Social Stress, Trust Between Technology and User, Physical Navigation Controls, and System Displays for Semi-Autonomous and Fully Autonomous Wheelchairs: A Proposed Experimental Design

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Matthew Morgan Huffman

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Anil Kumar

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Abstract

Smart wheelchairs are growing in popularity and will soon be a main stay in the wheelchair space. As technology grows, so will the importance for research into the social distress wheelchair users experience, trust wheelchair users have in their technology, system displays to alert users of system status, and physical navigation controls. By utilizing a 3x3x4x3x2 experimental design factoring in age, experience, type of wheelchair, system display, and physical navigation controls this research aims to illuminate how to reduce social distress and increase trust in smart wheelchair technology. By using a mixed subjects design, a greater depth into the relationship between fully autonomous, semi-autonomous, standard wheelchair, age, wheelchair experience, system displays, and physical navigation controls can be achieved.

Introduction

Contrary to the belief that most people are perfectly healthy, many people live with disabilities. Disabilities are broadly defined as impairment, either physical or mental, that substantially limits activities. This can range from being active fewer days during the week, or by being bedbound unable to move without assistance. Elkind (1990) estimates that 36.4 percent of Americans live with a disability. The high rate of disabilities showcases the importance for human factors professionals to consider this population when designing and researching. Disabilities must be kept in mind otherwise a large portion of the population will be segregated from a product or service. This can lead to poor experiences, or in some cases, render certain products completely unusable. This can be the case for many medical devices that people with disabilities rely on, such as wheelchairs. Disabled people are generally an afterthought, thus further emphasizing the need to design for them. Their reliance on devices is used to fulfil their most basic needs. They may already be feeling adequate in a world that does not prioritize or consider their needs. Wheelchairs come in a wide variety of different shapes and sizes, but ultimately, they are there to serve a critical function for the disabled community. They provide a more accessible path to those who have less mobility.

Smart wheelchairs are seen as a natural evolution from the standard wheelchair. Our everyday lives are becoming more technological after all. Despite this rapid technological growth there are an increasing number of concerns with smart wheelchair technology. When navigating the natural public environment in a standard wheelchair you will quickly notice that people’s behavior is rather unpredictable. Some people acknowledge you and try to clear a path, while others may never see you. Many people do not know how to respond appropriately to someone in a wheelchair. After all, everyone is different. In addition to social barriers, there are a wide range of physical barriers, such as steps, rough sidewalks, debris in walkways, doors, steep inclines, and miscellaneous floor obstacles that can cause major disruption for wheelchair users. As a result, navigating the world with a wheelchair poses a unique design and engineering challenge. When thinking about smart wheelchairs, they are often designed with one end goal in mind: to reach the destination. The goal is more often than not trying to go from point A to point B; however, they this misses a fatal flaw; to acknowledge the social stress and the trust level that the wheelchair user is experiencing. This is a major pain point for wheelchair users. Without considering this in the design phase it results in a less usable product with poor usability and substandard social experience. Through this lack of trust (or lack of high level of trust) it changes the experience for the smart wheelchair user. Imagine for a moment you are riding in a fully autonomous wheelchair, and you begin to approach a crowd. It's a busy intersection and some people are noticing you and others are not. You would be quite embarrassed and socially stressed if your wheelchair almost hit several people because of their unpredictable movements, constantly stopping and starting abruptly, and trying to turn quickly and rapidly. It will perform this way because the wheelchair is simply trying to navigate from point A to point B without considering the user experience. Having unpleasant experiences like this one would likely cause you to have less trust in wheelchair technology. This would create even more social stress in future, because of these poor experiences in uneasy environments in the past. Furthermore, educating the user with a comprehensive, but simple system display can help empower the user and instill additional trust in the technology. Self-driving cars are a good example of the power of a system display. Consider for a moment how much more trust you have in a self-driving car when you can virtually see that the car acknowledges its surroundings. Additionally, having physical navigation controls that are compatible with users who utilize smart wheelchairs would give them further control over their devices. This is particularly tricky however because people with more severe motor impairment are the same people who would benefit the most from this technology. This study aims to provide data on social stress, trust, system displays, and physical navigation controls for smart wheelchairs. This data will inform researchers of the some of the challenges to come and hopes to encourage further research on the topic.

