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ORIGINAL RESEARCH

Evaluating the effectiveness of an autism-specific public transport app for individuals on the autism spectrum: a pilot study

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ABSTRACT

Purpose: Autism is characterised by differences in social skills, limited communication abilities and repetitive behaviour, which often result in increased reliance on other people. Transportation is but one task that is commonly burdened on family members. Public transport is an inexpensive and widely available form of travel which facilitates independence. However, it presents unique challenges for individuals on the spectrum, as it requires complex skills including, but not limited to, understanding abstract information (e.g., maps, service schedules, etc.), problem-solving unexpected situations and timely management of transfers. As such, most individuals on the autism spectrum do not use public transport and have never considered using it. Here we evaluate the effectiveness of an autism-specific public transport app, OrienTrip, with autistic individuals and allied health professionals.

Methods: A total of 16 individuals on the autism spectrum (eight male and eight female participants) and 22 allied health professionals (19 females and three male participants) were recruited for the pilot study.

Results: We found that OrienTrip is effective in facilitating public transport use for autistic individuals. Individuals on the autism spectrum expressed their satisfaction with the app and agreed that it makes public transport easy to use. Similarly, allied health professionals also indicated that OrienTrip is helpful in assisting autistic individuals use public transport safely.

Conclusion: Our findings demonstrate that OrienTrip can be used to facilitate independent travel for individuals on the autism spectrum using public transport. This can improve community participation opportunities for autistic individuals, including enhanced education, employment and social outcomes.

➤ IMPLICATIONS FOR REHABILITATION

- Individuals on the autism spectrum heavily rely on other people, namely family members, for their transportation needs.
- Public transport is an inexpensive and widely available form of travel which facilitates independence; however, it presents unique challenges for autistic individuals, as such, most individuals do not use it or consider using it.
- In this research, we have developed and evaluated one of the first autism-specific public transport mobile apps that facilitates independent public transport use.
- This tool can improve community participation opportunities for autistic individuals, including enhanced education, employment and social outcomes.

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Introduction

Autism is a condition characterised by differences in social skills, limited communication abilities and repetitive behaviour, which often result in increased reliance on other people for everyday practices [1–3]. Transportation is but one task that is commonly burdened on family members [4–6]. Public transport is an inexpensive and widely available form of mobility [3], which facilitates independence and frees the burden of assisted travel [4]. It also has noted support among autism communities for its capacity to provide greater autonomy and improve quality of life [5–7]. However, this form of travel presents unique challenges for individuals on the spectrum, as it requires skills including, but not limited to, understanding abstract information (such as maps, service schedules, signs and landmarks), problem-solving unexpected situations, and timely management of transfers [4,5,8]. As such, we have developed a public transport trip-planner mobile application called OrienTrip, which was co-produced with autistic individuals, to make public transport use easier for people on the autism spectrum. Here, we evaluate the effectiveness and efficacy of OrienTrip through two pilot studies.

Community engagement, including education and employment, directly affects one's personal wellbeing, while participation in social activities has proven association with improved health outcomes [8,9]. Past studies have shown that community engagement correlates with improved happiness [10,11]. However, individuals on the autism spectrum have one of the lowest

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community participation rates amongst other disability groups [12–14]. For example, only 5.6% of autistic people have full-time employment two years after high school, and only 9.1% are working six years after graduation [14]. Similarly, more than 50% of individuals on the spectrum do not participate in education or employment in the first two years after high school, while more than 45% do not engage in any paid employment six years out [13]. Undoubtedly, lack of transportation is one barrier that affects community engagement for this population.

Most autistic individuals rely on family and friends for their transportation needs [4,7,15,16]. In fact, more than 80% of autistic adults depend on their parents to travel around the community [15], which often causes emotional and economical strain for both parties. For example, more than 72% of parents will forgo other activities to provide transportation for their autistic children. Similarly, more than 72% of individuals on the autism spectrum miss out on activities because the person responsible for their transportation is not available [6,17]. It has even been reported that some parents give up employment completely to support an autistic child [5].

Driving is a common mode of transportation but a complex task for many on the spectrum. Generally, people on the autism spectrum struggle to operate a vehicle due to an impaired executive function that causes inflexibility to routines, difficulty initiating new tasks, difficulty with transitions, inability to problem-solve, and reduced working memory [18–20]. In turn, these traits can affect one's ability to drive safely [6]. For example, it has been shown that people on the autism spectrum respond to hazards slower compared to those not on the spectrum [20]. Moreover, autistic individuals are more likely to become distracted by on-road elements such as billboards, advertisements and pedestrians [6], therefore, increasing the likelihood of traffic accidents. Although learning to drive can be a feasible achievement for autistic individuals, it is worth exploring other travel options such as public transportation.

Using public transport requires complex executive functioning and cognitive abilities. Notably, one needs to utilise and understand navigational artefacts including, but not limited to, maps, schedules, landmarks, signs and clocks to manage public transportation [7]. More than 50% of autistic individuals have reported difficulty in planning public transport trips [21], while more than 40% of people on the spectrum struggle to reach a transit stop without assistance [21]. Common irregularities in public transportation such as system errors, roadworks and unfavourable weather conditions can also result in excessive anxiety and stress [1,8]. As such, these factors can discourage many from travelling independently.

Despite these challenges, public transport offers unique benefits to individuals on the autism spectrum. First, it is an inexpensive travel option that can save individuals with disabilities over USD$4,500 a year on transportation [22]. Other studies have reported that parents spend more than USD$700 each month and over USD$85,000 in 10 years to cater to their autistic child's transportation needs [5]. Second, public transport is a preferred mode of independent travel by individuals on the spectrum. That is, people on the autism spectrum have reported that being able to use public transport improves their independence and quality of life [5,6]. Concretely, it has been shown that those on the spectrum who can travel alone are five times more likely to find and maintain employment than those who rely on others for transportation [23].

Finally, public transport aids personal health. According to the literature, a 40% decrease in car trips can significantly reduce risks of cardiovascular disease and type 2 diabetes [24]. As such, the resultant increase in physical activity, including walking and cycling, associated with public transport use can support general health [25,26]. Similarly, public transport has been shown to reduce emotional and economical stress through improved access to education, employment and social opportunities at an affordable cost [25].

OrienTrip

OrienTrip is a public transport trip-planning mobile application co-produced by autistic individuals to facilitate independent travel for people on the autism spectrum. Screenshots and description of OrienTrip are shown in Appendix A.

Five principles guided the development process. These are (1) safety, (2) increasing spatial awareness, (3) facilitating communication, (4) alleviating anxiety and sensory overload, and (5) simplifying trip planning.

Safety is a primary concern for individuals on the spectrum when using public transportation. Safety concerns include getting lost [14,27], boarding the wrong service [28,29] and being victimised [14]. In the literature, studies have reported that more than 40% of people on the autism spectrum have difficulties finding their way to bus stops without assistance [14]. Moreover, more than 43% worry about how other passengers will treat them while travelling [14].

Limitations in spatial awareness also pose barriers for individuals on the autism spectrum. These abilities include finding the correct stop, boarding the correct service and disembarking when appropriate. One previous study reported that more than 26% of autistic people do not use public transport because it requires too many transfers [14]; this is can be indicative of the difficulties faced in terms of time and route management. Further, the same survey revealed that more than 16% of autistic people do not use public transport because they have difficulty boarding and disembarking services [14].

Differences in communication and social skills—a core characteristic of autism—can also be a barrier in using public transport, as it requires dealing and being in the presence of large groups of people. Notably, travel demands the ability to communicate with the driver (e.g., when buying a ticket), interact with other passengers (e.g., asking them to remove their belongings from a seat before sitting down), and ask for assistance when required [5,30,31]. As such, the inability to clearly and concisely converse with people can cause significant anxiety and make public transport difficult to navigate [32].

Anxiety, a comorbid condition with autism, is expressed by the disproportionate fear of environmental stimuli [5,33]; this can directly affect an autistic individual's ability to use public transport. Although anxiety in this context has not been clearly studied, similar research with persons with cognitive impairments have reported that irregularities (such as late services, missing buses and poor weather conditions) can induce stress [28].

Similarly, hypersensitivity to stimuli (which can arise and affect one's experiences during travel) is extremely common in individuals on the autism spectrum [34]. For example, using public transport requires dealing with loud noises, rowdy kids, bright lights and billboards, and different smells. As such, it is common for autistic people to avoid crowded services due to sensory issues [5].

