Audio Guided Driving for People with Blindness with Seated Self-balancing Personal Transporters

Andreas Hub
BNI Blindnavigation International gGmbH
Ayestr. 2
88441 Mittelbiberach, Germany
e-mail: andreas.hub@blindnavigation.org

Jutta Cook
CO_4 Communications
Talfeldstr.10
88400 Biberach, Germany
e-mail: jutta.cook@co4-communications.com

***Abstract*—This paper presents a new approach to increase the range of mobility for people with blindness or severe visual impairments, while enhancing interaction-driven accessibility with sighted people. For the blind or visually impaired, covering longer distances often poses a special challenge; prolonged use of a cane or leaning on a sighted person can be exhausting and can lead to unhealthy and non-ergonomic motions. Guided use of a modified seated, self-balanced single person vehicle enhances accessibility of various environments, serves as physical training, offers great experiences and fosters both self-esteem and independence – thus serving as a catalyst for positive changes in many different aspects of life. Moving together constitutes implicit social interaction and social participation. In this paper, we describe the practical implementation and address challenges concerning the blind drivers' perception of velocity and direction of movement. We expect these challenges to be solved in the near future through the application of either existing or new haptic devices. Our tests with persons having visual, other sensory, or mobility impairments show that they are perfectly capable of driving an AddSeat®, which contributed to significantly increasing accessible environments, enhanced their mobility, expanded their social interaction, increased their physical fitness and greatly improved their general outlook on life.**

Keywords-Interaction-driven accessibility; visual impairments; self-balancing personal transporter; physical therapy training.

I. INTRODUCTION

For people with blindness, it is often a special challenge to cover longer distances. A prolonged use of a cane can be exhausting for the muscles in the hand, arm and shoulder. Walking alongside a sighted person for longer periods of time can be stressful, too, for people with visual impairments. Both can lead to unhealthy and non-ergonomic motions, causing muscle sores, cramps and other discomfort in the musculoskeletal system. Another aspect is that many people with sensory deficits have difficulties or are (for good reasons) afraid of using personal single seat vehicles developed for sighted drivers, such as bicycles, motor bikes or others, such as the Segway® PT (Personal Transporter) [1] that are operated in a standing position.

For a number of years, there has been ongoing research as summarized, e.g., by Mandel in [2] and there is an array of products on the market with a more or less implicit aim of autonomous driving for wheelchair users.

Figure 1. The picture shows a blind AddSeat® driver in an indoor environment.

In contrast to these projects, our study focused on the idea of letting blind people drive on their own as much as possible and be in charge of the device. We assumed that this in particular provides a feeling of freedom and independence, especially when the additional hints given by a sighted guide could be kept to a minimum.

For a few years, there have been several special wheelchairs on the market with only two wheels based on Segway® PT self-balancing technologies, such as a model named Genny Urban 2.0L and one named Freee F2, both available from Urban Mobility 24 [3][4].

Swedish manufacturer AddMovement [5] has one seated, single person vehicle also based on a Segway® PT, which we deemed suitable for this study. Their so-called AddSeat® comes equipped with a panic-braking mechanism that can be easily triggered by moving the seat glider backwards – a feature we thought useful as it compensates for the time-laps between the advice given by the guide and the actual reaction of the blind driver.

For our tests, we used an AddSeat® based on a Segway® PT i2 suitable for indoor environments (Figure 1) as well as outdoors (Figure 2).

Figure 2. The photo depicts one of our blind test persons outdoors in a full stop emergency brake action.

The dimensions of this model are quite narrow, making it hardly any wider than the shoulders of our drivers. This allows for access to any standard elevator. In addition, the AddSeat can turn on the spot as it only has one axle and does not need the additional front wheels of a conventional wheelchair. In outdoor tests with sighted people, it could be shown that the AddSeat® is suitable for gradual inclines as well as demanding ground conditions such as gravel, grass or even firm sand. The vehicle also mastered snowy spots where maneuvering a conventional wheelchair would be challenging. In tests with people with mobility impairments (amputations, paraplegia, autoimmune disorders, etc.) seated self-balancing transporters have already been proven to be a life-changing addition. Customers reported a tremendous increase in quality of life as it enhanced their mobility and independence, it opened up their social range of motion and allowed them to take on completely new roles within their family lives. The changes included self-determined shopping tours, and taking on considerably more responsibility for others, e.g., own young children or domestic animals [6][7].

