Viamigo

Monitoring Tool to Support Independent Travel by Persons with Intellectual Disabilities

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Persons with intellectual disabilities (PwIDs) often aspire to more social inclusion by engaging in more community activities but encounter social barriers when traveling independently. Therefore, PwIDs are often accompanied by family members, friends, or volunteers. In order to both support the independent outdoor mobility of PwIDs themselves and reduce the caregivers' burden, the geographic information system–based application "Viamigo" was developed (www.viamigo.be), which allows a personal coach to monitor an individual in real time from a distance. The goal is to teach PwIDs a known individual route that they can accomplish independently while being monitored by a personal coach, caregiver, family member, or friend who is taking care of the individual making the trip. Viamigo determines the location of the user and compares this in time and space within a predetermined range and automatically sends notifications to the coach in case the user deviates from the route, travels at an incorrect speed, or enters or leaves a safe or dangerous zone, among other factors. Besides this on-route functionality, Viamigo also allows the creation of geofences around destinations (to monitor whether the user stays within a predefined zone) and emergency tracking. The initial results are promising: PwIDs successfully used Viamigo for a heterogeneous set of trips performed by several travel modes (bus, cycling, and walking) for several activity purposes (both daily recurrent trips to the day center and trips for shopping, social, and recreational purposes) and for different distances.

Persons with intellectual disabilities (PwIDs) often aspire to being more socially included by engaging in more community activities (*1*). Maintaining outdoor activity is important to extend the period of high-quality living and thereby decrease the period when supporting services are necessary; it should therefore be considered as part of both residential care and community living. If PwIDs (as well as persons with disabilities in general) can be better supported in maintaining out-of-home activities, this ability is expected to have an overall positive effect not only on their and their caregivers' well-being and quality of life (e.g., sense of autonomy, preservation of dignity) but also on society in general. Community inclusion is an important goal for most PwIDs and their families (*2*), associated with improved individual and family quality of life as well as enhanced independence and self-determination (*3*). Also, from an economics point of view, there is a financial cost to the fact that PwIDs cannot participate in professional, social, or economic life because their mobility needs are not met.

PwIDs in supported-living schemes (e.g., living dispersed in the community) tend to have greater levels of social inclusion compared with those living in residential homes or campus-style settings (*1*). Low-support settings are preferable, both in terms of flexibility and quality of life for PwIDs themselves and in terms of cost for service provider agencies and families (*4*). In addition to living, working, and utilizing community amenities, community inclusion includes movement in and around public settings using public transportation (*5*), thereby increasing independence by offering more employment opportunities and by accessing both community facilities and recreational activities (*6*).

An important step toward building more inclusive societies consists of alleviating the challenges faced by persons with disabilities (*7*). Along with over 100 other countries, Belgium ratified the UN Convention on the Rights of Persons with Disabilities stating that society needs to take the necessary measures to guarantee the full exercise of rights to persons with disabilities (*8*), for example, by improving accessibility (*9*) and barrier-free access to public transportation. Increasing attention is being paid to the inclusivity of the mobility system, as evidenced by more accessible vehicles (e.g., low-floor buses) and stations, the design of public space, and adapted individual mobility services, among other factors. Large investments are made, mainly to improve the physical accessibility of public transport, since the discussion of accessibility is mainly focused on technical, structural, and constructional facts (e.g., kneeling buses) (*10*).

However, many PwIDs do not use the public transport system independently because of social barriers: anxiety about traveling alone, not knowing how to use the system, or lack of experience. There may be barriers for PwIDs when traveling independently (*10*) because of the lack of staff for assistance or the presence of unsafe areas or streets for walking (*11*), which impede or prohibit self-dependent use of transportation (*12*). Using public transport includes complex routes and schedules, possible transfer requirements, and unfamiliar destinations (*13*). Among other factors, PwIDs may encounter difficulties with changes in timetables or cancellations, leading to panic or loss of control (*10*). A study about PwIDs going missing showed that in 15% of the disappearances there was evidence that the missing person had a fascination with public transport or that he or she had been familiar with a particular route but a journey had been disrupted (*14*).

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Family or support staff may also limit independent traveling because of fear for individual safety (*13*). Since questions may arise regarding the ability to continue to travel independently, family members, friends, or volunteers may feel the need to become involved to provide additional companionship (*15*). It has been shown that there is indeed the need of a supportive network for the independent use of public transport by PwIDs (*16, 17*). It was shown previously that a possibility might be to equip PwIDs with mobile phones including a GPS tracking function, so that family members or caregivers can inform them about certain incidents, such as a significant delay or lateness of vehicles, or locate them when necessary (*10*).