Further, the ability to plan public transport trips requires travellers to understand complex navigation artefacts including service schedules and maps [8]. Evidently, difficulty planning

travel is a common barrier for individuals on the autism spectrum, as more than 50% have struggled to plan a transport journey [14]. People with cognitive disabilities have also been reported to criticise service schedules as being difficult to understand [28]. In turn, the logistical complexity of public transport can cause autistic individuals to avoid independent travel altogether.

As such, OrienTrip was created to address these challenges and make public transport easier to use. The core functionalities of the app, in its current version (1.0), allow users to:

1. plan public transport trips based on (a) current or source location, (b) destination and (c) arrival or departure time and date
2. find real-time crowdedness information of services
3. find detailed information about a planned trip, including the number of interchanges, estimated cost and estimated travel time
4. track their current location, updated in real-time, in reference to the stops on the journey
5. quickly call a designated contact without leaving OrienTrip
6. quickly share their current location with a designated contact
7. view evidence-based anxiety-management and sensory-overload strategies tailored for public transport use
8. quickly customise a virtual card to communicate with other people through written text.

To better visualise how OrienTrip can be utilised in a public transport journey, the imagined persona of an autistic commuter who has to travel to an educational institution from their home using public transport has been constructed in Appendix A.

To assess the effectiveness and efficacy of OrienTrip in facilitating public transport use, the purpose of this study is twofold:

1. To conduct a pilot study with individuals on the autism spectrum to understand their experiences with OrienTrip.
2. To conduct a parallel pilot study with allied health professionals, who have experience working with individuals on the autism spectrum, to gather insight that improves OrienTrip.

Methods

Participants

A total of 16 individuals on the autism spectrum were recruited for the study. This included eight male and eight female participants, with a mean age of 22 (*std* = 4.97 years). Seven participants reported public transport as their primary mode of transportation, seven relied on family members for travel, and two reported driving. The participants were asked to rank along a five-point Likert scale (1 = do not use public transport to 5 = use public transport more than eight times each week) the frequency of their public transport use each week. The median ranking was 2, signifying three to four times weekly.

In addition, 22 allied health professionals were recruited for the pilot study. This included 19 females and three male participants. Overall, 14 participants were occupational therapists, one was a psychologist, two were speech pathologists, and five participants classified themselves as social workers and carers. The mean age of this group was 31 years (*std* = 8.93 years), and the median experience, on a five-point Likert scale from 1 (0–5 years) to 5 (21+ years), with people on the autism spectrum was 1.

Data collection

Autistic participants were recruited through multiple channels including internal email lists, social media groups and autism groups. Overall, the recruitment process took over 12 months to complete. Based on the feedback gathered from those who were invited to participate in the study, most individuals on the autism spectrum neither used public transport nor intended to do so. Due to this barrier, recruiting people who met the inclusion criteria was particularly challenging. Despite this, the results of the pilot study were not negatively affected.

Allied health professionals were also recruited through multiple channels including social media groups and autism organisations. Overall, the process produced a good response rate over the six-month recruitment period.

Complete information about what the study entails and registrations for participation were presented and collected through Qualtrics. Two forms were set-up to collect separate enrolments for individuals on the autism spectrum and allied health professionals.

Procedure

Following enrolment, individuals in the autistic group were invited to download OrienTrip through TestFlight, an online service for over-the-air installation and testing of iOS applications. Participants were asked to use the app on their regular public transport journeys for two to four weeks. This process ensured that OrienTrip was consulted in different situations and that participants became fully familiar with the functionalities. After the trial period, the group was asked to complete a Qualtrics survey to share their experiences with the research team. All participants were given a AUD$50 gift card as a token of appreciation for their time.

Similarly, allied health professionals were, following enrolment, invited to download OrienTrip through TestFlight and use the app for the same 2–4-week period for familiarisation purposes. After this, participants were asked to complete a Qualtrics survey to share their thoughts about OrienTrip. Participants were also given a AUD$50 gift card as a token of appreciation.

Data analysis

Quantitative data analyses were performed using IBM SPSS Statistics 26 with the significance level set at $p < 0.05$. Participants' demographic data and their responses to the five-point Likert scale questions were entered for assessment to calculate the median and frequencies.

Qualitative data analyses were performed using NVivo version 11, and thematic analysis was completed using the principles outlined in Braun and Clarke [35]. These included (1) familiarisation with data, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, and (5) defining and naming themes. After the Qualtrics survey results were uploaded to NVivo 11, team members read through the responses multiple times and took notes to organise and generate frequented words and codes to develop the thematic framework. The research team then discussed and shared themes and keywords. This process continued until all team members agreed on the overall themes and subthemes. The team then interpreted the survey responses by analysing the findings.

Ethics

Ethical approval was obtained from the Human Research Ethics Committee at Curtin University (HRE2016-0086) in Perth, Western Australia.

Consent

Participants were provided with a digital information sheet through Qualtrics describing their role in the research. They were informed that their withdrawal from the study was acceptable at any time without negative consequences, and were subsequently provided digital consent confirming their participation. All study data were confidentially stored and maintained in line with the Western Australian University Sector Disposal Authority.

Results

Individuals on the autism spectrum

Autistic individuals were asked to rank the statement "OrienTrip is easy to use" on a five-point Likert scale, with 1 being "strongly disagree" and 5 being "strongly agree". Analysis found that the median response was 4 ("somewhat agree").

Further, participants were asked whether they required more instructions to use OrienTrip. Seven needed more guidance on using the app, while nine did not.

Autistic participants were then asked to rank the statement "OrienTrip is helpful in making public transport easier to use for individuals on the autism spectrum" on a five-point Likert scale, with 1 being "strongly disagree" and 5 being "strongly agree". Again, the median response was 4 ("somewhat agree"). Similarly, participants ranked their satisfaction with OrienTrip from 1 ("extremely dissatisfied") to 5 ("extremely satisfied"), which again averaged at 4 ("somewhat satisfied").

Thereafter, participants indicated on a four-point Likert scale their level of disappointment should OrienTrip no longer exist (0 = N/A, 1 = not disappointed, 2 = somewhat disappointed, 3 = very disappointed). The median was 2 ("somewhat disappointed"). Finally, when asked to rate OrienTrip out of 5, the median score was 4, while the mean score was 3.63 ($std = 0.62$).

Feature ranking

After using OrienTrip for two to four weeks, autistic participants were asked to prioritise the functionalities of the app based on helpfulness. Table 1 shows the ranking of functionality from highest (most helpful) to lowest (least helpful).

Primary benefit

When autistic participants were asked about the primary benefits they received from OrienTrip, three themes emerged. This covered (1) comparative ease when planning trips, (2) the support OrienTrip provides, and (3) tracking an existing journey.

Streamlining trip planning

The ability to plan trips easily was a prominent benefit of using OrienTrip. Participants expressed that the app simplified travel preparation, particularly, according to one, "because it's easy to plan when I need to leave". In addition, OrienTrip further streamlined the "timing of public transport", and clarified "the planning process of working out" a journey due to the "straightforward [and] easy-to-use" nature of the app.

The support OrienTrip provides

Some participants indicated that they benefitted from the support OrienTrip provided them. For example, the app allows users to call their carer, share their location, view anxiety-management and sensory-overload strategies, and communicate through a virtual card. One participant expressed that "being able to use public transport with the support I am receiving" makes the "experience enjoyable", particularly through the "assistance tab" (available on the app).

Another assistance option that was widely praised was the ability to manage anxiety during public transport travels. Notably, this provided "easy access" and "advice on how to calm down", as well as the opportunity "to gain good experience" while travelling. In addition, OrienTrip offered users "transporting skill[s] and tips to become less anxious", including "advice on how to cope with being on public transport". Indeed, this was a common view held among participants who had indicated their dislike for the crowdedness, anxiety, "drama" and being around rowdy passengers when using public transport.

Tracking a journey in real-time

The ability to actively track one's public transport journey was also widely praised. Participants found the feature had helped them "organise travel times more effectively" and better "visualise where I need to go and how" using the "saved trips" function. Other benefits included increased time management and the option to simplify travel routes.

People who would benefit from OrienTrip

When asked who, in their opinion, would benefit most from using OrienTrip, four categories emerged. This covered (1) people on the autism spectrum, (2) people with cognitive disabilities, (3)

Table 1. Ranking of functionalities of OrienTrip by individuals on the autism spectrum, sorted from highest (most important) to lowest (least important).