With these great gains in mind, the question was, if those could also be transferred to people with visual impairments.

The rest of this paper is structured as follows. Section II describes the technical features of the AddSeat® and its benefits for daily life. We also explain the briefing method used for our test persons. Section III describes the resulting feedback from our test drivers as well as possible implications. In section IV, we conclude with lessons learned and suggestions for future work, including desirable technical adaptions and how to enhance the enforcement of the rights of persons with disabilities.

II. Methods

Device: Driving an AddSeat® is quite simple and intuitive. For our tests, we used an AddSeat® model 5.1, equipped with a seat featuring pneumatic suspension and height adjustment. Those features bring a range of advantages. For one, it is more comfortable than a model with a fixed seat. Secondly, the user can raise the seat to a height that allows communication with standing people almost at eye level (depending on the person's height).

Sighted Addseat® drivers told us the elevated position also reduces or annihilates the claustrophobic feelings they often experience in crowds, when all they get to see in a regular lower wheelchair is the less attractive middle part of others' bodies. This feature is not only comfortable for both sides during talks, it also changes perception as it literally raises both partners onto the same level and thereby avoids the unpleasant feeling of being talked down to many people with all kinds of handicaps have to experience on a daily basis.

Handling: With both parking brakes on, the user places himself on the AddSeat®. Then the parking handles on the right and left side have to be released. Now, the PT is in balance mode and the user can start driving. A forward motion is achieved by moving the upper part of the body forward, backwards correspondingly. The underlying technical principle is a shift in the center of gravity. The AddSeat®'s seat is mounted on a sliding rail, enabling the driver to very rapidly shift his center of mass. A quick backwards or forwards shift allows the driver to perform very precise driving motions, such as needed in order to avoid moving obstacles. The quick backwards shift can also be used to rapidly stop the vehicle in an effective full stop emergency brake maneuver. This use of a sliding mechanism can reduce the braking distance by several meters, especially when moving at velocities greater than 10 km/h. For blind drivers, reconnaissance of moving obstacles or other people and animals definitely requires a sighted person to move along and advise appropriately, especially at higher speeds.

Our two blind test persons – one adult woman and one adult man – first received a short introduction to the functionality of the AddSeat®. Both test persons were working for several years as consultants, providing advice on medical aids to people with visual impairments. We knew of both being physically active and having good body tension. Therefore, we expected both to be able to steer the AddSeat® with controlled movements of the upper part of their bodies. In fact, we realized very quickly that they performed much better than some sighted subjects, even without visual feedback. Both drivers quickly grasped how to move forward and backward, how to navigate turns and how to stop using the gliding seat. They intuitively were able to turn in place, e.g., within a narrow elevator. This brief driving lesson only took a few minutes and in principle enabled our blind test drivers to handle the vehicle by themselves. During those explanations, haptic support was used to provide principle movement and velocity information as well as direction suggestions. For this, we used a haptic training method comparable to Riitta Lathinen's haptices and haptemes advices [8]. This method of very short haptic signs was originally developed to provide complex information such as room structures within seconds, using the surface of body parts of people with deafblindness. We adapted this method for navigation purposes. The role of the sighted guide was then to give either acoustical hints such as “more left or right” or “slower and faster” or to provide this kind of short haptic navigation advices. To enhance the forward movement, the sighted guide gave a gentle tap on the driver’s upper back until the velocity was appropriate with respect to the environment and the driver’s capacities. To trigger a left or a right turn, a finger tap was given on the corresponding shoulder. Braking or velocity reduction were induced by a softer and longer tip with the finger or hand on the front of the driver’s shoulder.

After this “haptic” driving lesson, further minimal driving hints were provided acoustically by the sighted guide – comparable to guided alpine or cross-country skiing. We consider this to be the preferred guiding method as long as there are no hearing problems or noisy environments.

III. Results

Both blind drivers learned to understand, to steer and to control the AddSeat® within a few minutes. Bigger challenges arose for the sighted guides, who had to keep up and provide adequate and precise acoustical navigation advice.

As part of the results we would like to cite one of our blind test drivers (A.K.): “At the exhibition “RehaCare” in Düsseldorf, I had the great possibility to take a ride on the AddSeat.