In order to both support the independent outdoor mobility of PwIDs themselves and to reduce the caregivers' burden due to companionship of the person during the trip, the geographic information system–based application "Viamigo," by which an individual can be monitored in real time from a distance, was developed. The goal is that PwIDs (i.e., the users) are taught a known individual route, which they can accomplish independently afterward while being monitored by a personal coach. This coach can be a caregiver, family member, or friend of the PwID who takes care of this individual while making a trip. The application determines the location of the user and compares this in time and space within a predetermined range, so that deviations from the planned route can be detected. In the case of deviations, the application automatically sends a signal to the coach and the exact location of the user can be identified in real time. By means of Viamigo, PwIDs have more confidence to travel independently, leading to a higher quality of life. Besides, the social network feels safer if the coach can detect in real time where the PwID is. Viamigo is an information and communications technology–based solution assisting PwIDs living independently in the community (according to the concept of ambient assisted living).

The paper is structured as follows: first, the general operation of the Viamigo application and its main characteristics are described in detail. Next, initial descriptive results of some pilot users of Viamigo are discussed. The paper concludes with a discussion of the strengths and challenges of the application and major conclusions.

OPERATION OF VIAMIGO

On-Route Functionality

The operation of Viamigo consists of three main steps. As a first step, the user (the PwID) learns to take a new route together with his or her personal coach. In a second step, the specific route is registered in the web interface together with some characteristics of the route like the sequence, preference of notification, and travel mode of route segments. Safe zones and dangerous zones can also be defined by the coach. When the user wants to make the trip independently after a learning period with the coach, he or she selects in a third step the desired route in the application on a smartphone. The coach automatically receives a signal on the phone when the user starts the trip, the user gets too far from the planned route or stays a long time in the same place, and when the user completes the route, depending on the predefined characteristics. Besides monitoring the route by notification on the phone, the coach can also follow the route of the user in real time on the website.

User Learns New Route Together with Coach

As a first step, the user learns to take a new route together with the personal coach. The route may consist of one or several travel modes and may include use of public transport (but not necessarily). The learned route is mostly a recurring trip that is or will be frequently executed by the user, for example, to work or to the day center, to family or friends, and to the nearest convenience store. After a learning period of one or several weeks, the duration of which is dependent on the capabilities of the user, the user should be able to make the trip independently being monitored by the coach.

Coach Registers Route of User in Web Interface

In the Viamigo web interface, a map is shown in OpenStreetMap, an open-source, community-built, and free application on which the different routes of the user can be registered and displayed. The Viamigo technology allows creating routes in a user-friendly and intuitive way, with automatic routing according to the transport mode. First, the coach creates a route, which consists of different points of interest, destinations, or intermediate points to which the user is traveling (e.g., work, home), with at least one start point and one end point. After creation of the route, further details of the specific route can be added, like the name of the route and the specific travel mode for the entire route or for each separate route segment.

Optionally, safe and dangerous zones can be defined. Examples are a mountain biker who is allowed to deviate in the forest from the proposed route as long as the biker stays in the green (safe) zone or an industrial zone that is identified as a red (dangerous) zone because of the high amount of truck traffic.

Preferences for notification can be defined. By default, the coach will be alerted when the battery of the user device becomes low, when the GPS reading is too old, or when the user device does not seem to have connectivity anymore. Also, the coach can get an alert if the user deviates more than a specified distance from the route (e.g., more than 100 m), stays in the same place for a certain time duration (e.g., more than 10 min), or goes into or out of a safe or dangerous zone; all alerts are individually adjustable by the coach so that they are tailored to the needs and capabilities of the specific user (Figure 1).

User Wants to Travel Route Independently and Is Monitored in Real Time by Coach

When the user wants to make a trip independently that had been learned earlier (Step 1) and was registered by the coach (Step 2), the PwID selects the desired route on his or her smartphone by the name of the route or by a predefined, personalized picture of the route. When the user has selected a route and thus wants to start making a trip, the coach receives a signal on his or her own smartphone that the user wants to depart. The coach can now confirm this trip or can reject it. Meanwhile the user gets a message to wait for the response of the coach. If the trip is confirmed, the user gets a message that the trip can be started. If the trip is rejected, the user gets a warning symbol not to start the trip and has the option to call the coach to ask for further information, instructions, or both (Figure 2).

On the basis of the predefined characteristics (Step 2), the coach may receive several notifications during the route of the user, including but not limited to the following:

- Start of the route. After approval by one of the coaches, all coaches (both the responsible and the observing coaches) automatically receive a signal that the user has started the requested trip.