Literature Review

There are variety of features that may make a wheelchair “smart”; however, for this paper I will be categorizing wheelchairs as semi-autonomous or fully autonomous. Semi-autonomous wheelchairs are defined by wheelchairs that can react to the environment but are unable to make complete decisions without user input. They can act without direction but are often reactionary. This can be seen through hazard avoidance, stability control, and speed control. Fully autonomous wheelchairs are defined by being able to self sufficiently navigate from one location to another without intervention from the user. Both of these technologies are a giant leap forward for wheelchair users and has the potential to drastically improve the lives for the people who use them. Yet, there are glaring usability issues that are not accounted for. The most important considerations that must be accounted for are, but are not limited to, trust between wheelchair and user, physical navigation controls, system displays, and social stress. In order to frame the layers of complexity, that expand past the main usability issues, we need to consider that these technologies have drawbacks.

Many wheelchair users report the importance of agency over their movement. This agency empowers them to gain control over that aspect of their life, in this case movement. Some people rely on technology to help them complete their daily tasks, so by being able to control the one thing that gives them the ability to move on their own it provides them with a sense of pride and accomplishment. With this being said, not every wheelchair user is able to self-propel, so there is a lot to be gained by using a semi-autonomous or fully autonomous wheelchair. Consideration must be given to the group of users who may want old school technology, because it gives them a sense of agency. This group of people rely on a wheelchair as a vehicle to get could around and would be stripped of their freedom without it (Breed & Ibler, 2008). Naturally, they would benefit from smart wheelchairs, such as ones that provide collision avoidance, but they would perceive any change in the way they navigate with a wheelchair to be one that strips them of their freedom to do so themselves. These features take away from their power that a wheelchair provides them with. This is an important distinction from other groups who would most benefit from a semi-autonomous or fully autonomous wheelchair. Special consideration must be given to the reason why someone uses a wheelchair to begin with and what they stand to gain by using a semi-autonomous or fully autonomous one. The takeaway here is that a smart wheelchair is not for everyone and should not be designed for everyone.

A wheelchair can have a variety of different goals and the way in which these goals are met change rapidly. Scientists and researchers are coming up with creative ways to give direction to an autonomous or semi-autonomous wheelchair. Jung-Hae and Byung-Jae (2017) invented a design and tested an electric wheelchair using a QR code and magnetic band to navigate. This specific invention is one of the many unique ways that scientists are coming up with ways to control smart wheelchairs. It operates by using self-localization technology by scanning QR codes strategically placed throughout a room. By having this strategy, the wheelchair can determine where it is, and where it wants to go. This is an important distinction because it illustrates that the wheelchair is fully autonomous. The wheelchair can navigate to its desired location without any user intervention. This is in contrast to a semi-autonomous wheelchair which does not have that capability. A semi-autonomous wheelchair can aid the user in avoiding obstacles and completing some tasks but does not have the ability to get the user from point A to point B (Uchiyama, Tarver & Eunice 2008). Uchiyama, Tarver, and Eunice also discussed the different technologies used for evaluating a wheelchairs environment. They discussed vision modules at length, specifically about ultrasonic sensors and visual based information systems. There are pros and cons for each of them, but they illustrate the need for an array of sensors even for a basic semi-autonomous wheelchair. It's difficult for the wheelchair to make any decision without an immense amount of data.

This plays directly into why it is so important for smart wheelchairs to consider the trust a user has in it and the social distress that a user is capable of experiencing. A user trusting the technology to navigate the environment is critical for the wellbeing of the user. These scientists and technologies discuss the specifics of why the technology is needed to navigate, but do not mention how they will aid users in stress social situations. In the event the smart wheelchair is navigating a busy crowd, or a grocery store for instance, there is an immense amount of opportunity for social distress. The psychological wellbeing of a person is closely tied to social support and lack of social distress (Holahan & Moos 1981).

There is light at the end of the tunnel, however. Tomari, Kobayashi & Kuna (2014) have produced groundbreaking work within this space. They have focused on creating a navigation-based system that responds to the users' head cue. Specifically, they have focused on the socially acceptable nature of movement and social stress. They have evaluated the complex nature of wheelchair navigation and how the user may feel social pressure to navigate a certain way that cannot be mimicked by a robot. Most importantly though, they have created a framework for catering to the social issue. The wheelchair user creates a comfort zone by using head ques and the program interprets certain areas as acceptable and other areas as not. This is dynamic and changes as needed. It updates throughout each trip and each head que change. Through this data driven approach, it can potentially improve social stress for smart wheelchair users. This technology can be combined with other smart wheelchair technology that focuses on complete automation. In combination these two technologies can achieve the best of both worlds.

