes, including diminished life satisfaction, heightened social challenges, feelings of loneliness, and difficulties with sleep, such as insomnia. These struggles can have profound and devastating consequences. Studies indicate that individuals on the autism spectrum are considerably more prone to contemplating, attempting, and tragically, dying by suicide compared to the general population.

ASD often co-occurs with other developmental and psychiatric conditions. Specifically, 84.1% of the ASD children met DSM-III-R criteria for at least one anxiety disorder, 25% met criteria for Obsessive compulsive disorder[1], 29.2% suffer from social anxiety disorder, 28% have ADHD diagnosis[2] Furthermore, "some genetic disorders are more common in children with ASD such as Fragile X syndrome, Down syndrome, Duchenne muscular dystrophy, neurofibromatosis type I, and tuberous sclerosis complex. Children with autism are also more prone to a variety of neurological disorders, including epilepsy, macrocephaly, hydrocephalus, cerebral palsy, migraine/headaches, and congenital abnormalities of the nervous system." [3]

1.2 Recognizing Biases and Addressing Disparities in Healthcare

Autism is a complex spectrum disorder characterized by a diverse array of symptoms and severity levels among affected individuals. This inherent variability poses considerable challenges in establishing clear diagnostic criteria, often resulting in misdiagnosis or delayed diagnosis. While the precise etiology of autism remains elusive, researchers suggest a multifaceted interplay of genetic and environmental factors contributing to its development. Consequently, the presentation of autism is highly heterogeneous, further complicating diagnostic efforts.

One of the fundamental difficulties in diagnosing autism lies in the overlap of its symptoms with those of other developmental disorders. Distinguishing between these conditions can be arduous, leading to diagnostic confusion and the co-occurrence of multiple conditions in affected individuals. Additionally, traditional diagnostic criteria have primarily been derived from research focused on male populations, potentially overlooking or misidentifying autism in females and individuals from diverse cultural backgrounds. Recognizing this bias is crucial in ensuring equitable access to diagnosis and support services.

Gender disparities in autism diagnosis are quite striking. The female-male diagnostic discrepancy underscores the importance of adopting culturally sensitive and gender-inclusive diagnostic approaches to capture the full spectrum of autism presentations accurately. Studies have indicated that females with autism may exhibit different symptom profiles or employ coping mechanisms such as masking to camouflage their autistic traits, further complicating diagnosis and intervention efforts.

Furthermore, disparities in autism diagnosis extend beyond gender to encompass race, ethnicity, and socioeconomic status. Research has shown that children from minority and economically disadvantaged backgrounds may experience delayed diagnosis or reduced access to support services, perpetuating systemic inequalities in healthcare provision. Cultural stigmas surrounding neurodiversity and mental health also play a significant role, influencing individuals and families' willingness to seek diagnosis and support.

Despite the progress in the medical domain concerning autism, certain phenomena remain poorly researched. Autistic masking, for instance, is a very common phenomenon observed in individuals with autism wherein they suppress or conceal their autistic traits in social situations to blend in or appear more socially adept. While masking may facilitate social interactions and mitigate stigma, it can exact a toll on mental well-being, contributing to heightened stress, anxiety, and feelings of alienation. Research suggests that masking is more prevalent among females with autism and may contribute to underdiagnosis or misdiagnosis, highlighting the need for greater awareness and understanding of this phenomenon[4].

Addressing the challenges associated with autism diagnosis and support requires a multifaceted approach that acknowledges the diverse needs and experiences of individuals across different demographic groups. Failure to recognize and address these disparities may perpetuate inequities in healthcare provision and exacerbate the impact of autism on affected individuals' lives.

2 Perspectives and Challenges Faced by Autistic Individuals in public Transportation

2.1 Encountered Challenges

Anxiety and stress are common challenges that autistic individuals face while using transportation on a regular basis[5]. Stress stems from the worry that they could commit mistakes when traveling, such as skipping important stops or not knowing if their regular transit plans will change. Their daily tasks become more challenging as a consequence of their elevated emotional state. Moreover, Autism Spectrum Disorder (ASD) may cause balance and motion sickness, sensitivity to noise in the surrounding environment, to tactile perception, lighting or smells. These appear as an additional barrier when using public transportation and make it frightening.