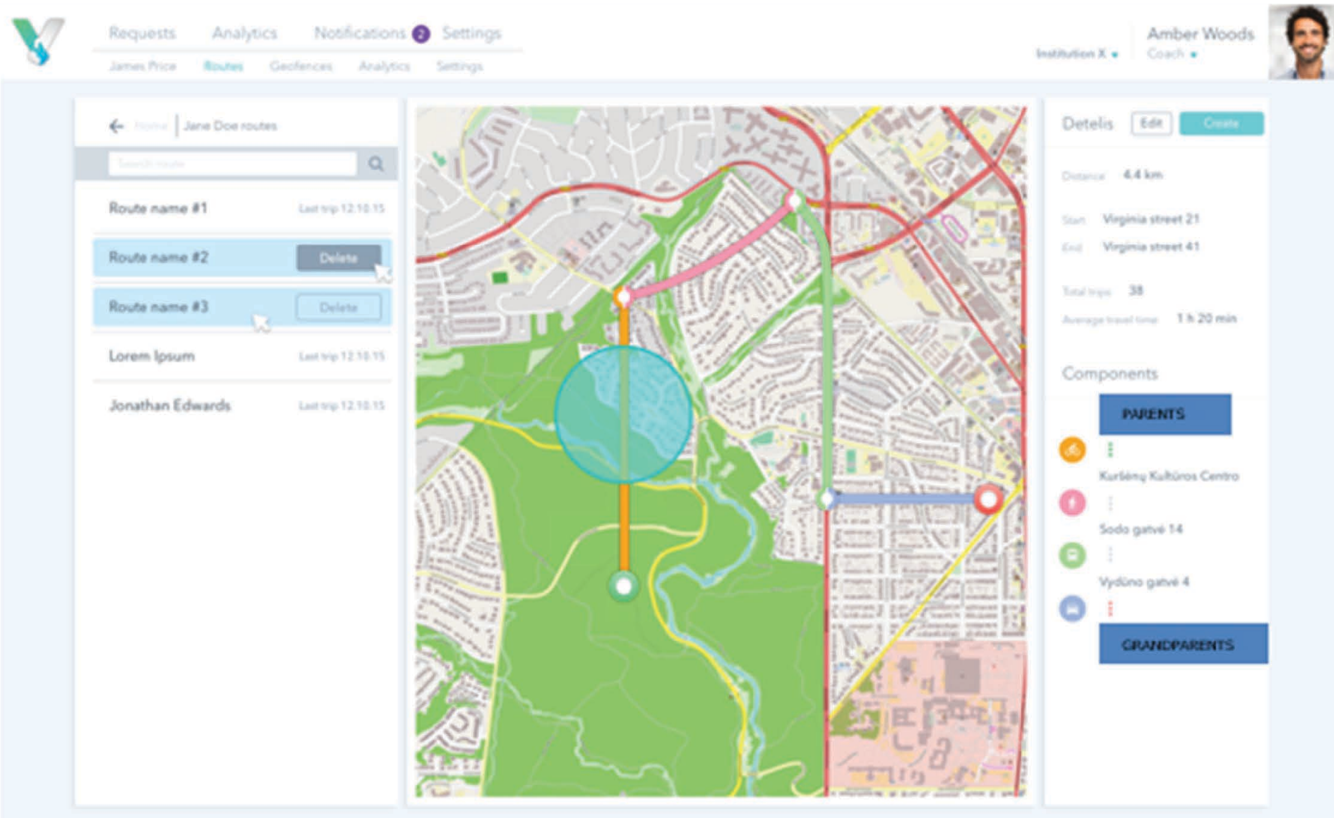

FIGURE 1 Overview of web interface of Viamigo: creating route segments.

- Deviation from the route. If the user deviates from the route, this action could indicate that the right route has been forgotten, so the coach can contact the user with further instructions. These settings can be very strict in the beginning (e.g., get a signal when the user deviates more than 100 m from the route) but can be made more flexible later (e.g., get a signal when the user deviates more than 1 km).
- Entering or leaving safe zones. The coach can be notified when the user has entered a safe zone (e.g., the area around the home, which is very well known by the user) and thereby knows that the user can stay in this zone without experiencing any difficulties. The coach can get a signal when the user has left this safe zone, so the coach knows that from that part of the route the user may encounter some difficulty.
- Entering or leaving dangerous zones. The coach can be alerted when the user has entered a dangerous zone (e.g., a busy intersection or a complicated station environment), so the coach can choose to call the user to ensure that everything goes well.
- Incorrect speed. If the user uses an incorrect speed (e.g., when traveling by public transport), this could indicate that there is a delay (possibly leading to longer travel times). Another example of something that is potentially wrong is a high speed measured on a segment where the user is supposed to be walking.
- Standing still for too long. If the user is standing still for too many minutes (e.g., more than 5 min), individually adjustable by the coach, this situation could be explained by the fact that the user is confused about the continuation of the trip and needs more instructions from the coach. However, by monitoring the location of the user in real time (through the smartphone or website), the coach can detect if the user is just performing some short activity during the trip (e.g., buying something in a shop located on the route).
- Route completed. After completion of the route, all coaches automatically receive a signal that the user has successfully completed the trip (so the users do not have to be monitored further).