A different approach that scientists have taken to tackle social distress for wheelchair users is to create a side-by-side robotic wheelchair that improves accessibility, comfort, and social stress (Nguygen & Jayawardena, 2018). This is a brilliant idea; however, they acknowledge the flaws that it does not consider all of the different ways people walk, and the unpredictable nature of human pathing. This is shown through data that illustrates distance errors when moving between crowds and pedestrian crossings. It’s nearly an impossible task with the ever-changing paths humans can take in a crowd. This further emphasizes the importance of coming up with creative ways, and keeping in mind, social stress and increasing trust within the user and the smart wheelchair. As a result of this unnatural pathing, the robotic path finding is unnatural and awkward. This awkwardness passes down to the wheelchair user and creates social stress, confusion, and lack of trust. Another aspect to consider are the controls in which the wheelchair user has access to.

Physical navigation controls present another unique problem. It’s often the people who have more severe disabilities that are unable to control minor hand movements with a great deal of accuracy that benefit the most from smart wheelchairs. This population requires more specialized controls. These controls are especially important because this group of people stand to use smart wheelchairs more than any other group. As mentioned previously, there are a variety of unique designs that can help aid the control of a wheelchair, but they are specialized and rather unique. These can range from head controls, chin controls, tongue controls, and breath controls. They are very specialized designs for specific individuals who have specific impairment, thus creating a space where there is a unique wheelchair for everyone. This gives way to a refined navigation control system that can take its place. By combining many of these navigation systems into a modular system, it would enable the user to pick the method that is most suited to their needs. This would also allow the wheelchair to be more adaptable in the event the users health continues to change. For instance, the control module is the same on the wheelchairs and you simply swap out the type of technology used for navigation. While the importance for physical navigation controls is absolutely necessary, so is displaying system status.

Displaying system status is a crucial aspect of the smart wheelchair space. This is true of all system displays, but when the potential for social distress is high and trust is low, it is imperative. An accurate and information rich system status helps to establish trust (Miller et al., 2016). The authors go on to say that the user will test the technology to determine if it is trustworthy and during these initial calibration tests it's of vital importance that trust is established. This plays a major role in the user experience and will greatly change the outcome. Since these wheelchairs already have highly advanced technology systems integrated into them it is a small step forward to integrate specialized technology that can be utilized to give feedback on the system status. This can take the shape of haptic feedback, audio feedback, and visual feedback. Haptic feedback has been shown to dramatically increase user satisfaction (Zhang et al., 2021), but also, it's fairly accessible since the feeling of touch is usually intact. In this context, haptic feedback can take the shape of vibrating the handles of the wheelchair in anticipation of a turn. When the wheelchair is about to take a right or left turn the appropriate side would give a slight cue beforehand. Furthermore, when collision avoidance activates both handles can vibrate simultaneously. Audio feedback can be used alongside haptic and visual, or separately depending on the situation. Audio feedback has been shown to increase satisfaction and grow a relationship with the product (Gaspar et al., 2014). As a result of growing a relationship with the product this can enhance trust. Audio feedback can be utilized by giving audio cues before the wheelchair makes a maneuver, or by simply stating what action it is performing at all times. Lastly, visual feedback is by far the most important system status. During fully autonomous actions the display can show the planned route with obstacles detected. This can let the user know that the wheelchair acknowledges obstacles and plans to avoid them. This feedback also provides second to second updates on what is going on and how the wheelchair is going to respond to the environment. This allows the user to feel at ease and intervene if necessary. The intent is to be accessible as possible and provide the user with as many different options that may suit their varying needs. A combined mix of feedback systems will net the best result given the range of disabilities and how these are data rich environments (Nikolic & Sarter, 2001). Similarly to the physical navigation controls, a modular design is going to be the most effective tool. By mixing and matching based on the individual needs it will allow a user to create a wheelchair that is tailored them. This can even be pushed further by providing a modular roadmap as mentioned above. This would then allow a user to pick the option that most suited them, thus allowing the wheelchair to be more affordable and customizable.