First, I had to find out how to really get myself positioned on the seat and that I could easily determine directions by moving my body forward, backward and to the sides. The first motions were a little bit shaky, but once I got used to the AddSeat and learned how to control it, riding became more and more fun. After a short while, I got a good feeling on how to move backward and forward and how to slow down or to speed up. After we moved around through the halls for a while, we went outside and I could ride the Add-Seat in “open-air”. I enjoyed moving through the crowd, listening to the noises around me. In addition, it was a warm, lovely afternoon. Much too soon, the ride was over and we had to get back to the booth where we had started off. In a nutshell: I enjoyed this experience a lot and would do it again any time.” The statement of the second person (S.P.) was quite similar with regard to contents.

Both blind test persons reported that it was not always clear for them whether they were driving forward or backward as they were missing visual input, in particular when moving slowly. For the same reason they reported difficulties estimating their current velocity.

Although blind use of an AddSeat® is not completely without risks, the atmosphere during the tests was very relaxed. And it turned out that joining in this new type of sports activity offered pure fun for the test drivers as well as for the sighted guides. While guided skiing can only be done in special places and when snow is available, guided driving with AddSeats® does not have those restrictions. It can generally be performed anywhere at any given time.

The results from additional test drives and discussions with other blind people about seated self-balancing personal transporters were that these vehicles can and will have many more implications aside from fun and sporting activities. We include these implications in the following section.

IV. Conclusion and Future work

The idea of letting blind people by themselves handle a vehicle that can travel up to 20 km/h might at first glance look somewhat dangerous. And many people with sensory deficits have difficulties or are afraid of using personal single seat vehicles developed for sighted drivers, such as bicycles, motor bikes or vehicles operated in a standing position like a regular Segway® PT.

On the other hand, blind skiers proved able to reach amazing speeds beyond 100 km/h. In our study, it was not our aim to determine how fast one can go or to look into legal aspects such as registration, liability insurance or restrictions to access in different places. Our main focus was: can persons with blindness or visual impairments safely maneuver an AddSeat®, and what positive implications do they stand to gain?

During our test drives we learned:

- Driving an AddSeat® is not without risks (which might be the nature of many things fun) – in particular when driving with visual impairments or blind.
- Under the pre-condition of good control over the upper part of their body, driving an AddSeat® can greatly enhance the quality of life for the blind as well as people with visual impairments.
- Steering an AddSeat® is sport and good physio, as it provides training for a better control of the upper body in an ergonomic position by supporting improvements of the abdominal and back muscles.
- Even drivers lacking physical fitness are able to cover long distances in a healthier position for the upper part of their body, compared to conventional wheelchairs. The range of an AddSeat® can extend 30 km depending on several factors such as wind speed and direction, the driver’s weight, the contour of the terrain or the traction of the wheels. This greatly enhances the radius self-determined and largely independent movement for the driver.
- We are sure that audio pilot systems used in blind alpine skiing can significantly enhance the quality of navigation advices as well as allow for better and more regular conversation between the blind driver and the guide.
- From our tests with sighted people with mobility restrictions, we established the large influence of the AddSeat® on the aspects of life we differentiated as “fun”, “freedom” and “family & friends”, resulting in a more self-determined, independent, non-discriminated and equitable life. We do not see any reasons why those results should not apply to blind people. However, we recommend that blind people drive only with an experienced guide – perhaps on a second vehicle in order to keep up – especially in challenging environments such country lanes, steep roads etc., and most certainly at higher speeds.

- After all our experience concerning navigation support for people with blindness and deafblindness [9]-[11], there is no doubt that quite a number of them will be able to profit from driving AddSeat®. However, people with complete deafblindness will benefit strongly from additional interfaces to interact with the sighted guide. One option would be to use slightly modified systems, such as the NavBelt [13]. Alternatively, other additional handheld devices offering adaptive control elements and a haptic compass could be applied [14].
- Guided AddSeat® driving might be the basis for important additional social interactions as well as a healthy, ergonomic way of moving also for people with multiple mobility restrictions concerning sensory and/or physical aspects.

FUTURE WORK: To solve the issues of missing information for blind drivers concerning current position, movement direction, orientation and velocity, we implemented human advice. In the future, we suggest to standardize acoustical or haptic advices or the use of additional technical support. So far, we identified two possibilities. One: Haptic devices to be either carried on the driver's body or mounted to the AddSeat®'s seat or steering bar. The other option would be the implementation of autonomous driving systems used in cars or other wheelchairs with four wheels. During our experiments however, we gained the impression that our test persons appreciated the self-determination and independence coming with being in control of the machine.