Besides monitoring the route by notification on the smartphone, it is also possible to follow the route of the user in real time on the web interface. The coach can see on the map where the user is at that moment and can see all sent notifications as well. When the user deviates from the route, the coach can make a phone call to the user to explain what he or she needs to do or can travel to that point to pick up the user, depending on the abilities of this specific user.

Geofencing and Emergency Tracking

Viamigo also allows monitoring whether the user stays within a predefined zone. For example, when the user has arrived at the destination after the trip, the coach might want to check that the user stays within the surroundings of this destination. It is possible for the coach to simply create a geofence around this location, the preferences for notifications of which can be defined as well.

In addition, if the user is not being monitored during a specific trip, but the coach does not know where the user is at a specific moment, the coach can start the functionality of "emergency tracking," whereby the coach can detect the location of the user in real time through the smartphone or the website.

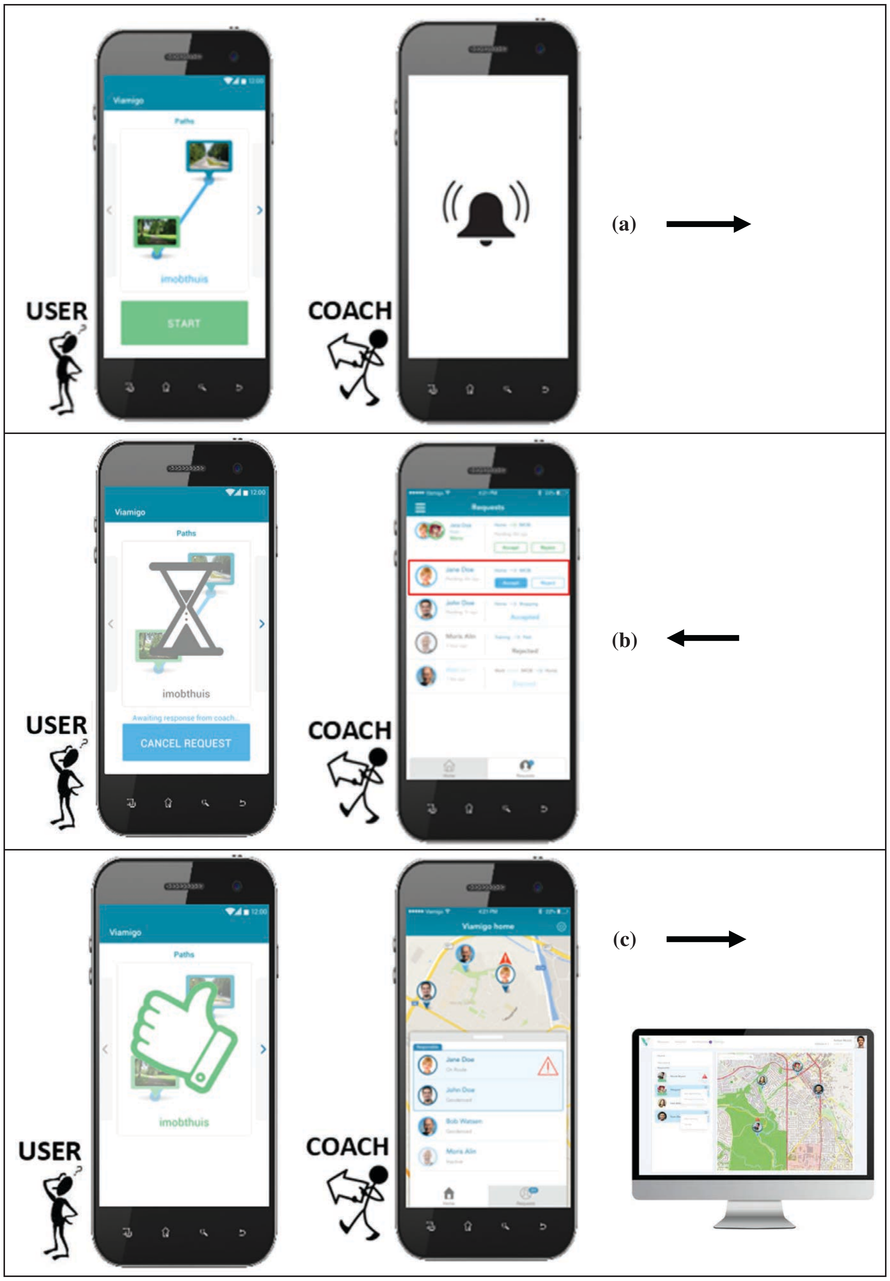

FIGURE 2 Steps in operation of Viamigo: (*a*) selecting a route by user, (*b*) waiting for response of coach, and (*c*) monitoring by coach in real time by smartphone and website.