Many people with ASD feel forced to rely on parents and caregivers. However, another significant concern comes from this heavy dependency on family for transportation. This dynamic induces inconveniences and stress for both adults with ASD and their immediate support circle[6]. This reliance affects their autonomy but also has a broader impact on the convenience and flexibility of their everyday life. The phase of transition following school completion, usually around age 21, presents an additional set of difficulties. As school transportation and government support end, people with ASD and their families enter a world of newly discovered transportation complexity. Many individuals with ASD have limited walking skills, which makes it harder for them to get around freely in public places and increases their dependency on others for transportation. The safety concerns associated with driving are alarming, particularly from the perspective of concerned parents, despite an expressed interest on the part of autistic individuals in obtaining a driver's license for the sake of independence.

Furthermore, specific worries about crowding and safety are real roadblocks for people with ASD to use public transportation[7].

2.2 Current Adaptations

To mitigate those difficulties, people with ASD use a variety of adaptive techniques when navigating public transportation.

One of the most widely spread strategies is avoiding public transportation completely and using their support networks, which include family and caregivers[6]. This approach helps to reduce stress and anxiety normally associated with travel. However, as explained above, it makes them strongly dependent on others to travel.

Another important strategy is to carefully plan their route in advance[5]. This helps people with ASD to know where to go and anticipate changes, which gives them a sense of control. Other tactics used to reduce stress when using public transportation include avoiding crowded areas or selecting off-peak hours.

Rather than using public transport, some individuals find comfort in utilizing bicycles for short-distance travel[7] for more autonomy. They usually lean towards self-reliance and express a preference for drawing on personal coping mechanisms rather than seeking external help. Another effective coping mechanism consists in setting up routines[7], which reduces anxiety by introducing familiarity into their travel experiences.

The use of technological tools, such as smartphone applications, plays a crucial role in helping individuals with ASD. It makes it easier to plan paths and to check transportation schedules. It also enhances their autonomy during travel. To manage sensory challenges, music, and headphones provide them with a controlled auditory environment and relief from noise sensitivity[5].

2.3 Expectations and Foreseen Solutions

Individuals with ASD are subjected to high levels of anxiety whilst using transportation. In order to reduce the anxiety felt in transit, sensory-friendly measures specially tailored for them would be implemented[5]. These measures should include the selection of less noisy paths for transport or the installation of dedicated areas in waiting areas for people with sensory sensitivities. Straight-forward communication from transport companies would also reduce stress caused by uncertainty and randomness.

People with ASD would feel better if universal design principles were implemented in transport infrastructures[5]. It would facilitate access for everyone, disabled and non-disabled people alike, and improve public transportation for all users.

To help them gain independence in their daily transits, people with ASD expect new technologies to simplify their everyday life, for example, with dedicated applications that consider their personal needs. They would also benefit from training programs to help them navigate public spaces autonomously. Those programs would start during the school curriculum, and smoothen the transition between school and adult life[6]. Moreover, driver education programs should adapt to people with ASD and allow them to pursue their existing interest in driving[6].

Their requests finally regard the global awareness about ASD by setting up public education campaigns to enhance awareness about the characteristics of ASD. Those awareness campaigns would aim to facilitate social integration for adults with ASD[6]. They also want targeted training modules for transportation staff, like vehicle operators or front-line staff, to address issues specific to ASD more easily and increase understanding and assistance to people with ASD[5].

3 Proposed solution designs

Nowadays, the specific needs of people with ASD regarding urban transportation are increasingly being taken into account in the development of new technologies. To answer those needs, new solutions are emerging. These solutions can be divided into three groups, guiding assistance, urban planning and wearable devices.

3.1 Guiding systems

The aim of this solution is to guide the user from a point A to a point B with a range of parameters regarding the user's environment, mainly through a phone app[8][9].

The solution consists of guiding people with ASD towards transport centers and buildings[8]. The solution is implemented by an application on the user's phone which suggests a route respecting some criteria defined by the user. For instance, the user can select a route with fewer people or less noise. The idea is to locate autistic individuals in the area and guide them by giving them information on their phone. To locate the person, two approaches are considered. The first approach consists of using a semantic 3D model of the buildings and combining it with 2D-3D recordings of images to provide a 3D localization of the user. The second approach involves using sensors to locate a beacon generated by the user's phone. To achieve this, some researchers suggest using AI, which will use information based on surveillance cameras around the user[8]. This AI could be trained according to specific criteria, thus enabling people with ASD to have an itinerary adapted to their specific needs.

