Haptic Guided Driving with Seated Self-balancing Personal Transporters for People with Deafblindness

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***Abstract*—In this paper, we will present the experiences from our work in progress with a first test drive with a new seated self-balancing personal transporter by an entirely deafblind driver, supported by a guide. Our aim is to help reduce the feeling of isolation and dependency and the restrictions in the range of mobility deafblind people report. Using this personal transporter greatly enlarges the distance a deafblind person can cover in a self-determined way. Being active and moving together constitutes significant, essential social interaction and social participation. It offers a very relaxed atmosphere of independence while fostering a relationship of mutual trust. Within this paper, we describe how it works and also some challenges concerning the deafblind driver's feelings about missing visual information such as the position, the driving direction and the current velocity. These challenges might be solved in the near future by using additional existing or new haptic devices. We are confident that, this way, we could make significantly enlarged environments accessible in a smart way for people with deafblindness as well as for people with additional physical restrictions.**

Keywords-accessibility; deafblindess; mobility; haptics; self-balancing personal transporter.

Figure 1. Successful tests with sighted people with other mobility restrictions (in this case a high leg amputation) were the motivation to expand these tests to guided driving with a deafblind person.

I. INTRODUCTION

For years, there have been numerous research projects, e.g., the Rolland project [1], as well as a number of quite sophisticated products on the market, enabling drivers to use electronic wheelchairs autonomously or with only a minimum of motoric input, such as eye trackers, minimal joysticks or other control mechanisms that can be operated, e.g., with only one finger or a small head motion.

In contrast to these wheelchairs, the self-balancing personal transporter we used demands real physical activity from its driver. The so called AddSeat® by Swedish manufacturer AddMovement [2] is a self-balancing seated single person vehicle based on a Segway® Personal Transporter (PT). It was initially developed to enable people with physical mobility restrictions such as amputations, paraplegia, autoimmune disorders, etc. to move around more self-determined than in a regular electric wheelchair.

In field reports and video documentations, we were able to show that driving a seated self-balancing Personal Transporter for several weeks can significantly increase the independence and quality of life. This includes feelings of joy and fun brought on by experiencing the physical sensations of movement. This is also applied in challenging environments such as trails, grass, snow, or sand where it would be difficult or impossible to maneuver with other types of wheelchairs (Figure 1).

People with complete deafblindness rarely have an opportunity to feel the physical forces that come with driving a motor-powered vehicle on their own, such as acceleration or centripetal forces, including the fun and the feeling of freedom that can be related with driving faster. However, from our previous work concerning navigation support for people with deafblindness [3]-[7], we know some of their dreams of freedom and independence concern mobility, including the wish to drive extremely fast vehicles, such as motorbikes even Jet Skis®. Especially in cases where deafblindness occurs only later in life, people might already have gained the experience of driving, and really want to do it again. With this background in mind, we established the idea of letting a first, suitable deafblind test person drive an AddSeat® (Figure 2).

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Figure 2. The photo shows the test driver on the vehicle, receiving a short briefing on how to steer the AddSeat® sighted guide using Lorm fingerspelling.

Good posture and control of the upper body is the main pre-condition to being able to steer an AddSeat® in a controlled manner. This applies to sighted drivers, too. According to our experience, some people with complete deafblindness have very good posture and body control even though they are lacking visual or acoustical input, which makes visual or acoustical corrections of malposition impossible.

In prior tests with people with mobility impairments, the AddSeat® technology has already proven to be a life-changing addition [8]. Participants 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. Additionally, it turned out that people without mobility restrictions can benefit from this vehicle, too. The AddSeat® can cover distances beyond 30 km. Its big wheels and good traction even make decent slopes, farming roads or broader trails in the mountains accessible. We see a special benefit in this way of locomotion for people with visual impairments, as 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. Both can lead to unhealthy and non-ergonomic motions, causing muscle sores, cramps and other discomforts in the musculoskeletal system.

During prior experiments with blind AddSeat® drivers, we saw that their abilities to control both their bodies and the vehicle often surmounted those of sighted subjects. In comparison to persons with deafblindness, blind people have the advantage of being able to estimate their current position, direction, and velocity by using acoustical input; they either use noises in the environment or produce sounds of their own, as a click of the tongue, singing, talking or knocking the cane on the floor, etc. The acoustic response of those sounds helps them to detect environmental structures, such as open doors, and to estimate their own velocity or the velocity of others, such as the Doppler frequency shift of cars near crosswalks. People with complete deafblindness are void of this kind of sensory input. With both visual and hearing senses missing, their sense of gravity and appertaining their sense of body control plays a more important role than in people without sensory restrictions.