Main Characteristics

To the best of the authors' knowledge, other GPS-based systems that exist on the market are solely tracking systems, most of which involve at least one crucial user requirement that is not met, such as notifications that are not defined or not working properly in specific circumstances; not being user-friendly enough; or lacking robustness (e.g., no notification when the system is not working because of a poor GPS signal) (*18*). During the user-centered design development process of Viamigo, the heterogeneous needs, preferences, and constraints of the target group (PwIDs) are fully taken into account, ensuring that the resulting solution is tailored to the target population and therefore meets all key user requirements.

A short (but not limitative) list of important characteristics of Viamigo are described as follows.

Form Factor

The smartphone used is commodity hardware. Benefits are that the purchase cost is limited (since no additional device is needed), users are less likely to forget to take it when leaving the house compared with a custom-dedicated device, and it is less stigmatizing for the users themselves (since it is less visible for outsiders that it is an assistive instrument used by PwIDs). In case of problems, the user can always use the phone to call the coach.

History of Traveled Routes and Locations

The detailed overview of traveled routes and locations provides useful insights into the behavior of the user as well as into potential difficult or dangerous locations. This information can be used to efficiently practice the problematic segments of the routes together with the coach.

Individually Adaptable Settings

The coach can personalize the preferences for notification dependent on the specific needs and abilities of the user. The settings can easily be changed during the user's learning process; it is possible to set the limits to be less strict (or more flexible) in time if it appears that the user manages to travel the route without perceiving any problems.

Community of Coaches

Viamigo allows the linking of several users per coach, a functionality tailored to health care facilities in which employees can monitor multiple users at the same time with their own application. Viamigo also allows linking of several coaches per user, who can belong to different settings, both formal (employees of a health care organization) and informal (family members). For example, a user going from home to the day center in the morning can be monitored by his or her mother as coach while for the trip back home in the evening can be monitored by a caregiver as coach. Viamigo builds a virtual organization on behalf of the user. In the case of multiple coaches, the distinction between responsible (confirming the trip as the first coach) and observing coaches makes it clear who has the responsibility to monitor the user during a specific trip.

Geofencing

Safe and dangerous zones can be set by the coach both before the trip (in the web interface) and ad hoc during the trip (on the smartphone). Preferences for notifications can be defined in terms of entering or leaving the zone and the time duration of staying in the zone, among other factors.

Focus on Robustness

The communication and the design are focused on robustness. The communication runs through centralized channels (PubNub push messaging service) that have a significantly higher reliability than, say, Google cloud messaging or Apple push notifications. If push messaging fails, the application degrades to a less strict form of real-time communication (representational state transfer application program interface calls). If the battery level of the user's smartphone is low or the smartphone of the user has insufficient Internet or GPS connection, the coach will automatically be notified.

Cloud Experience for Coach

The coach can use any device (and also multiple devices at the same time) to monitor the user. By responsive design, the application seamlessly works on smartphone, tablet, and personal computer.

Configurability of Alerts

Viamigo has a comprehensive set of possible alarms that can be monitored by the coach, including dwell time, deviation from the route, no network, GPS connectivity, or all four.

INITIAL RESULTS FROM PILOT USERS

Preliminary results from five PwIDs using the Viamigo application between 7 and 15 months are presented. Participants were recruited from outpatient care organizations (day centers) for PwIDs and were given a full explanation of the study, its purpose, and their role. All participants had at least one coach, generally a family member or a caregiver from the day center, who was able to monitor their trips. All participants were men and were diagnosed with an intellectual disability. The analyses discussed here are the product of a small sample of participants and are therefore only based on descriptive statistics (without testing for significant differences). Advanced statistical analyses are needed in follow-up research with a larger sample to test whether the presented trends can be generalized.

Trips Performed with Viamigo

All traveled trips by the participants are aggregated so that general trends emerging from the data can be observed. The results from all users showed that for the majority of trips, Viamigo was used for trips by public transport (more specifically by bus) and typically a walking segment was also included as before or after transport from or to the bus stop. Viamigo was also used for several cycling trips. The number of trips that a person generates at a certain time could be used as an indication of the person's activity level (*19*).