The other solution involves guiding people with ASD around the city[9]. This solution is also an app that the person can have on their phone. This application is similar to other guiding apps, but can take into account parameters such as gradient, length, accessibility and time. Using this information, it is possible to create different routes for each type of user. This would make people with ASD able to plan their routes accordingly to their needs.

3.2 Urban Planning

Urban planning gives the city a possibility to build its spaces to accommodate the citizens. This type of arrangement is permanent, and benefits the population as a whole rather than only targeting people with ASD, unlike solutions discussed before. No user action is required to benefit from urban planning.

The aim of this urban design is to make it easier for people with ASD to move around independently[10]. To achieve this, it is necessary to take into account the various problems that arise on the street and that the modifications to the layout must address. These include noise and regularly dangerous situations. To achieve this, the design proposes various solutions that can be used altogether. The first step is to define a route from a car park to a main point in the city. After that, one of the next steps is to reduce car traffic. It can be achieved by creating low-speed islands to discourage through-traffic, adding parking areas at the entrances of the neighborhoods, or reducing the size of roads in favor of pavements. Another step is to mark dangerous areas to make them easier to identify. This can be done by marking the regular route taken with a vertical line on the ground. In safe areas, the line is blue; in dangerous areas, the line is red, indicating that one should proceed with caution. The final stage presented involves using this route to create parks and quiet spaces, adding trees and benches to the city.

This type of development also benefits people without ASD, by improving the quality of life in the city[10].

3.3 Wearable assistive technologies

This type of technology is designed for autistic individuals as a wearable device. The goal of those devices is to improve the quality of social interaction for people with ASD by suggesting adjustments to their behavior.

The main idea is to correct the stereotyped behavior of individuals with ASD[11]. There are many types of devices with this goal in mind that cover a number of stereotyped behaviors. Here are some of the technologies:

Eye contact and Joint Attention: They are another key aspect of social skills training, especially for autistic infants and toddlers. The idea is to use mobile eye-tracking glasses mounted with a camera to automatically detect patterns of mutual eye-contact and notify the person with ASD if needed.

Proximity and distance: Autistic people have troubles knowing the right physical distance between individuals during social interactions. This technology evaluates the distance between the user and their interaction partner, and indicates whether or not it is a comfortable social space.

Atypical Prosody: The acoustic quality of an autistic person's voice and prosody can be unusual and can lead to a misinterpretation of a form of nonverbal communication (flat tone, loud voice). A system built on Google glasses called SayWAT constantly monitors the voice volume and pitch of users and provides alerts when atypicality is detected. They receive trigger alerts via plain text or animation with different colors depending on the severity of the situation.

Stereotypical Behaviors: This idea uses wireless Bluetooth accelerometers worn on the right wrist, back of the waist, and left ankle of a person in conjunction that recognize 7 types of stereotypical behaviors.

General Social Skills: Most existing WATs target one aspect of social interaction. The exception is MOSOCO (Mobile Social Compass), which targets a range of social skills and is built on the social compass curriculum. It includes 24 core lessons from basic non-verbal communication to more complex social problem-solving. It is a mobile application that augments a real life social situation and provides visual and verbal support.

4 The limits of the solutions

As we mentioned previously, numerous solutions exist in order to simplify urban transportation for people with ASD. However, nowadays, we do not yet have a perfect solution. Even though the existing solutions can help people with ASD, they all have multiple flaws. First of all, the resources are limited and not adapted to every person. Moreover, existing infrastructures are sometimes incompatible with newly found solutions, making it difficult to implement aforementioned solutions.

Furthermore, most solutions are not ideal because they force autistic individuals to adapt to neurotypical norms, instead of considering their real needs. We should instead turn our focus towards diagnosing autism better and earlier.

4.1 The existing solutions are limited

Despite great efforts to find suitable solutions, most of the existence ones are very far from being sufficient. A lot of autistic people can have trouble driving and most of them prefer to use public transportation[7][12], but the public transportation is still lagging behind with regard to certain issues. Indeed, most of the people with ASD feel anxious due to the stress of doing bad things, like missing their stop. Also, the noise, smell, light, and motion sickness can be trouble for them. But most of them still have confidence in their ability to use public transportation[5].