Structure of this paper: Section II describes the technical features of the AddSeat® and the methods we used for the briefing the deafblind person as well as for the driving support provided by the sighted guide. Section III describes the results concerning the astonishing feasibility of the principle, but it also addresses the remaining challenges concerning mainly technical issues such as hardware integration. In Section IV, we conclude this early stage of our investigations and suggest a compass for the future work in this new field of research for people with deafblindness.

II. METHODS

Driving an AddSeat® is quite simple and intuitive. The AddSeat® is the only self-balancing vehicle available on the market that is equipped with a panic-braking mechanism, so far. For our tests, we used an AddSeat® model 5.1 equipped with pneumatic suspension and height adjustment. We deemed those features essential in testing seated Segways® with a deafblind person supported by a sighted guide. Those features bring a range of advantages for sighted people, too. For one, it is more comfortable than a model with a fixed seat. Secondly, the user can raise the seat to allow communication at almost eye level with others standing, depending on the person’s height. This feature is not only comfortable for both sides, but being at eye level also greatly changes people’s perception.

The first thing the driver has to do is to place himself on the AddSeat®. Next, the parking handles on both sides have to be released. Now, the vehicle is in balance mode and the user can drive forward by moving the upper part of the body forward or correspondingly backward by shifting the center of gravity to the rear. The seat of the AddSeat® is mounted on a sliding rail. Thus, the driver can very rapidly shift his center of mass. A quick backwards or forwards shift allows the driver to perform precise driving maneuvers such as avoiding moving obstacles. It can also be used to quickly stop the vehicle in an effective full stop emergency brake maneuver. Implementation of this sliding mechanism reduced the braking distance by several meters, in particular when driving at speeds exceeding 10 km/h. In order to avoid collisions with moving obstacles or other people, it was necessary to have a sighted person walk along and advise appropriately.

Our deafblind male driver received a short briefing from a sighted guide by using Lorm fingerspelling [9]. He quickly grasped how to move forward and backward, how to navigate turns and how to stop by using the gliding seat. He intuitively was able to turn in place. This brief driving lesson only took a few minutes and in principle enabled the deafblind test driver to handle the vehicle by himself. During this short driving lesson, haptic support was used to provide

Figure 3. The photo depicts the sighted guide standing behind the driver, giving him the haptic sign for driving straight ahead with the same velocity by moving the back of the hand up and down the driver's spine.

Figure 4. This picture shows how finger tapping on the by the corresponding shoulder was used as haptic sign for left and right turns.

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 [10]. 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 (Figure 3). To trigger a left or a right turn, a finger or hand tap was given on the corresponding shoulder (Figure 4). 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. For safety reasons, we had a third person chaperone every test in the background as to minimize risks in the initial phase of the test.

III. RESULTS

The deafblind test driver learned to understand, to steer and to control the AddSeat® within a few minutes. The challenge for the sighted guide was to provide adequate and precise navigation advices using haptic commands.

As part of the results we would like to cite our deafblind test driver (P.H.) (information in [..] was shown in signs): "It's a pity that I can't see a little. Otherwise I would start immediately to drive around. My biggest problem is to be completely blind. I can well imagine that people with limited visual impairments can use it [quite easy]. It's also possible [for me] to feel safe [because it's stable to the side]. To help with orientation for [completely] blind people, we need something additional." In addition, he reported that it was not always clear for him whether he was driving forward or backward, in particular when driving slowly, as he was missing all visual or acoustical input. For the same reason, he reported difficulties estimating his current velocity. The used haptic and direct type of driving advice offers the advantage that it can be translated into action a lot more intuitively and faster than conventional sign language or fingerspelling.

IV. CONCLUSION

Our main focus was on feasibility – can a deafblind person steer a single seat personal transporter – and what are the emotional and social effects associated with moving self-determined at greater speeds. We have reached a couple of conclusions.

The physical task of steering the AddSeat® is mainly a matter of upper body control which we found not to be negatively influenced by the co-occurrence of visual and acoustic impairments. Our deafblind test person performed better than some sighted testers, a fact we attribute to his heightened sense for posture and position. However, we have to say that we picked our deafblind test person based on the precondition of a good general mobility as to make successful testing more probable.

After a quick instruction session with haptic translation, our test person was able to steer the vehicle by himself with the help of a very limited set of haptic guidance signs such as left, right, forward, back or keeping a steady pace. We conclude that these basic instructions could also be given by a sighted guide lacking knowledge of Lorm language, thereby potentially widening the circle of interactive contacts a deafblind person can have. Guided driving on an AddSeat® might therefore be the basis for an increase in important social interaction.

Our previous tests with sighted people with mobility restrictions showed the AddSeat®'s significant positive influence on more than mobility. Three dimensions of life which we labeled "fun", "freedom" and "family&friends" yielded especially positive results: self-determined driving enabled those test persons to be more independent and lead a more equitable life with less discrimination. It can be reasonably assumed that driving an AddSeat® can also enhance the quality of life for people with deafblindness, as well as for their partners, family members, friends and caregivers.