In Figure 3, the peak in the morning hours (between 8:00 and 9:00 a.m.) is clearly visible, indicating the almost daily recurring

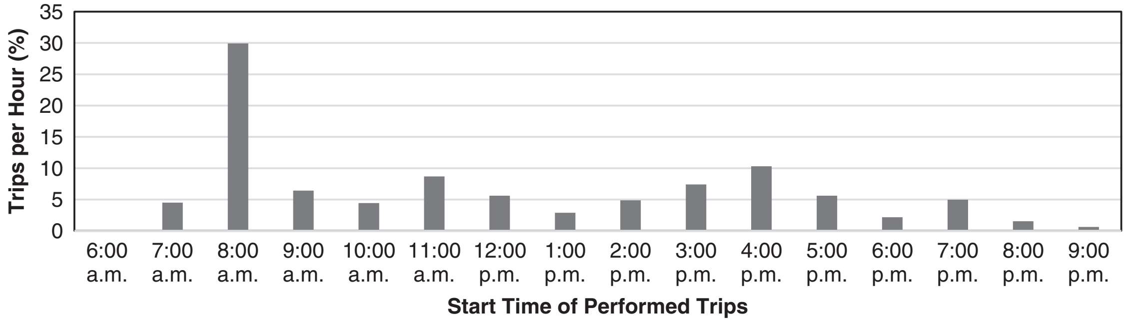

FIGURE 3 Percentage of trips per hour performed by all participants.

trips of the participants from their home location to the day center. There is a second, lower peak in the afternoon (between 3:00 and 5:00 p.m.), indicating the homeward trip from the day center. Participants are also making trips during the other hours of the day, for example, in the late morning and in the evening; this result demonstrates that the Viamigo application is used not only for the recurrent trips from or to the day center but also for more flexible trips for other activity purposes. For example, after a while, Pilot User 5 also used Viamigo to travel to some friends (social activity), to a restaurant and a cafeteria, to the nearby station, to a seminary center, to the doctor, and to a fitness center, among other destinations.

Time Between Route Request and Response by Coach

Figure 4 shows the number of seconds between the route request by the user and the approval or rejection by the coach. The results show that in the majority of the route requests, the coach responds within a very short time period of less than 30 s, so the user does not have to wait long before being allowed to start the trip (if confirmed). The time between route request and response by the coach is shorter in the early morning hours (between 7:00 and 8:00 a.m.) as compared with other hours of the day (e.g., in the later morning or during the afternoon). This finding can possibly be explained by the fact that the early morning trip to the day center always occurs around the same time, so the coach expects the user to leave at that time and is therefore more prepared to accept the request and monitor the user. During the rest of the day, the coach may be busy doing other things (e.g., working) and the departure time of the user's trip may be less fixed, so it can take somewhat longer before the coach responds. However, because of the fact that multiple coaches can be linked to one user, the user can always start the trip as soon as one of the coaches has given approval.

Number of Notifications During Trips

In general, 61% of all notifications to the participants are due to route deviation, 28% are related to an incorrect speed, and 11% to entering or leaving a dangerous zone. There seems not to be an obvious relationship between the number of notifications and the travel mode used.

Figure 5 shows that in the majority of trips, the participants receive between one and five notifications during each trip. Except for User 5, in around 85% of the trips the participants seem to be able to complete the trip with only a few notifications. However, notifications are not always problematic or undesirable, since, for example, a dangerous zone may lie on the route and has to be passed, for which the coach might have predefined receipt of a signal each time the user enters or leaves this dangerous zone. This can be one of the reasons why the coach of User 5 gets more than five notifications in 40% of the user's performed trips. Another explanation may be that this user is still learning a new route, for which the coach has chosen to set strict limits (e.g., a notification when the user is deviating more than 50 m from the route or is standing still for more than 2 min).

Distance of Registered Routes

Despite the fact that the pilot users started using Viamigo recently, the results show that the trips that they are making independently by using Viamigo are both short and longer trips. Figure 6 shows that the majority of the registered trips in the web interface (by the coach) are between 5 km and 30 to 40 km. User 5 seems to use Viamigo also for six trips that are more than 40 km, which can explain why the number of notifications for this user (see subsection on number of notifications) is higher than that for the other users.

DISCUSSION OF RESULTS AND CONCLUSION

Persons with intellectual disabilities often aspire to being more socially included by engaging in more community activities but may encounter social barriers when they travel independently because of lack of experience, lack of staff for assistance, unexpected timetable changes, or cancellations, among other factors. A supportive network is necessary for the independent use of public transport by PwIDs, who are often accompanied by family members, friends, or volunteers while traveling. In order both to support the independent outdoor mobility of PwIDs themselves and to reduce the caregivers' burden,