Rank	Functionality description	Median ($n = 16$)
1	The ability to calculate routes	2.0 (IQR = 3)
2	The ability to view information on the interchanges of a route	3.0 (IQR = 3)
3	The ability to view crowdedness information of services	4.0 (IQR = 3)
4	The ability to track journeys in real time through a simplified linear map	4.0 (IQR = 4)
5	The ability to view anxiety-management strategies for public transport	6.0 (IQR = 5)
6	The ability to call a caretaker from OrienTrip	6.0 (IQR = 3)
7	The ability to call emergency services from OrienTrip	6.50 (IQR = 4)
8	The ability to share current location with a caretaker	7.50 (IQR = 3)
9	The ability to view sensory-overload strategies for public transport	7.50 (IQR = 6)
10	The ability to communicate through a customisable virtual card	8.50 (IQR = 4)

Interquartile range (IQR).

people with anxiety issues and (4) people who are new to public transport.

People on the spectrum proved the most common suggestion to this question. This was anticipated, as OrienTrip is designed and advertised for this particular cohort. Other responses ranged from "people with autism or ADHD", "autistic people and people with anxiety issues", "those that find it hard to keep track of time or those on the spectrum", and "ASD [autism spectrum disorder] individuals with filtering difficulties" because the features are "so simplified".

Some participants suggested that people with other disabilities (which, according to one participant, can "affect their ability to plan things") could also benefit from OrienTrip. These responses included people who cannot travel independently and people with planning and "executive functioning problems". This further covered individuals who get "confused using modes of transport by themselves" and "those that find it hard to keep track of time".

Some participants indicated that people with anxiety issues—that is, "who need to take public transport but are unable to due to anxiety"—could also find the app useful. These responses may have emerged because OrienTrip offers a comprehensive list of anxiety and sensory-overload management strategies that are tailored specifically for public transport use. Notably, one participant even suggested that "people who might need the very useful "assistance option" " could be of benefit.

Finally, autistic participants suggested that individuals who are new to public transport and those who cannot travel independently might value the app. In particular, "people who like visual … maps when they are on public transport" and "help when to know to get off", as well "people who use public transport on new routes", will find OrienTrip useful. Further, "someone who needs help planning trips", struggles "to keep track of time" or "has not caught public transport before" might value a tool like OrienTrip to streamline safe travel.

Limitations of OrienTrip

Participants were asked about the biggest problems they experienced when using OrienTrip. Here, the aim was to understand how the app can be improved to make the user experience more pleasant and stress-free. The responses can be categorised under three themes, covering (1) missing features, (2) difficulty to use and (3) inability to provide the best route.

Missing features

This category of responses highlighted the missing features participants wished the app contained. For example, one suggested we integrate "features with music and books … to limit what one needs to take" with them, such as additional devices or having to switch apps, while travelling.

Another suggested we add visuals of landmarks on the journey map to help users better understand where to disembark on existing services, particularly by knowing "when to push the bell". This also included "commands for busy, crowded buses". That said, OrienTrip does, in its current state, provide a straightforward linear map that lists every stop on a journey, with users" locations updated in real-time (see Figure A.8).

Another suggested that the map should automatically zoom in to their current location after opening: "When walking and tapping on the list to see the map, it doesn't show you where at this stage you are walking. If it zoomed in after tapping to your walking route, that would be good to have."

Difficult to use

One theme that emerged regarded the level of app usability. Participant responses centred around the app's user interface, with comments ranging from confusion "to navigate" OrienTrip, to its general absence of visual appeal "due to the lack of visual aids". This regarded "colours [and] word choices", "boring" interface and failure to display "some of the bus routes", which "were not clearly marked". Overall, these comments highlight that the app interface can be improved to make OrienTrip more intuitive and stimulating for users.

Routeing problem

Finally, some participants reported that OrienTrip did not display the travel routes they usually take. For example, one respondent explained that the app "did not show the route I usually take on footy match days, as it was a special event bus that only runs on match days". Others claimed that when unable to locate their bus timetable, "there wasn't somewhere I could get some help on the app" for assistance.

This issue can be a routeing-algorithm problem, which causes OrienTrip to ignore some travel routes. Another possible explanation can be that the routes participants were expecting to locate were deemed "inefficient" as a result of the app locating more logical routes with shorter travel times. This issue can be investigated in future studies.

Stressful experiences with public transport when using OrienTrip

Only four reported that they experienced some form of anxiety and stress when using public transport. In particular, participants identified crowded services as the source of their anxiety, mainly with "certain people coming onto [the] bus", thus, inviting "anxiety thoughts" to arise. Another explained that "it's more the rushing and amount [of] people in … public transport" that triggers unease.

When asked if OrienTrip was helpful in managing their anxiety, one participant stated that it provided "advice on how to calm down". Another described their anxiety as such:

I had to tell the bus driver where I wanted to go, then I had to give him the money and my purse was hidden in my bag so I was fumbling, trying to find it and then I had to get the coins and give them to him; then I had to take the ticket and the change and I just felt like I was going to mess up but that's how I always feel when I'm buying something.

Public transport requires performing quick, successive tasks (e.g., boarding, asking for a ticket, handing others cash, pocketing the change, getting the ticket and finding a seat). When queried if OrienTrip was helpful in alleviating stress, one responded, "no, [but] maybe if someone else did it for me … now that I think about it, that's probably not helpful to me overall".

Others expressed that "the stress mainly came from the boredom" of travel and expressed that the app's ability to manage anxiety was not helpful in this situation. However, when asked what would be helpful, they wished for features that would alleviate or even "solve boredom issues".

Allied health professionals

Allied health professionals were asked to rank, on a five-point Likert scale, the statement, "OrienTrip is easy to use". The responses ranged from 1 ("strongly disagree") to 5 ("strongly agree"), and returned a median score of 4 ("somewhat agree").

Table 2. Ranking of functionalities of OrienTrip by allied health professionals, sorted from highest (most important) to lowest (least important).

Rank	Functionality description	Median ($n = 22$)
1	The ability to calculate routes	1.5 (IQR = 4)
2	The ability to share current location with a caretaker	3.50 (IQR = 4)
3	The ability to call a caretaker from OrienTrip	5.0 (IQR = 4)
4	The ability to view anxiety-management strategies for public transport	5.5 (IQR = 4)
5	The ability to view information on the interchanges of a route	5.5 (IQR = 5.25)
6	The ability to view crowdedness information of services	6.0 (IQR = 4.25)
7	The ability to view sensory-overload strategies for public transport	6.0 (IQR = 3.5)
8	The ability to track journeys in real time through a simplified linear map	6.5 (IQR = 4)
9	The ability to call emergency services from OrienTrip	9.0 (IQR = 5)
10	The ability to communicate through a customisable virtual card	8.0 (IQR = 5.0)

Similarly, participants were asked to rank whether "OrienTrip is helpful in facilitating public transport use for individuals on the autism spectrum" on a five-point Likert scale, with 1 being "strongly disagree" and 5 being "strongly agree". Again, the median rank was 4 ("somewhat agree").

Upon asking the participants to indicate their level of overall satisfaction with OrienTrip on a five-point Likert scale (1 = extremely dissatisfied, 5 = extremely satisfied), analyses found a median of 4 ("somewhat satisfied"). In subsequently rating the app out of 5, participants scored OrienTrip a 4 (IQR = 1), returning a mean rating of 3.7 ($std = 0.72$).

Feature ranking

After using OrienTrip for two to four weeks, allied health professionals were asked to prioritise the app functionalities based on helpfulness (in their opinion) to those on the spectrum. Table 2 shows the ranking of functionalities from highest (most helpful) to lowest (least helpful).

Primary benefit

Allied health professionals were questioned about the primary benefits people on the spectrum would receive from using OrienTrip. The responses were thematically organised into five categories, covering (1) trip planning, (2) coping strategies, (3) accessible support options, (4) independent mobility and (5) trip tracking.

Planning trips

One of the most prominent benefits of using OrienTrip was the ability to plan and manage trips. Specifically, respondents valued the capacity to plan a detailed travel journey to reduce uncertainty, either listing "all stops [a] bus will be making … so [users] can follow whilst travelling" or providing "stability and clear directions" during a trip. In addition, participants praised the app's value as a "resource to assist the majority of the [travel] process", which is "easy to use and simple to navigate to ascertain info on train scheduling, facilitating public transport use". Finally, one respondent liked "how specific it is with locations for walking, streets and bus stops so that an individual can plan their whole trip" while "reducing any unexpected situations".

Coping strategies

The ability to manage anxiety and sensory overload during transport journeys was cited as equally beneficial for autistic individuals. Participants emphasised the importance of being able to cope with overwhelming situations "when in the community", including the provision of "helpful tips to manage anxiety while travelling" and "holistic … strategies given to support individuals with ASD".