Summary of Findings

As alluded to earlier in the literature review, the key to wheelchair design is that it needs to remain flexible. Social stress, trust, system displays, and navigation controls all change rapidly depending on the environment. Everyone is different and everyone’s unique situation requires a different solution. Having a wheelchair that is adaptable and able to overcome challenges is paramount. The smart wheelchair needs to empower the user to control the challenges that the chair cannot face on its own. It's impractical to think that a smart wheelchair can predict everything in an everchanging environment. Rather, a focus should be deployed on a more fluid design with modular compatibility at its core. This research will help to provide a optimal and clear path forward to reach a more user centric smart wheelchair design.

Rationale and Objectives of the Study

The objective of this research is to determine the effects of smart wheelchairs on users' social distress and trust of the technology. Additionally, this research is to determine what type of system status is most effective, and what physical control layout is most useful. This research also aims to paint a path forward to refine our technologies to produce a more user centric smart wheelchair design. Ultimately, this data can be used to design better future technologies and to bring awareness to the variety of issues that smart wheelchair users may experience. The issues that smart wheelchair users experience are often overlooked for the sake of better technology. Their user experience is on the back burner while functionality is pushed forward. In practice, however, many designs cause a great deal of stress for the end user and are not practical. For instance, autonomous wheelchairs have the capabilities of moving a user from point A to point B, but they do not consider how a user may feel. The wheelchairs perform poorly in social situations, especially with pedestrians, because there is a lot of nuanced movement that is involved when navigating a crowd. These types of situations can cause a great deal of social distress. This can also be true of a variety of obstacles. Autonomous wheelchairs move unnaturally, and the user cannot intervene in a way that is human. This results in social distress and awkwardness. This awkwardness is a barrier of entry for people who may otherwise want to use more automated wheelchairs. The same could be said about the current state of system status displays, and physical controls. This paper helps to illuminate a clear path forward to help alleviate these pain points.

Hypothesis 0_1: Fully autonomous wheelchairs have low levels of social distress and high trust values.

Hypothesis 0_2: Younger wheelchair users have lower levels of trust and social distress than older wheelchair users.

Hypothesis 0_3: The more wheelchair experience you have the more you trust smart wheelchair technology, and the less social distress you experience.

Hypothesis 0_4: Using a semi-autonomous wheelchair produces lower levels of trust and higher levels of social stress.

Hypothesis 0_5: Both younger and older participants find a fully autonomous wheelchair to have lower levels of social stress and higher levels of trust than a semi-autonomous wheelchair.

Hypothesis 0_6: System status is more effective when using multimodal methods (visual, audio, haptic).

These hypotheses have been identified because they have the highest impact and would result in the most useful outcome. They also are what I would expect the outcome to be, thus if any of them differ from the expectation it would warranty further analysis. There are additional hypotheses that would also produce interesting results; however, I have narrowed down the list to these six. Additional research should be conducted based on the findings of this study, especially if any results defy the expectation.

Methods and Procedures

Technology has been on an upward trend, and thus is well integrated into smart wheelchairs already. These methods and procedures are poised to pinpoint and extract meaningful data from relevant factors. Ultimately, the results from this study can be used to improve the lives of those who use smart wheelchair technologies. An experimental design will be conducted to gather the most meaningful data. For the experimental design there are five groups of independent variables. The first group of independent variables for this study are fully autonomous wheelchair, semi-autonomous wheelchair, and a standard wheelchair. The second is age. Age is being used as a categorical variable with two states: young and old. The third group of independent variables is wheelchair experience. This is grouped by how many times a month you use a wheelchair: 0 times a month, 1-5 times a month, and 6+ times a month. The fourth group of independent variables are system display. This is grouped by audio display, visual display, haptic display, and a combination of all three. Navigation controls are the last independent variable. This is measured by tongue navigation, joystick navigation, and QR code with magnetic band navigation. There are a few dependent variables depending on how the data is analyzed. Trust and social distress relative to wheelchair type (standard, semi-autonomous, and fully autonomous), system display status (audio, visual, haptic, all 3) relative to social distress and trust, and physical navigation controls (tongue navigation, joystick navigation, and magnetic band navigation) relative to social distress and trust. Trust in this context is broadly defined as the culmination of functionality, reliability, and helpfulness of the wheelchair.