Another problem is the lack of accessibility of public transportation. This alternative is crucial for the mobility of people with ASD, but it exists numerous inequalities regarding its accessibility. For instance, suburbs and rural areas do not have as much public transportation as the center of a big city[6].

Moreover, the existing mobile apps to help to guide people with ASD in their city are not perfect and can be improved. Some of these apps are only available in one specific city, and their functionalities could be improved in order to be really helpful. For example, the application Viana+Acessível that we presented before (part 3.1) is only available in the city of Viana de Castelo, so people living in other cities cannot benefit from it. Also, this app does not have the possibility to choose a path made of multiple destinations, it does not use crowdsourced data, and it has no mention of public transport. In short, this app can be really helpful to people with ASD, but its accessibility is limited to only a few people, and it is a shame that it does not include public transportation, knowing that they are crucial for the mobility of people with ASD[9].

4.2 Some of the solutions could not be compatible with the already existing infrastructures

Some of the solutions to help people with ASD to walk around the cities consist of reorganizing them in order to have a better quality of life, like in one district of the city of Sassari, in Italy, which name is Sardinia[10].

Unfortunately, not all the cities in the world will agree to do all these reorganizations. The experimentation in Sardinia was made in a small district, but it would be difficult and expensive to apply this solution to the whole city, let alone a bigger one.

Moreover, in a city where most of the people drive by car and the road is already built, it may not be possible to reduce the size of roads in favor of sidewalks because it would cost too much money and most people would be against it. Besides, in some cities, it can also be complicated to build more quiet zones with trees, as they already have too many buildings and roads and there is no more space to build new parks. Building a quiet zone would imply destroying another infrastructure, whose owner would be against.

These solutions are interesting for future projects but cannot always be applied easily to all infrastructures.

4.3 Most of the solutions force people with ASD to adapt

A lot of technologies designed to help people with ASD are criticized because they force autistic people to adapt to the social norms we know instead of really helping them. For example, as mentioned in the paragraph 4.3, this article talks about numerous gadgets which have one thing in common: they see autism as a disability and help autistic people adapt to the social norms[13]. However, some autistic people prefer not to see it as a disability, but as a different way of behaving. Therefore, it would be better to have technologies to help them find their own ways of communicating with their partners.

4.4 The importance of the diagnosis

Another type of solution would be to improve the detection of ASD on the children. Like it has been described in the introduction, it is very important to detect this trouble the earlier that is possible. In this way, we can cite a solution which uses new technologies like VR. The idea is to make some games that will test the children, this includes tutorial levels, in-game day levels, mental stressor mini-games, and physical exercise mini-games[14].

This type of solution, unlike the other, will not directly improve the usage of transport for the person with ASD. But this can still be a great way of improvement that can be developed.

Conclusion

In conclusion, this state-of-the-art review highlighted the multiple difficulties faced by people with autism spectrum disorders (ASD) in navigating public transport systems. Whether it's increased anxiety, sensory sensitivities, dependence on healthcare providers or limited accessibility, the barriers faced by this part of the population underline the urgent need for innovative solutions to support inclusion and autonomy.

Existing accommodations, such as careful route planning and the use of support networks, offer partial relief but often come at the detriment of independence. What's more, while emerging technologies are promising for meeting specific needs, they are not without their limitations. From problems of compatibility with existing infrastructures to concerns about the imposition of neurotypical norms, the path to truly inclusive mobility requires a nuanced and comprehensive approach.

The solutions proposed, ranging from sensory-friendly urban design to wearable assistive technologies, offer a glimpse of a more inclusive future. However, their effectiveness depends on resolving key issues, such as resource limitations, infrastructure compatibility and the imperative of empowering people with ASD rather than imposing compliance.

In addition, the importance of early diagnosis and intervention is a crucial aspect that deserves attention. By taking advantage of innovative technologies, such as virtual reality-based diagnostic tools, we can identify ASD at earlier stages, enabling targeted support and interventions that can have a positive impact on individuals' ability to navigate the world around them.

As we move towards a more inclusive society, it is imperative to prioritize the voices and needs of people with ASD, ensuring that solutions are not only adaptive, but also empowering. By encouraging collaboration between researchers, policymakers and the autistic community, it is possible to harness the transformative potential of technology to create transportation systems that effectively serve all members of society, regardless of neurodiversity.

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