Finally, one participant praised OrienTrip's novelty among other travel apps:

The factors I feel set apart this app from other orientation apps are the helpful tips. I find this a great idea for particular clients who experience high anxiety around public transport to simply read and remind them of tips to assist with sensory overload and anxiety.

Accessible support options

Allied health professionals also praised the support options available on OrienTrip. Specifically, their responses cited features such as the ability to call a caregiver, share location with a caregiver, and the option to communicate *via* virtual card, which would be useful to those on the autism spectrum. Notably, "the fact that their caregivers can also check up on their locations is very handy, as this will reduce carers' anxieties and increase independence".

In terms of assistance, OrienTrip offers "support options readily available within the app", which are "very useful to have … all in the one space". One respondent expressed that they "liked the option of a virtual assistance card", while another praised the "carer/emergency contact options, and the ease of planning a trip (times, routes, costs)". The "safety features … that can alert caregivers and reduce stress associated with public transport" were further praised, as well as the convenience of having "one app for multiple necessary functions".

Independent mobility

Some responses indicated that OrienTrip can facilitate "independent mobility" for those on the autism spectrum. In particular, the app provides "one resource to assist the majority of the process involving public transport", as well as "confidence in travelling alone". Further, individuals can "gain more independence" by empowering users "to plan a trip from start to finish, as well as problem-solve any issues that may arise specific to someone on the spectrum". Overall, the health professionals emphasised that OrienTrip provides autistic individuals with the tools required to navigate public transport safely.

People who would benefit from OrienTrip

Participants were asked to list groups that would benefit most from using OrienTrip. Responses were organised into four categories, covering (1) people with high-functioning autism, (2) individuals with anxiety disorders, (3) individuals with other disabilities, and (4) youth and children.

People with high-functioning autism

Respondents acknowledged that autistic individuals would value OrienTrip, but emphasised its true benefit for people with high-functioning autism and those with some autonomy. In particular, respondents believed that people with "the skills and level of independence to take public transport safely on their own" or "someone with higher literacy skills and … reasonable tech literacy" could use OrienTrip successfully. Further, those in their "late teens and adults with autism or anxiety" would value the app, "as long as they have good literacy skills" or "higher cognitive capabilities [such as] relatively good receptive language skills, [and the] ability to read and utilise functions".

Other participants explained that OrienTrip better suits "someone who is quite high functioning, as it requires a fair bit of ability to access the application". They would also have to possess "good insight to look at prompts that will help them manage sensory overload [and] anxiety".

Individuals with anxiety disorder

This theme emerged with respect to people on the spectrum "who may struggle to independently take public transport due to anxiety, sensory overload and communication difficulty", including neurotypical individuals. Notably, responses suggested that anyone with anxiety issues "and is wanting to be more independent" can benefit from OrienTrip. In addition, people, particularly "young adults with social anxiety" or someone either "learning to use public transport" or experiences "anxiety around travelling on public transport", might find the app helpful in terms of alleviating stress.

People with disabilities

Some respondents indicated that individuals with special needs and those who require navigation assistance could benefit from OrienTrip. The app can support a "verbal person with special needs", as well as "individuals with any disability who use public transport, especially trains on a daily or weekly basis to get around cities". Further, OrienTrip simplifies travel for people "needing precise and clear instructions for getting [to destinations] and back again", and individuals "with exec function difficulties, anxiety [and] communication difficulties".

Young people and children

Finally, some responses highlighted that "youths and children" can also benefit from the tools and support available on OrienTrip. Notably, "teenagers and young adults transitioning from school to work, individual[s] engaging in transport training, [and] anyone wanting to increase their independence in the community" may find the app useful.

Suggestions to improve OrienTrip

Participants were asked to explain how OrienTrip can be improved to better cater to the needs of individuals on the autism spectrum. The responses were thematically organised into three categories aimed at (1) simplifying OrienTrip, (2) adding more features, and (3) supporting people with other disabilities.

Simplify OrienTrip

This theme emphasised that OrienTrip is text heavy and can be challenging to use for people with literacy difficulties. Comments indicated that the app can be further simplified by utilising more visuals and removing unnecessary user-interface elements:

> I think literacy skills can sometimes be a challenge for people with ASD, and that even when literacy skills are strong, it can be difficult to process written text when under stress or sensory overload. I think including a pictorial display option for sections like "assistance" may broaden the range of individuals that this could be used with—for example, [an] image or GIF of someone breathing calmly withing anxiety-management tips. Individuals could choose which method of display was most helpful.

> [Put] categories in for the sensory overload tips, [as] there is a lot of writing and you have to click and scroll. Consider adding … visuals on the assistance tab [and] … the ability to limit just to a region (i.e., Perth only). [It] can be overwhelming when all of the places come up.

> When searching locations, international destinations come up first as suggestions. This may frustrate someone with ASD and limited literacy skills, as they need to put in more info to get the Australian destinations to show up.

Overall, respondents provided clear suggestions to help streamline the user experience. These included:

- "more visuals to support text", as "this would not be good for someone with lower literacy"
- "more symbols [instead of] writing, so that individuals who have reading difficulties can access the app"
- "icons that individuals who can not read will understand", as well as "speech output"
- decluttering "the layout slightly to help those with visual scanning difficulties" and possibly adding "graphics [and] symbols for low-literacy clients", including the "option to increase [and] decrease font".

Additional features

Some responses highlighted additional features that can assist users when taking public transport. For example, participants suggested we enable the option to customise the app interface to suit individual needs, adding voice recognition and text dictation for those with low literacy skills, as well as the possibility to manage and top-up one's travel card. In particular, one explained that OrienTrip needs a "customisation aspect for customers who are non-verbal and respond well to visual-based tools". This includes:

> customisable features to suit each individuals' personal requirements (e.g., add images of stops), text-to-speak function (for customers with literacy deficits), ability to add keyword[s] [and] requests as a virtual assistance card (for non-verbal customers (e.g., 'excuse me', 'would you mind pressing the bell for me', 'my stop is next'), [and a] personal detail section within the app (e.g., if customer gets lost, can show details to others for assistance).

The respondents also suggested that we add "locations to access additional assistance, help [and] additional problem-solving strategies in the form of visuals". For example, an "I am lost" feature will help users "find an adult and show [their] virtual card", including "what to do if your SmartRider runs out of money".

Others suggested OrienTrip include:

- "voice recognition of queries or in-calling caregiver, caretaker, emergency services [and] Transperth info", as well as "notification alerts [for] delays in scheduling, price of journey, link integration with SmartRider, Siri-type voiceover for those that may have poor reading literacy, [and] change in font size and colour for those with visual impairment or colour blindness"
- "options for different states like Transperth for checking money on cards"

- "basic communication commands on crowded buses and trains"
- "stop numbers in detailed journey plan to help [a] person track which stop they are at"
- "a locked section for holding a card or carers card to provide them with discounted fares, as this information could be saved safely on the app".

Support people with other disabilities

Some responses indicated that additional features might benefit individuals with other disabilities. For example, participants suggested we make the user interface accessible "for individuals with sensory loss" and visual impairments through "contrasting background colours", the "option to increase [and] decrease font sizes", enable "screen rotation", and include voice recognition capability as well as the "option of using dictation for people who can't read [and/or] write". The latter functionality was also suggested for those with low literacy skills.

Discussion

This pilot study has shown that OrienTrip facilitates public transport use for individuals on the autism spectrum. The findings show that the app was well received by all 16 autistic individuals and all 22 allied health professionals who participated for analysis. Individuals on the autism spectrum expressed that they "somewhat agree" (4), on a scale of 1 ("strongly disagree") to 5 ("strongly agree"), that OrienTrip makes public transport easy to use (see Figure 1). Moreover, these participants scored the app an overall rating of 4 out of 5. Similarly, allied health professional indicated that they also "somewhat agree" (4) on app helpfulness, based on the same five-point Likert scale (see Figure 2). They gave OrienTrip an overall score of 4 out of 5.

Autistic individuals agreed that planning public transport trips was easy with OrienTrip. This opinion was evident when the participants expressed that they benefitted most from the app's "calculating routes" functionality. This finding supports previous studies that report 50% of autistic individuals have difficulty planning public transport trips [14]. The participants further emphasised this perspective when they ranked the "ability to calculate routes" functionality the highest (most important) in helpfulness by the autistic individuals (see Figure 3). Allied health professionals expressed a similar opinion. Overall, they regarded the ability to plan detailed trips as one of the primary benefits users on the spectrum can receive from OrienTrip. Similarly, this perspective was reiterated in further analyses, in which health professionals also ranked "the ability to calculate routes" functionality highest (see Figure 3), clearly highlighting its usefulness to people on the autism spectrum.