Future work should also include the question, if the AddSeat® can be used to support more people with visual impairments and different degrees of restrictions. More research should be conducted to determine whether the positive effects of using an AddSeat® can be translated into other aspects of life, such as the workplace. Maybe it is possible to create new kinds of workplaces or make existing employment opportunities accessible for these groups of people.

Lastly, one of the major stumbling blocks also needs to be addressed in the near future: the question under which legal conditions and/or training requirements the blind driver and the guide are allowed to drive on public streets in different countries. Our tests have shown that suitable, hearing test persons were able to steer seated personal transporters indoors and outdoors with a high degree of precision, supported by a sighted guide. The United Nations' Convention on the Rights of Persons with Disabilities [15] requires all parties to support technologies and solutions affording persons with disabilities include the rights to accessibility, the rights to live independently and be included in the community (Article 19), to personal mobility (article 20), habilitation and rehabilitation (Article 26), and to participation in political, public, and cultural life as well as recreation and sport (Articles 29 and 30). Therefore, rules and regulations on a national, regional and local level should be amended in order to allow for blind people to operate such vehicles in combination with a guide.

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REFERENCES

[1] http://www.segway.com/ 2018.03.07

[2] C. Mandel. Navigation of the Smart Wheelchair Rolland. Kumulative Dissertation, 2007.

[3] http://www.urbanmobility24.de/genny.html 2018.01.31

[4] http://www.urbanmobility24.de/Freee.html 2018.01.31

[5] http://addmovement.com/ 2018.03.07

[6] http://addmovement.com/customervideos.html 2018.01.31

[7] http://addmovement.com/AddMvideos.html 2018.01.31

[8] R. Lahtinen. Haptices and haptemes. A case study of developmental process in touch-based communication of acquired deafblind people. PhD thesis, 2008.

[9] A. Hub, J. Diepstraten and T. Ertl, "Design and development of an indoor navigation and object identification system for the blind" Assets '04: Proceedings of the 6th international ACM SIGACCESS conference on Computers and accessibility, pp. 147-152, 2004.

[10] A. Hub, "Map Requirements and Attainable Public Policy for an Installation-free Worldwide Navigation and Information System for the Blind" In: Proceedings of the 9th International Conference on Low Vision (Vision 2008), July 7-11 Montreal, Canada, 2008. [Online]. Available from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.230.927&rep=rep1&type=pdf 2018.02.04

[11] A. Hub, "Integration of Active Tactile Control Braille Technology into Portable Navigation and Object Recognition Systems for the Blind and Deafblind" In: Proceedings of the 9th International Conference on Low Vision (Vision 2008), July 7-11 Montreal, Canada, 2008. [Online]. Available from: ftp://ftp.informatik.uni-stuttgart.de/pub/library/ncstrl.ustuttgart_fi/INPROC-2008-128/INPROC-2008-128.pdf 2018.01.01

[12] A. Hub, "Guiding Grids in Augmented Maps for Precise Installation-Free Worldwide Blind Navigation" In: Proceedings of the California State University Northridge Center on Disabilities' 23rd Annual International Technology and Persons with Disabilities Conference (CSUN 2008), March 10-15, Los Angeles, CA, USA, 2008. [Online]. Available from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.230.1905&rep=rep1&type=pdf 2018.02.04

[13] J. Borenstein, "The NavBelt - A Computerized Multi-Sensor Travel Aid for Active Guidance of the Blind" In: Proceedings of the CSUN's Fifth Annual Conference on Technology and Persons with Disabilities, Los Angeles, California, March 21-24, pp. 107-116, 1990.

[14] J. Winterholler and B. Janny, "Innovative Haptic Interface for Navigation" In: Proceedings of the California State University Northridge Center on Disabilities 28th Annual International Technology and Persons with Disabilities Conference (CSUN 2013), February 25 - March 2, San Diego, CA, USA, 2013. [Online]. Available from: http://www.csun.edu/cod/conference/2013/sessions/index.php/public/presentations/view/130 2018.02.01

[15] United Nations. Convention on the Rights of Persons with Disabilities. [Online]. Available from: http://www.un.org/disabilities/documents/convention/convoptprot-e.pdf 2018.01.30