Participants

Participants can be of varying ages and have varying wheelchair experiences. The wheelchair experience can be with standard wheelchairs, or smart wheelchairs. Exclusion criteria requires the participants to have the strength and mobility to self-propel a standard wheelchair. They also need to be comfortable with using smart wheelchair technology. Any accommodations the participants need is also asked for and if the accommodations cannot be met, they will be excluded. Ages of 18+ are accepted and will be grouped into two categories. The younger category is 18-50 and the older category is 50+. These age groups have been decided to create a divide and determine if there is a difference between the two. The cut off age of 50 was specifically chosen because there is a disproportional amount of people who use wheelchairs greater than 50, and I want to gather comparative data. A large sample of participants will be recruited to fill out the screener survey. Out of this sample 120 participants will be randomly selected based on which between group they fit into. Twenty participants will be selected for each between group. The breakdown of the groups can be seen in Figure 1. Demographic and descriptive characteristics will be gathered, such as, age, gender, frequency of wheelchair use, mobility status, and current technology comfort level.

Experimental Design

A 3x3x4x3x2 experimental design will be used to determine smart wheelchair users' perceived trust and social distress, and how system display and navigation controls play a role. There are five groups of independent variables. The first of five independent variables are wheelchair type: fully autonomous, semi-autonomous, and standard wheelchair. The second independent variable is age, younger or older. The third independent variable is wheelchair experience. This is grouped using the following 3 levels: 0 times using a wheelchair monthly, 1-5 times monthly, and 6+ times monthly. The fourth group of independent variables are system display. This is grouped by audio display, visual display, haptic display, and a combination of all three. Navigation controls are the last independent variable. This is measured by tongue navigation, joystick navigation, and QR code with magnetic band navigation. There are a few dependent variables depending on how the data is analyzed. Trust and social distress relative to wheelchair type, system display status relative to social distress and trust, and physical navigation relative to social distress and trust. A mixed subjects design will be used. The between groups can be seen in Figure 1 to the left of the blue boxes and the within groups can be seen inside the blue boxes. Trust will be measured through a trust survey (Appendix B). The Likert scale will be converted numerically and averaged to produce a single trust score. This survey was created by examining the works of Lankton, McKnight, and Thatcher (2014) who discovered that human-like technology trust is translated into system-like technology trust. They relayed competence, integrity, and benevolence into systematic terms such as functionality, reliability, and helpfulness and found these are how humans evaluate trust in technology. Social distress will be measured through a social distress survey (Appendix C). Similarly, this Likert scale survey was created based on the works of Watson and Friend (1969) who produced groundbreaking work for evaluating social anxiety. These concepts have been adapted and applied to the context of smart wheelchairs and the social distress that can be caused. These survey results will also be averaged numerically and condensed into a single social distress value. The effectiveness of the system display will be evaluated through a survey (Appendix D). A Likert scale will be used, and the results will be averaged to produce an overall number to illustrate the effectiveness of the system display. The efficacy of the physical navigation controls will be assessed through a survey (Appendix E). A Likert scale will be used, and the results will be averaged to produce an overall number to demonstrate the usefulness of the physical navigation controls. The participants will be asked to complete one trial through obstacles using each of the three wheelchairs, each of the four system displays, and each of the three physical navigation controls. They will be asked to fill out the trust survey, social distress survey, system display survey, and physical navigation control survey after each trial.

Materials

The following wheelchairs will be required for the experiment: fully autonomous wheelchair, semi-autonomous wheelchair, and standard wheelchair. A fully autonomous wheelchair is a wheelchair capable of going from point A to point B with very little user intervention, with the user primarily illustrating their goal and being hands off. A semi-autonomous wheelchair is capable of assisting the user in avoiding obstacles and keeping on a desired path. There are a wide range of technologies that can achieve this goal, but these standardized functions will classify any wheelchair under these titles. A standard wheelchair is a wheelchair without any technology. Additionally, a system display that uses audio, visual, and haptic feedback. This system needs to be able to be configured to turn off any number of the functionalities, such that only one modality is active at a time. Lastly, physical navigation controls that allow the user to use their tongue to navigate the wheelchair. Broadly, as long as the tongue can control the speed and direction of the wheelchair it will suffice. A traditional joystick-based wheelchair navigation will be required, and a QR based navigation method. The QR based navigation should be modeled after Jung-Hae and Byung-Jae's (2017) model. Besides wheelchair technology, the IRB consent form (Appendix A), the trust survey (Appendix B), the social distress survey (Appendix C), system display survey (Appendix D), and physical navigation control survey (Appendix E). In addition, foam obstacles in varying shapes and sizes will be required. Approximately 10 cubes of at least 1 foot by 1 foot in diameter is required. A large space is required to setup obstacles for the participants to navigate around. A video camera is required to record the users. A stopwatch is also required to time users speed in completing their navigation through obstacles.