The findings also revealed that individuals on the spectrum strongly desire predictability when using public transportation. Autistic participants ranked "the ability to view information on the interchanges of a route" and "the ability to view crowdedness information" second and third in usefulness, respectively. Indeed, past studies have also shown that predictability is a strong regulator of anxiety [36]. For example, it has been reported that an autistic individual's improved ability to foresee a situation is correlated with decreased anxiety levels [36]. Evident in this study,

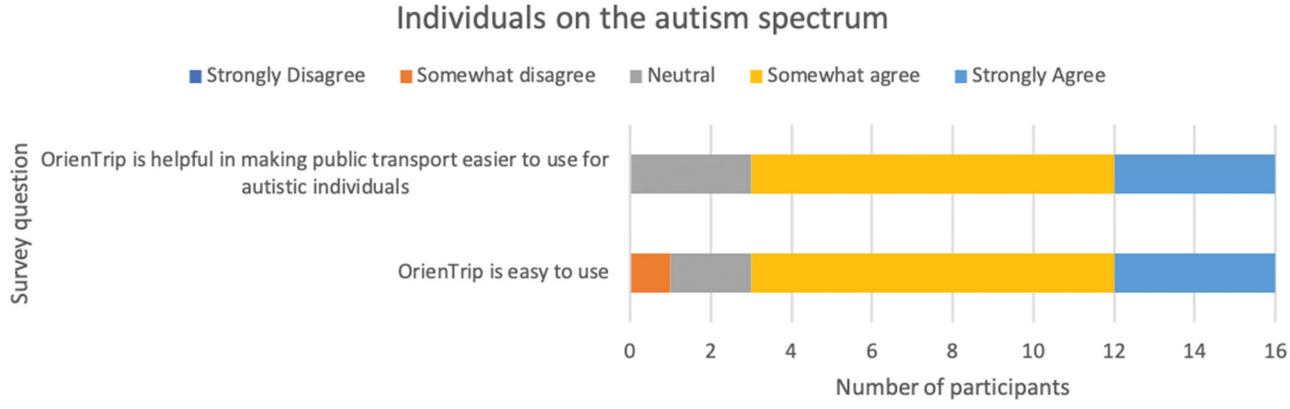

Figure 1. Individuals on the autism spectrum agreed that OrienTrip is easy to use and makes public transport more accessible.

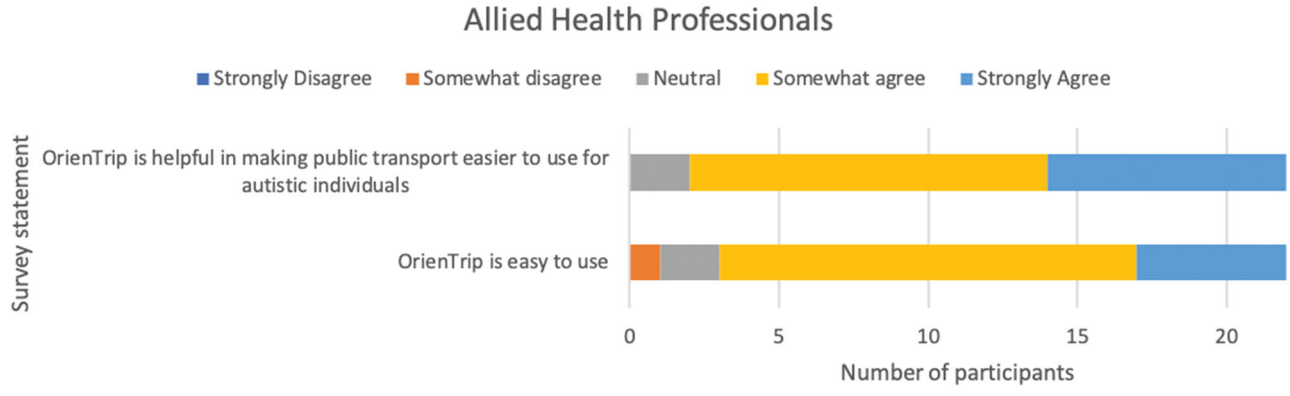

Figure 2. Allied health professional agreed that OrienTrip is easy to use and facilitates public transport use for autistic individuals.

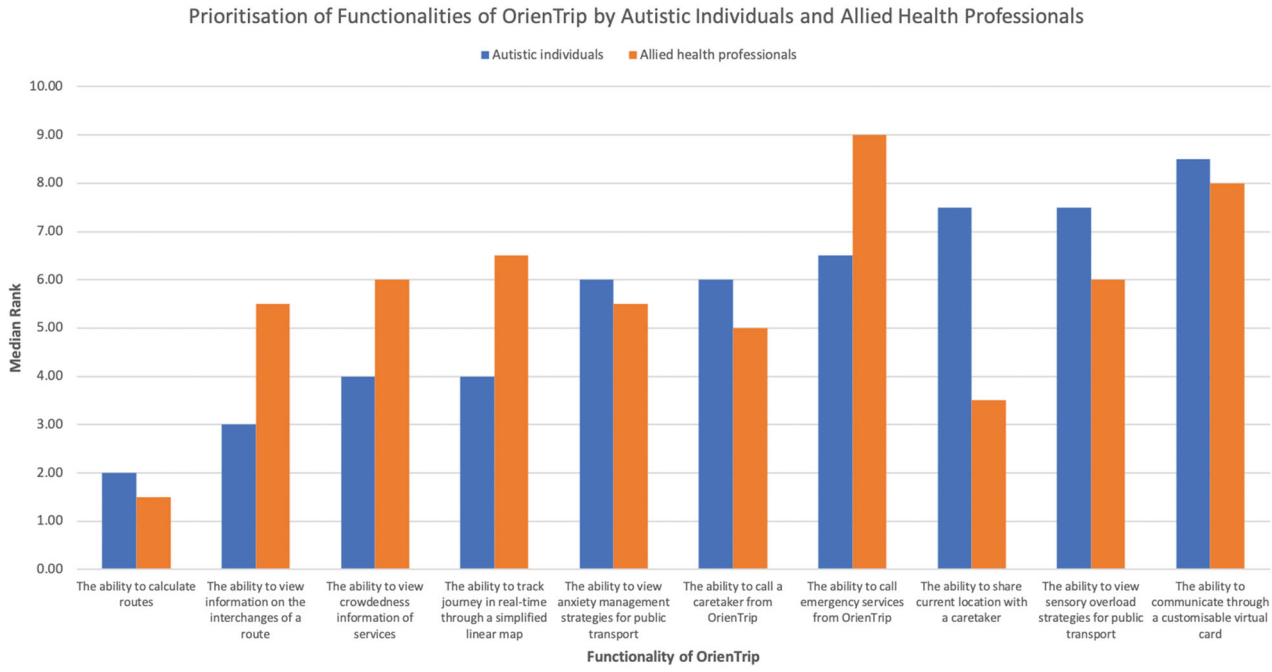

Figure 3. Participants on the autism spectrum and allied health professionals prioritise the functionalities of OrienTrip differently.

the findings support this perception. Allied health professionals also expressed a similar opinion, ranking "the ability to view information on the interchanges of a route" and "the ability to view crowdedness information" fourth and fifth, respectively.

Autistic individuals also highlighted that OrienTrip's assistance options helped them experience more enjoyable public transport trips. For example, participants expressed that they benefitted from the anxiety-management strategies, ranking them fourth in terms of usefulness. One participant reported that the anxiety-management assistance option helped them to alleviate a stressful situation on one of their journeys.

When examining the literature, anxiety management has been shown to facilitate independent travel [37], while maintaining control over negative thoughts (e.g., "I am not capable of using public transport") makes public transport more manageable [28]. Similarly, allied health professionals emphasised the usefulness of the app's anxiety-management assistance option, deeming it one of the core distinguishing features of OrienTrip. Overall, they ranked the feature fourth in terms of usefulness.

Other functionalities were reportedly helpful for travel purposes. For example, individuals on the spectrum ranked the journey map (shown in Figure 3) equal third in importance and usefulness. The purpose of this map was to facilitate spatial awareness through an intuitive user interface, particularly because (according to previous studies) people with intellectual disabilities have difficulty disembarking at the correct stop [4,29]. Similarly, another functionality, the "call caretaker" feature, was ranked equal forth, highlighting its importance for autistic users. Allied health professionals expressed that this functionality enables OrienTrip to increase autistic people's confidence to travel independently, and, as such, ranked the "share current location with caretaker" and "call caretaker" functionalities second and third, respectively. These safety measures ensure a safe journey and peace of mind for carers [14,15].