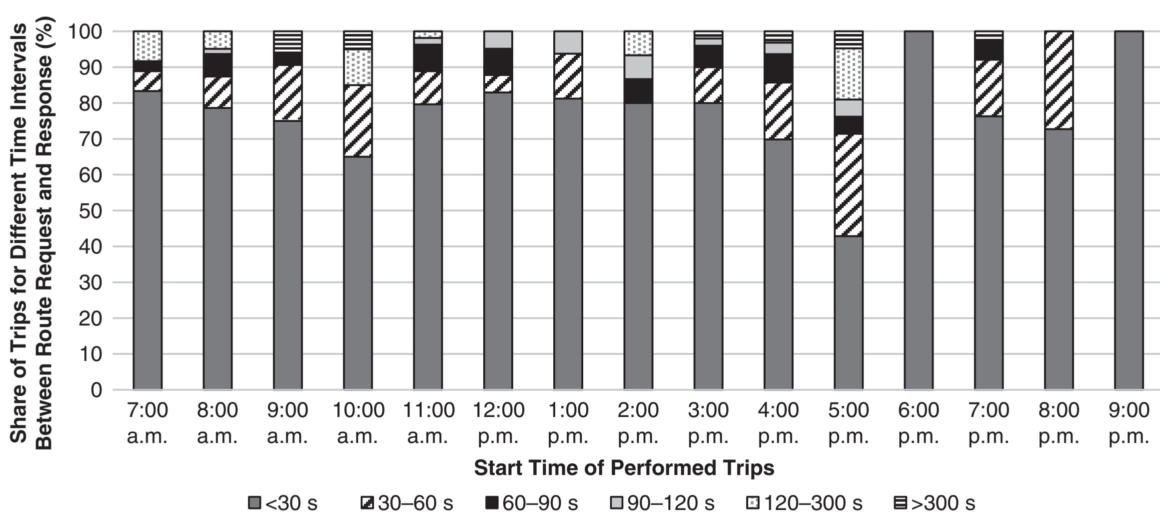

FIGURE 4 Number of seconds between route request by user and approval or rejection of trip by coach.

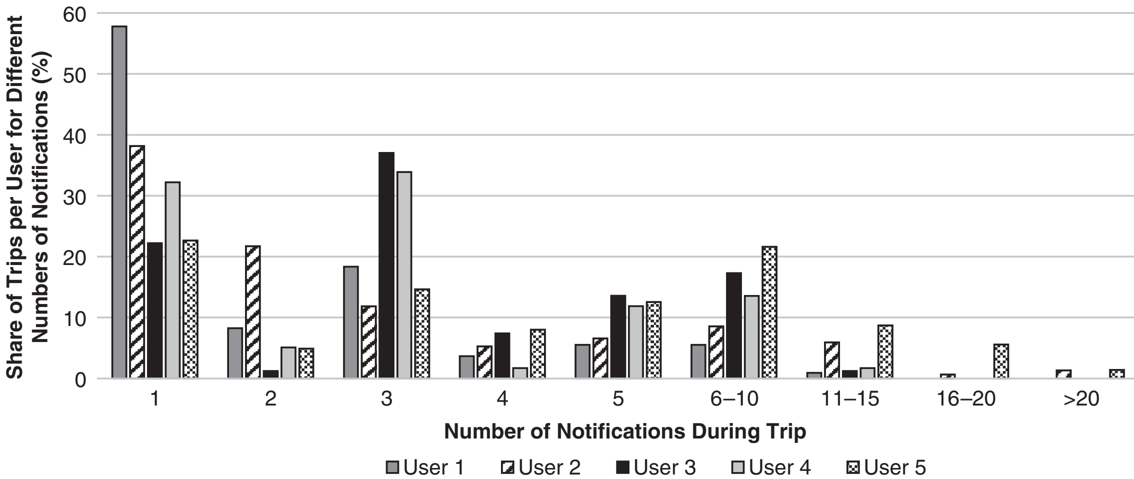

FIGURE 5 Number of notifications per user during the trip.

the geographic information system–based application Viamigo was developed, through which an individual can be monitored by a personal coach in real time from a distance. The application determines the location of the user and compares this in time and space within a predetermined range and automatically sends a notification to the coach in case of deviations from the route.

The initial results from a small number of pilot users showed promise; Viamigo was used for a heterogeneous set of trips: trips performed by several travel modes (bus, cycling, and walking trips), trips performed for several activity purposes (both daily recurrent trips to the day center and trips for shopping, social, and recreational purposes), and trips with different distances (both short and longer trips). Viamigo is currently being improved on the basis of the needs and preferences of the target population; follow-up studies in larger samples are needed to assess if the presented trends can be generalized.