Procedures

The 120 participants will be individually given the consent form to read and sign (Appendix A). They will then be asked if they have any questions about the experiment. The 120 participants were then divided into their respective 6 groups (Figure 1). They will then be assigned a time and date to come into the research facility. Prior to the arrival of participants, the research facility will be populated with the foam cubes to create obstacles on the ground for the participants to avoid during their trial. Each participant will be asked to navigate through the obstacles with each wheelchair type, system display, and physical navigation controls. Prior to the start of each trial the participants were asked if they were familiar with how to use a wheelchair, smart wheelchair, display, or physical navigation controls. If the participant was not familiar, then a brief tutorial was given. After each trial the participants were given the respective survey.

Research Budget

Since fully autonomous wheelchairs are slowly entering the market, it is hard to come up with a specific budget for them. The perfect product does not exist and many of them are only fully autonomous with very specific restrictions, such as, certain rooms, buildings, and locations. I have allocated $25,000 to a fully autonomous wheelchair because that is the cost of a fully autonomous wheelchair that can navigate throughout airports in Singapore and Japan. Semi-autonomous wheelchairs are available for between a few thousand and $10,000. With some low-cost build it yourself options. As a result, I have allocated $5,000 to the budget. The wheelchair should be very obtainable within that budget. A system display that can perform audio, visual, and haptic feedback with the ability to turn off each individual modality costs roughly $2,500. This has a high cost because it has to integrate with the smart wheelchair to create a 3D model of the room and display it to the user, in addition to alerting the user to a variety of issues. The physical navigation controls have a budget of $10,000. This would need to be engineered in house, because the methods needed for the study are not commercially available. Commercial office spaces are available nearby for around $4,500 a month that have the required square footage that we need. We should not need more than 1,000 square feet. It is anticipated that each participant will only require one hour each to complete the study. Each wheelchair trial should take less than 15 minutes and each survey should take less than 5 minutes. 200 hours of undergraduate student hours have been allotted for data analysis and help with the research as needed. 250 (duration of study) + 30 hours of graduate student hours has to been allocated to oversee the study and do data analysis and research planning. 20 hours of faculty hours has also been allocated to oversee the research.

Analysis of Data

The data will be extracted from the surveys and compiled into an excel spreadsheet in accordance with the experimental design. The data was then examined through a mixed subjects factorial ANOVA. The between subjects are the 6 groups created from age and wheelchair experience (Figure 1). The within groups are each wheelchair type (fully autonomous, semi-autonomous, standard wheelchair), system displays (audio, visual, haptic, combination of all), and physical navigation controls (tongue navigation, joystick navigation, and QR code with magnetic band). An alpha of 0.05 will be used and the newest version of Minitab will be used to analyze the data.

Concluding Remarks

Overall, the importance surrounding trust between wheelchair and user, physical navigation controls, system display, and social stress cannot be emphasized enough. A heavy focus has been made on the technology behind smart wheelchairs, but little consideration has been made for the overall user experience. This research aims to improve the user experience by empowering the next generation of smart wheelchairs to consider these often-dismissed factors. By educating researchers, designers, human factors professionals, and engineers the shortcomings of the smart wheelchair can be overcome. The research as envisioned could not be conducted due to non-availability of the materials required to conduct the experiment during the proposed research period.

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Appendix A

REQUEST FOR YOUR PARTICIPATION IN RESEARCH

What Role Does Smart Wheelchair Technology Play in Trust and Social Distress

Matthew Huffman – San Jose State University graduate student.

PURPOSE
This study is aimed to help illustrate the role of trust and social distress when using smart wheelchair technology. It also evaluates the role of system status, and physical navigation controls in relation to trust and social distress. This in turn would help design future smart wheelchair technologies with a more human centered perspective, with an emphasis on the user experience.