Finally, we sought to understand how OrienTrip could be improved to more effectively aid and encourage public transport use. Here, the investigation revealed a recurring theme: autistic participants found the app difficult to use. Their responses included comments such as "not very visually appealing", "difficult to navigate" and "boring user interface". Evidently, the interface is one of the most important aspects of a software application, which has been shown, for example, to support positive user experience when effective and negative user experience when poorly designed. Indeed, a "bad" interface can even cause users to give up the software completely despite its many benefits [38,39].

Second, the responses from allied health professionals revealed a similar theme, in that most felt the app was too complicated. For example, responses indicated that the user interface is text heavy and can be difficult to understand and process for some autistic individuals, especially under stressful situations. Suggestions to improve OrienTrip included making the text bigger, using visual aids and implementing text dictation to improve accessibility for autistic individuals with low literacy skills and/or individuals with other disabilities.

Overall, the findings suggest that OrienTrip successfully facilitates public transport use for people on the autism spectrum. Both groups—that being autistic individuals (see Figure 4) and allied health professionals (see Figure 5)—expressed their satisfaction with the app, and generally agreed that its functionalities (including the detailed trip-planning feature, anxiety and sensory coping strategies, and safety functionalities such as the ability to share one's location) can enhance the capacity of autistic users to navigate public transport independently.

However, the study also found that OrienTrip, in its current version, can be difficult to use and is visually unappealing. Nonetheless, this user-interface issue can be improved through increased image and icon use and improved colour selection. Future studies can investigate this and improve the app using the feedback collected in this study.

It can be concluded that technological tools such as OrienTrip can be utilised to assist individuals on the autism spectrum travel autonomously, without reliance on other people, using public transport. Independent mobility can improve community participation opportunities for individuals on the autism spectrum, including enhanced education, employment and social outcomes.

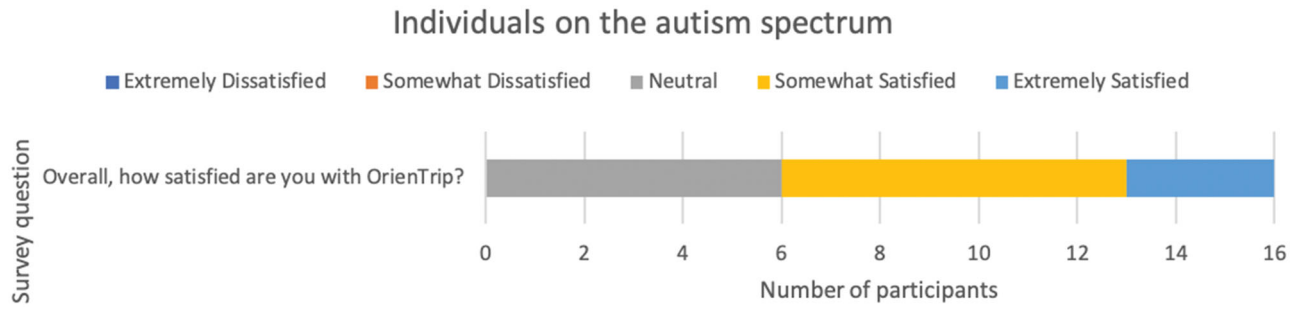

Figure 4. Individuals on the autism spectrum expressed overall satisfaction with OrienTrip.

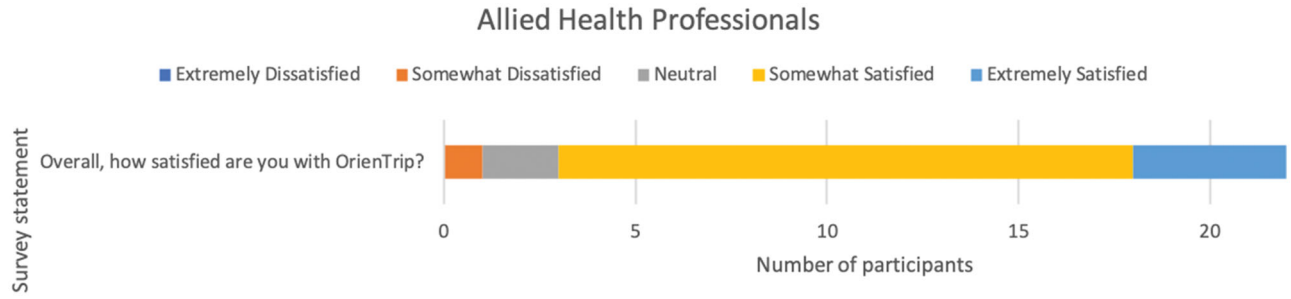

Figure 5. Allied health professionals expressed overall satisfaction with OrienTrip.

Limitations

A limitation of the study regards the sample size of the autism group, which may not adequately represent the entire autism population. This is because all autistic individuals are different and their experiences with public transport will vary. Similarly, the sample size of the allied health professional group may not be representative of the entire allied health professionals population.

It is also important to note that participants in the autism group had self-reported their autism diagnosis. Although it is unlikely that the sample included individuals who did not meet the autism diagnosis criteria, the possibility cannot be ruled out.

The pilot studies conducted in this paper had relatively small sample sizes, which could be regarded as a limitation. Future studies can investigate the effectiveness of OrienTrip through a large-scale study, such as a randomised control trial, which involves a larger number of participants.

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Appendices

Appendix A: Persona of an individual on the autism spectrum travelling using public transport

Michael, a person on the autism spectrum, plans to visit an educational institution in Museum Street, Perth, Western Australia. He wants to leave his house at 3.00 pm in the afternoon.

To prepare for the trip, Michael decides to first review the sensory-overload strategies. He does this by tapping the 'assistance option' in the top-right corner of the OrienTrip home screen (Figures A.1–A.3).

As Michael is sensitive to bright lights, he taps the 'bright lights' option to review what he can do to manage this sensitivity (Figure A.4).

After reviewing these strategies, he decides to pack his sunglasses and hat for the journey. Next, Michael decides to plan his

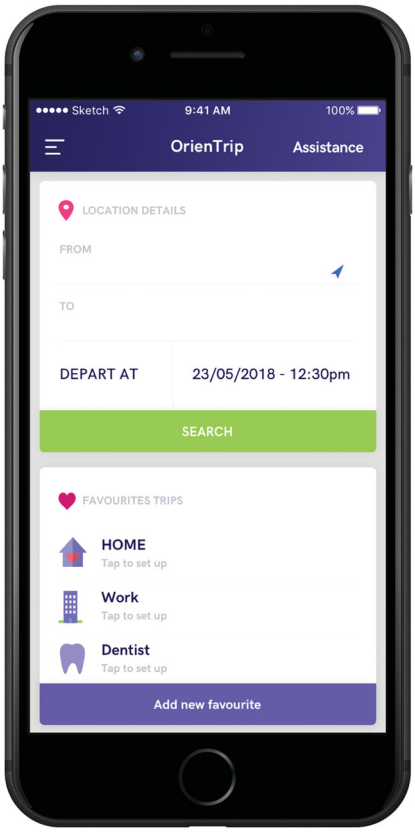

Figure A.1. Home screen.

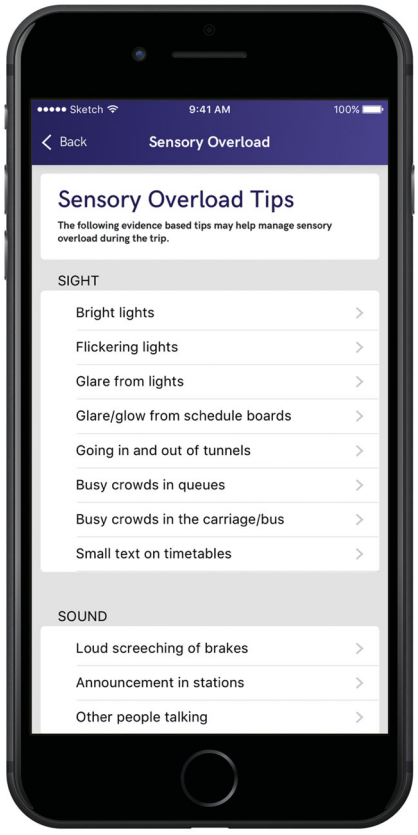

Figure A.3. Sensory-overload strategies.