Driving an AddSeat® is not without risks, in particular when driving deafblind. We strongly recommend that deafblind people drive only with an experienced guide, especially in challenging environments such country lanes, steep roads etc. and most certainly at higher speeds. Deafblind drivers will need a way of receiving constant advice while moving. The relationship between the driver and the sighted guide is one of extreme mutual trust, as the driver lays his well-being and ultimately his life into the hands of his guide. The sighted person in return takes over the responsibility of safeguarding his guidee, relying on him to perform the required actions. This can be a great step towards breaking the isolation.

With its range of up to 30 km, the AddSeat® lets drivers cover long distances. Its off-road capabilities make a wide array of different environments accessible to deafblind people. As the AddSeat®'s movement is controlled by shifting the driver's center of gravity, every change of speed or direction also serves as a work-out to improve the abdominal and back muscles.

FUTURE WORK:

This work is at an early stage. The next step will be to increase the number of usability tests while establishing a questionnaire that allows for an evaluation of a wider range of variables. We also suggest a comparison between sighted, blind, and deafblind drivers as well as design options for the haptic feedback device that could then be utilized for all groups.

After our research experience concerning object recognition and navigation support for people with deafblindness, there is no doubt that quite a number of them will be able to profit from driving an AddSeat®. People with complete deafblindness will have the best experiences with additional support from haptic interfaces implemented to interact with the sighted guide or by driving completely autonomous – conceivably through the integration of autonomous driving systems used in the car industry or in electronic wheelchairs with four wheels. Those systems, however, might imply that in the future the driver has nothing to do at all while driving. All our tests, also with sighted people, have shown that the drivers actually enjoy the very act of driving; driving alone or together with a guide is fun, because they get to perform the task themselves. It is this activity that sets driving an AddSeat® apart from their usual, passive experience of being taken somewhere. We gained the impression that this is particularly the case with blind users as well as with our deafblind tester, too. Therefore, we decided to focus our future work on ideas for systems that allow the driver to keep in control of the steering rod and the motor power, with navigation support from a sighted guide through a haptic interface. Here, future research can look into two different options. One is to have a haptic assistance system controlled by the guide attached directly onto the driver's body. The other possibility is to integrate the haptic interface onto or into the AddSeat®. An example of a body-fixed system that might be used with slight modifications in combination with the AddSeat® is the NavBelt [11]. It provides acoustic information and additional vibrating haptic information within a belt around the body. This system could be particularly helpful concerning direction advices from the guide. The NavBelt has the advantage that the driver keeps both hands free to steer the AddSeat® more safely than with just one hand.

Our previous research proposed alternative systems which are more or less handheld, such as the following: A portable Braille display connected to a smartphone with a special navigation software provides technical orientation support for people with blindness and deafblindness as developed in previous work [12]. This system uses short Braille patterns of two or three Braille characters, some of them animated, to indicate for example a right or a left turn. By using such short navigation advices, the blind user can be informed about the appropriate direction and speed faster than with complete written text information in Braille. The other proposed functional system [13] uses a haptic phone keyboard as basic user interface and applies additional adaptive control elements including a haptic compass. This allows the user to feel the direction of motion and to determine the current mode of the system without asking for it or without changing to another level in the program hierarchy. The advantage of this system is that it can be used as a compass-based navigation system.

When looking at future systems that might be fixed somehow to or on the AddSeat, we first think about slightly modified systems such as "The ViibraCane" based on the remote control of a Wii® game console proposed by Schmitz [14] that could be integrated into the handles of the steering rod. Another possibility would be to integrate vibrating or tactile elements into the seat to enhance the navigation support and to shorten reaction time similar to systems used in fighter jets [15][16]. Those kind of systems will be able to solve the challenges of missing information on current position, movement, direction and orientation for deafblind drivers. Future work should furthermore include the question if the AddSeat® can be used to support deafblind – with varying degrees of restrictions – in other fields, such as the workplace, or if it might be possible to create new kinds of workplaces for this group of people still experiencing discrimination in many aspects of life.

Finally, in the near future the question needs to be addressed how the requirements of the United Nations' Convention on the Rights of Persons with Disabilities [17] can be implemented by all parties to the convention on a national, regional and local level in order to afford deafblind people the right to participate in traffic with support from a sighted guide in order to benefit from this innovative and interactive technology. The sighted guide would need a secure command over only a very limited number of tactile gestures. This could be the basis for a sustainable way of "breaking the isolation", as it would multiply the number of potential communication partners usually limited by knowledge of complex languages with tactile signs. Even if this interaction would first pertain to navigation support only, it can still make all the difference for everybody involved.

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