PROCEDURES
The 120 participants will be individually given this consent form to read and sign. They will then be asked if they have any questions about the experiment. The 120 participants will then be divided into their respective 6 groups (Figure 1). They will then be assigned a time and date to come into the research facility. Prior to the arrival of participants, the research facility will be populated with the foam cubes to create obstacles on the ground for the participants to avoid during their trial. Each participant will be asked to navigate through the obstacles with each wheelchair type, system display, and physical navigation controls. Prior to the start of each trial the participants were asked if they were familiar with how to use a wheelchair, smart wheelchair, display, or physical navigation controls. If the participant was not familiar, then a brief tutorial was given. After each trial the participants were given the respective survey.

POTENTIAL RISKS
Due to the uncertain nature of new technologies, there could be potential errors that result in undesired operation of the smart wheelchairs. To mitigate any potential risk to participants, all obstacles that participants will be asked to navigate through will be well padded and/or made of foam. This will ensure there is zero risk to the participant if a collision were to occur. Since this is partly a research study into social distress the participants may feel some social distress during the study. Supportive services will be available in the event they are requested by the participants. In addition, many participants will have some wheelchair experience and may require one at all times. The research location will be wheelchair accessible and pose no risk to participants.

POTENTIAL BENEFITS
This research study down the road may benefit participants by providing more user focused smart wheelchair technologies that they themselves can use. The participants will also be contributing to generalizable knowledge within the wheelchair space and provide a steppingstone for more researchers to continue to create more refined smart wheelchair designs.

COMPENSATION
Each participant will be offered $100 for each hour of their time in the research facility. This

compensation is given for their voluntary involvement in the research study and will be paid to them via cash.

CONFIDENTIALITY
This data will be unpublished but remain accessible within San Jose State University. The data will be striped of any identifying information and will not be traceable back to the participants. The demographics of the participants as well as their wheelchair experience levels will be linked to their survey results.

PARTICIPANT RIGHTS
Your participation in this study is completely voluntary. You can refuse to participate in the entire study or any part of the study without any negative effect on your relations with San Jose State University. You also have the right to skip any question you do not wish to answer. This consent form is not a contract. It is a written explanation of what will happen during the study if you decide to participate. You will not waive any rights if you choose not to participate, and there is no penalty for stopping your participation in the study.

QUESTIONS OR PROBLEMS
[The following sample text summarizes the contacts that need to be included on the consent form.]

You are encouraged to ask questions at any time during this study.

- For further information about the study, please contact Matthew Huffman – Matthew.huffman@sjsu.edu
- Complaints about the research may be presented to Dr. Kumar - anil.kumar@sjsu.edu.
- For questions about participants' rights or if you feel you have been harmed in any way by your participation in this study, please contact **Dr. Richard Mocarski,** Associate **Vice President for Research**, San Jose State University, at 408-924-2479 or irb@sjsu.edu

SIGNATURES
Your signature indicates that you voluntarily agree to be a part of the study, that the details of the study have been explained to you, that you have been given time to read this document, and that your questions have been answered. You will receive a copy of this consent form for your records.
Participant Signature

____
Participant's Name (printed) Participant's Signature Date

Researcher Statement
I certify that the participant has been given adequate time to learn about the study and ask questions. It is my opinion that the participant understands his/her rights and the purpose, risks, benefits, and procedures of the research and has voluntarily agreed to participate.

____
Signature of Person Obtaining Informed Consent Date

Appendix B

Trust Survey

	Very Poor	Poor	Fair	Good	Very Good
How would you rate the functionality of the wheelchair?					
How would you rate the reliability of the wheelchair?					
How would you rate the helpfulness of the wheelchair?					

Appendix C

Social Distress Survey

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Do you feel calm when using the wheelchair?					
Do you find yourself wanting to avoid people when using the wheelchair?					
Do you feel most relaxed when surrounded by no one while in the wheelchair?					
Being in a new place with the wheelchair makes me feel nervous.					
When faced with obstacles while riding the wheelchair I feel anxious.					
I tend to want to turn around and leave when faced with obstacles/people while riding the wheelchair.					
I find myself excited to see how I will overcome new obstacles while riding the wheelchair.					

Appendix D

System Display Survey

	Very Poor	Poor	Fair	Good	Very Good
How would you rate the functionality of the "display"?					
How would you rate the confidence you had in learning about the chairs navigation?					
How would you rate the helpfulness of the "display"?					
How did the "display" impact your social stress?					
How would you rate the efficacy of the "display"?					
How did the "display" impact your trust?					