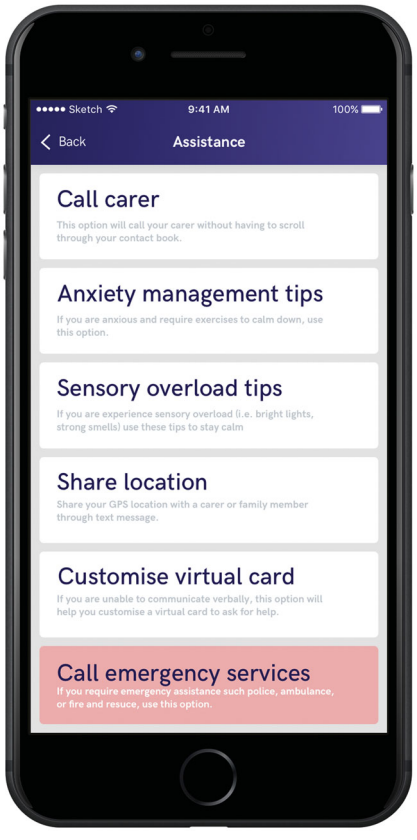

Figure A.2. Assistance options.

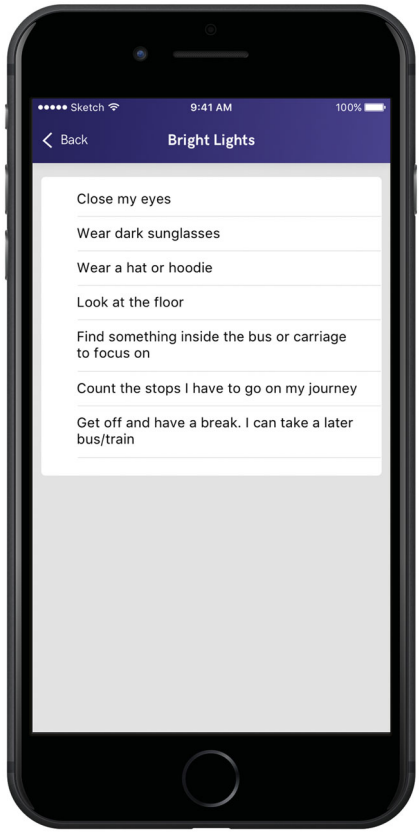

Figure A.4. Bright lights strategies.

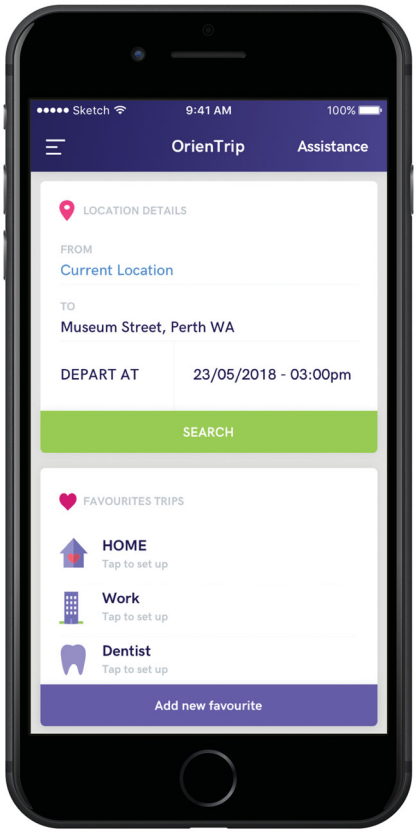

Figure A.5. Michael plans his trip.

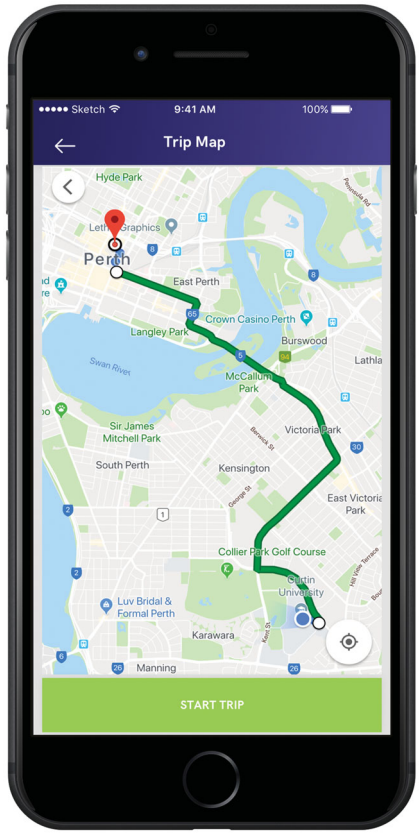

Figure A.7. Journey map.

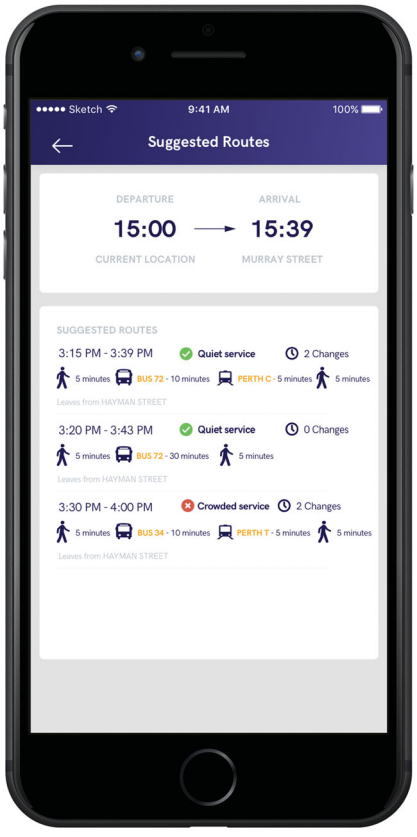

Figure A.6. Calculated routes.

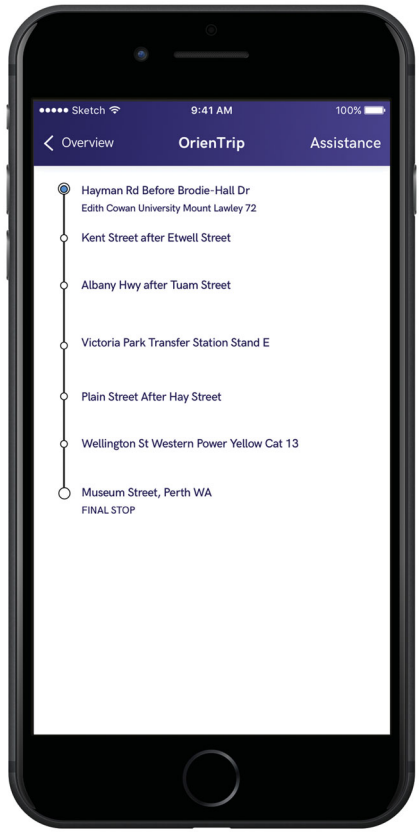

Figure A.8. Trip-tracking screen.

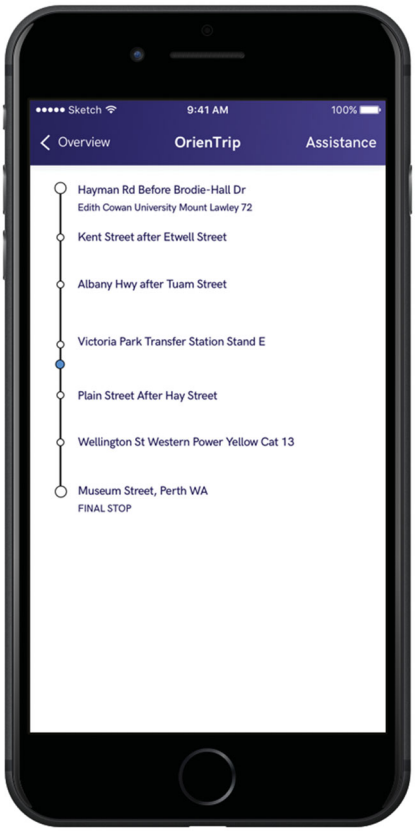

Figure A.9. Trip progress update.