Viamigo attempts to meet several articles of the UN *Convention on the Rights of Persons with Disabilities* (*8*). The use of Viamigo contributes to more independent living of PwIDs in the community because it facilitates their movement in and around the community by eliminating transportation barriers (Article 9, Accessibility). Viamigo enhances the personal mobility of PwIDs with the greatest possible independence because it ensures that they can make trips in the manner and at the time of their choice and at affordable cost (Article 20, Personal Mobility). Furthermore, Viamigo encourages their participation in social and recreational activities and makes possible more autonomous travel to several destinations without the need for an attendant during the trip (Article 30, Participation in Cultural Life, Recreation, Leisure, and Sport). Viamigo can be used by PwIDs with different severities of disability, but users should have at least the ability to realize that he or she must request the trip and also understand what it means for a trip to be not approved.

Besides supporting the independent outdoor mobility of PwIDs themselves, hereby enhancing their community participation, autonomy, and quality of life, Viamigo offers advantages on different levels. The social network of a PwID feels more confident and safe because the coaches always know where the user is in real time. Moreover, since the coaches do not have to accompany the user during each trip, their burden is significantly reduced and they can now perform their own activities during these regained time periods. Viamigo also offers financial advantages for the government since more PwIDs would be able to make their trips independently, for example, by using public transport, and fewer PwIDs would use costly demand-responsive transport options, a substantial portion of the costs for which might be paid by society (*20*). Finally, from the use of Viamigo, the locations can be identified where many PwIDs deviate from their route and that could be perceived as the most problematic. Viamigo is therefore also helpful at a more strategic level: this information is useful for cities or regions in order to make their environments more accessible. For example, if multiple PwIDs from the same region (e.g., clients of a health care organization)

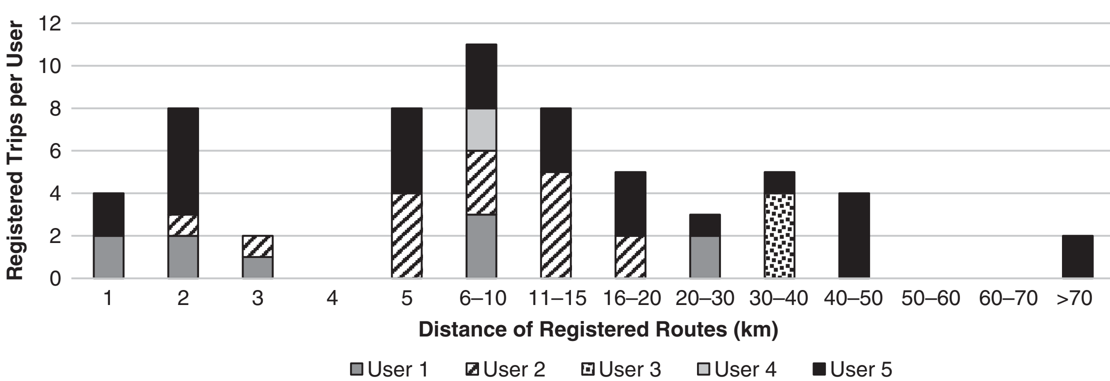

FIGURE 6 Number of registered trips per user for different distance intervals.

used Viamigo, the mobility organization for that region could use the data about the locations where these persons deviate from their routes to prioritize specific accessibility measures.

A number of limitations may be considered. One might argue that the target group of PwIDs is vulnerable to being abused by others through violations or theft of the smartphone or may easily drop the phone so it will be broken. However, the application has been tested on a range of smartphones that goes from entry level to the more expensive and does not require any specific hardware that is not available on a regular, less expensive smartphone. With regard to breaking of the smartphone, rugged smartphones are widely available and used by construction workers in rough environments. One might also worry about what would happen if the PwID deviates from the route or in case of unexpected cancellations or delays of the public transport, which may lead to panic reactions because no one is accompanying the person during the trip. However, in the case of problems, the user can easily call one of the coaches for further instructions. Since Viamigo allows linking of several coaches per user, at least one coach will always be available who can be contacted and can provide additional support for the user.

It may be questioned whether Viamigo causes a violation of the privacy of the users (i.e., the PwIDs) since the coach is able to monitor their location in real time. However, the experiences of the pilot users showed that they had no "Big Brother" feelings while making their trips but on the contrary felt more confident, precisely because they were being monitored and could easily be supported in potential problematic situations. Since data are collected of the user's trips, these data should be treated according to the European Union data protection law. Information that is sent between coaches and users (e.g., the current location of the user) will need to be embedded in secure authentication and authorization protocols to guarantee the privacy of the user. In this small sample, the experiences of the users were only anecdotally surveyed. In a follow-up study in a larger sample, it would be interesting to test the user's experience of Viamigo by using standardized qualitative outcome measures. Further research about the privacy issues of Viamigo is being conducted. Finally, as Viamigo combines several state-of-the-art technologies, it provides a robust solution in which both PwIDs and coaches can have confidence.

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