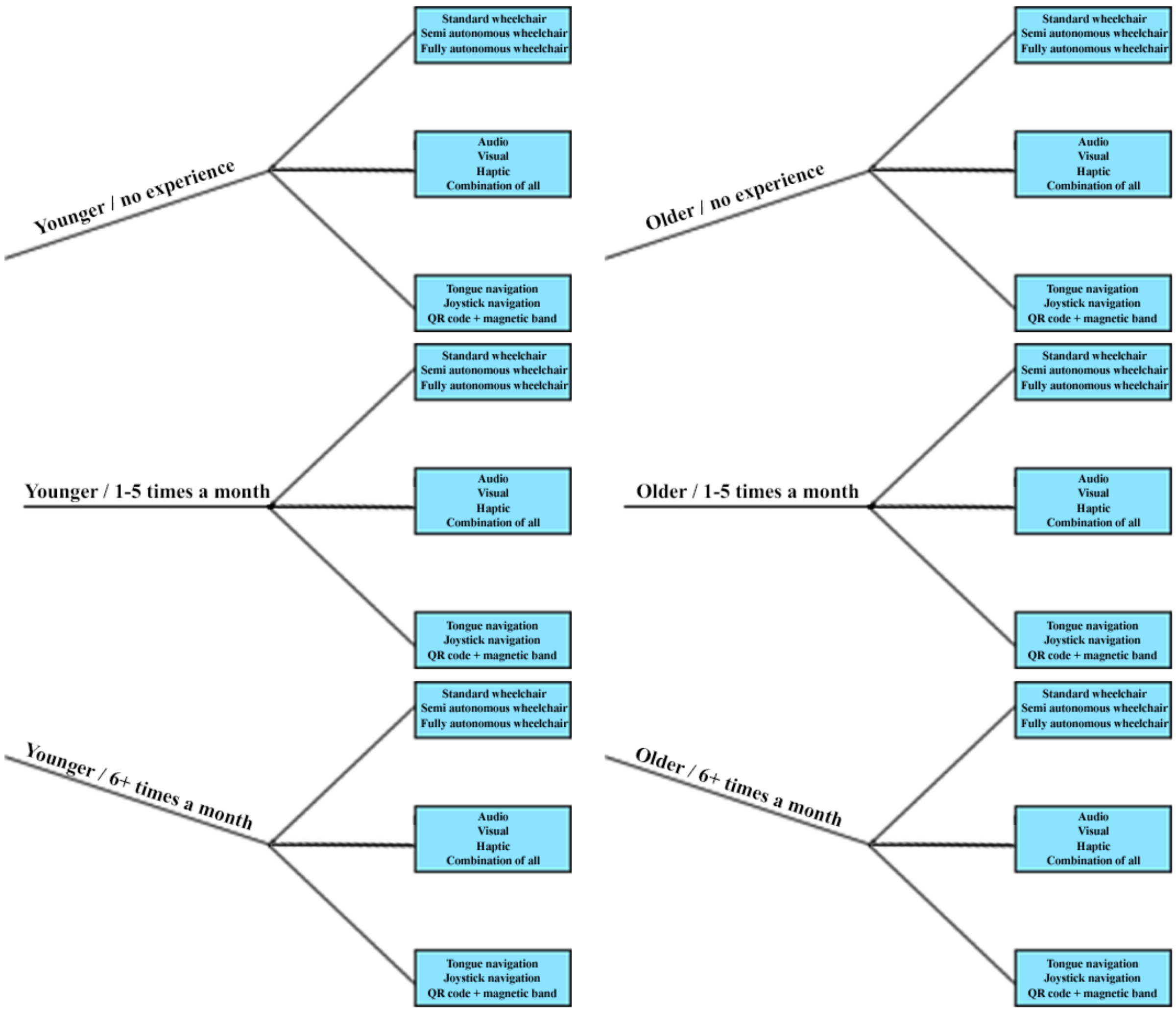
Appendix E

Physical Navigation Controls

	Very Poor	Poor	Fair	Good	Very Good
How would you rate the functionality of the controls?					
How would you rate the confidence you had in your ability to control the chair?					
How did the controls impact your social stress?					
How would you rate the efficacy of the controls?					
How did the controls impact your trust?					

Figure 1

Mixed Subjects Design Tree



Note: The between groups can be seen in Figure 1 to the left of the blue boxes and the within groups can be seen inside the blue boxes.