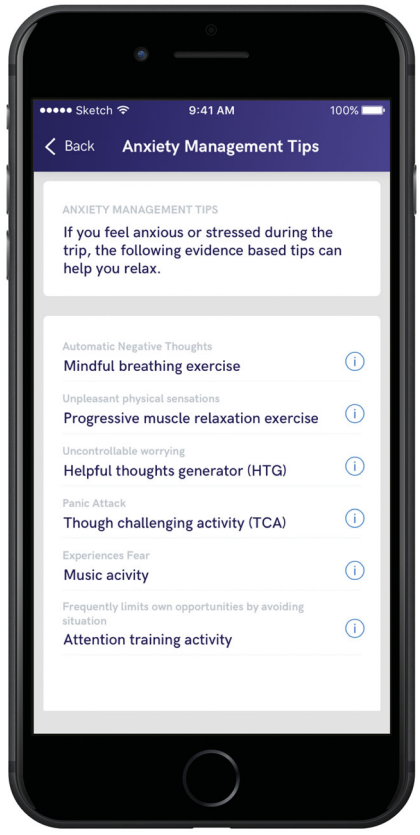

Figure A.11. Anxiety-management tips.

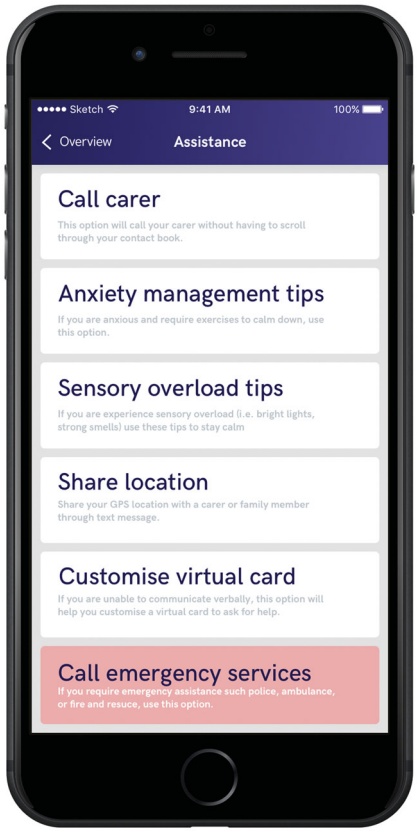

Figure A.10. Assistance options.

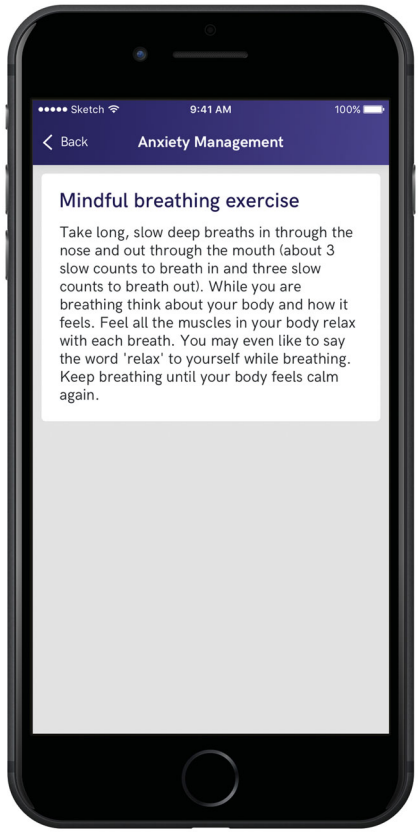

Figure A.12. Mindful-breathing exercise.

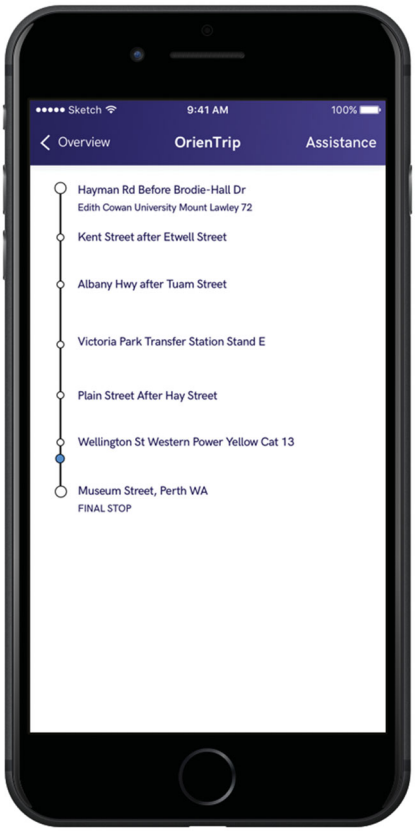

Figure A.13. Trip progress map.

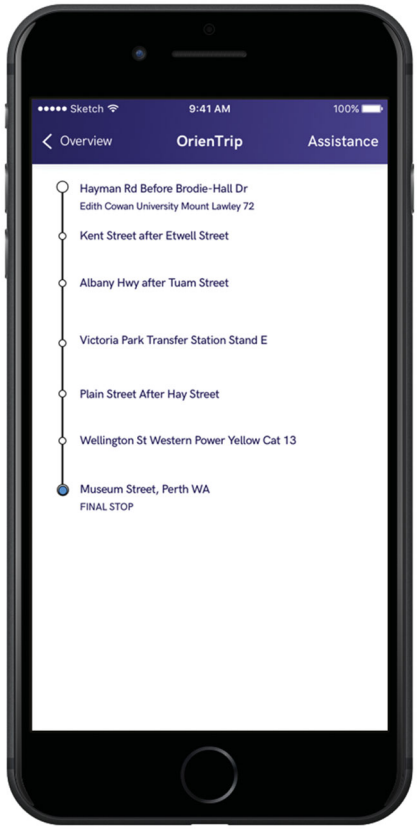

Figure A.14. Journey map and final destination.

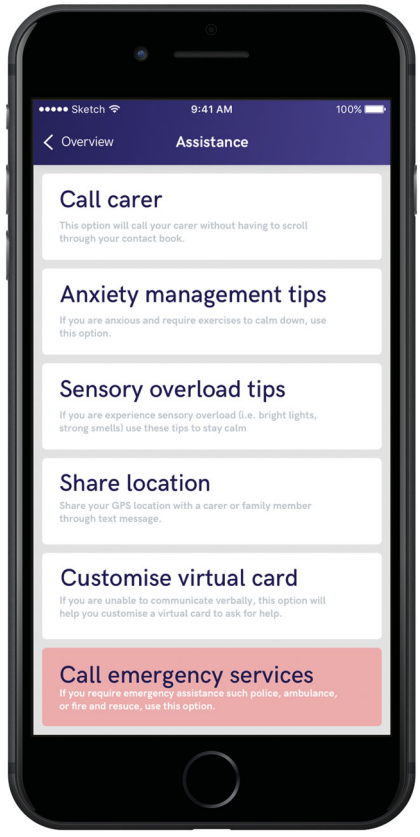

Figure A.15. Share location function is the fourth option on the assistance screen.

trip. Figure A.5 shows what he inputs into OrienTrip to calculate a route for the journey.

OrienTrip calculates and suggests three routes for Michael. As shown in Figure A.6, the app also displays the predicted crowdedness of the travel routes, as well as the number of interchanges required. Similarly, a detailed description of each route is presented to assist the user in selecting one that is tailored to their needs. As such, Michael selects the second route, as it requires zero interchanges and is expected to be quiet.

As shown in Figure A.7, OrienTrip then displays an overview of the journey. When Michael has an overall understanding of the trip, he taps the 'start trip' button.

The trip-tracking screen, shown in Figure A.8, presents a real-time update of the trip progress. Each dot on the trip line signifies a stop along the route, and the blue dot is the current location of the user with respect to the overall journey. As Michael progresses, the blue dot updates in real-time, informing the user where they are on their journey.

For example, in Figure A.9 Michael has just passed the fourth stop, Victoria Park Transfer Station Stand E, on his journey.

At this point, Michael becomes anxious. He begins to have negative thoughts about missing his stop and getting lost. To manage this anxiety, he navigates to the assistance option, located at the top-right corner, and finds the anxiety-management tips tool (shown in Figure A.10).

In the anxiety-management tips screen (shown in Figure A.11), Michael finds and taps the automatic negative thought option (Item 1), which is a mindful-breathing exercise. This is shown in Figure A.12.

He practices this exercise until he feels calmer and in control again. He returns to the journey map and continues monitoring his trip.

As shown in Figure A.13, Michael has just passed the final stop before his destination. Now, he presses the 'stop' bell to signal the driver to stop at the next station.

Evident in Figure A.14, Michael disembarks the bus when it arrives at Museum Street, Perth. His final destination is just across the street from the bus stop, so he does not require any walking directions.

Finally, Michael decides to assure his caretaker that he has safely arrived at the destination by sharing his location (Item 4) through the assistance functionality. This is shown in Figure A.15.