Advance Connectivity and Automation in the Transportation System

Understanding the Impact of Connected and Automated Vehicles for Pedestrians who are Blind or Partially Sighted

Published: October 2019

This report reflects the views of the CNIB Foundation and not necessarily the official views or policies of Transport Canada.

About the CNIB Foundation

Celebrating 100 years in 2018, the CNIB Foundation is a non-profit organization driven to change what it is to be blind today. We deliver innovative programs and powerful advocacy that empower people impacted by blindness to live their dreams and tear down barriers to inclusion. Our work as a blind foundation is powered by a network of volunteers, donors and partners from coast to coast to coast.

About the CNIB Foundation's Project

With partial funding from Transport Canada's Advance Connectivity and Automation in the Transportation System program (ACATS), CNIB has undertaken activities in partnership with experts in transportation design considerations as well as extensive backgrounds in the field of mobility for persons who are blind or partially sighted.

The project consisted of three phases:

1. A literature review looking at global best practices on mobility and transportation for persons who are blind or partially sighted. This research was undertaken by Professor Wall Emerson of Western Michigan University;
2. A stakeholder survey of persons who are blind or partially sighted developed and administered in partnership with the University of Toronto and CNIB's research department;
3. Stakeholder outreach and engagement.

About our Partners:

Professor Khandker Nurul Habib, Ph.D.
Department of Civil Engineering, University of Toronto

Professor Habib holds a Ph.D. in Civil Engineering. He has held various professional roles with consulting firms across Canada. Professor Habib is a current member of the Transportation Association of Canada. From 2006, he has been a member of the U.S. Transportation Research Board (TRB). One of his roles with the TRB has been as a Member of the Committee on Telecommunication and Traveler Behaviour.

Dr. Mahadeo A. Sukhai, Ph.D.
The CNIB Foundation – Head of Research and Chief Accessibility Officer

Dr. Mahadeo Sukhai is responsible for all research projects and collaborations CNIB engages in, as well as project lead for the development, implementation, maintenance and evaluation of a culture of accessibility for CNIB. He brings considerable experience to the CNIB, having worked in bio medical genetics research since 2007. Dr. Sukhai's role in this project was to oversee the development, implementation, execution and evaluation of the stakeholder consultations.

Professor Robert S. Wall Emerson, Ph.D.
Western Michigan University

Professor Wall Emerson holds a Ph.D. in Education and Human Development which he obtained in 1999 from Vanderbilt University. Since 2004, he has held various roles with the Department of Blindness and Low Vision Studies at Western Michigan University.

Professor Wall Emerson is recognized as a leading researcher in the field of low vision and blindness studies having published extensively on wayfinding/orientation and mobility for persons who are blind. He has conducted extensive research and is well published in the area of human vehicle interactions particularly as it relates to persons with sight loss and hybrid/quiet vehicles.

His role in this project was to review global literature looking at best practices within the field of vehicle to human interface as it relates to persons who are blind or partially sighted.

The research undertaken by Professor Wall Emerson underpins many of our recommendations as to future studies required to truly understand and manage the impacts of connected and autonomous vehicles on pedestrians with sight loss.

Lui Greco
Manager Regulatory Affairs, CNIB Foundation

Lui Greco acted as project manager where he oversaw all aspects of the work being performed by partner organizations and to ensure consistency with the CNIB Foundation's mandate.

Prior to joining CNIB in 2011, Mr. Greco worked with the Government of New Brunswick Premiers' Council on the Status of Persons with Disabilities as well as consulting roles with large international information systems and business processing organizations.

Mr. Greco brings a life perspective to this work having navigated streets and sidewalks around the world as a person who is completely blind.

Contents

Executive Summary

This report, prepared by the CNIB Foundation, reflects the views of CNIB and does not necessarily reflect the official views or policies of Transport Canada.

The research undertaken by CNIB consisted of three phases:

1. A global literature review aimed to understand best practices with respect to autonomous vehicles and their impact on pedestrians with sight loss;
2. A survey of persons with sight loss to assess their perceptions of autonomous vehicles and their strategies on navigating the built environment, and;
3. Stakeholder engagement with Canadian players in the field of autonomous vehicles.

Our goal was to develop an understanding of how pedestrians who are blind or partially sighted will be impacted when Canadian jurisdictions allow fully autonomous vehicles to navigate city streets and highways.

This report provides seven recommendations which CNIB hopes will inform policy development across Canada and perhaps even international jurisdictions.

Our recommendations include:

- Richer statistical analysis of road fatalities to capture characteristics of vulnerable road users;
- Adoption of uniform traffic rules across Canada's disparate jurisdictions;
- Future research initiatives need to apply a disability lens;
- Accessibility and usability of onboard vehicle interfaces;
- Smart city data models need to operate under an open data model facilitating access by systems and mobile apps which enable way finding for persons with sight loss;
- Development of onboard algorithms which will respond appropriately should a pedestrian with sight loss inadvertently find themselves in a crosswalk at the wrong time;
- Avoiding adoption of signals which rely exclusively on visual queuing to indicate a vehicles state.

This report consists of three distinct sections, coinciding with the deliverables identified above. These are the literature review, stakeholder survey and CNIB's analysis and outreach efforts.

Introduction

As connected and autonomous vehicles emerge on Canadian roads, we will experience fundamental changes in how Canadian streets are navigated both by vehicles and pedestrians. These changes will impact vulnerable road users, particularly those who are blind or partially sighted.

Conventional wayfinding strategies for vulnerable road users will remain viable up to and including SAE Level[1] 3, where the automated driving system performs all aspects of mode-specific driving, but the human driver must be ready to take back control when needed.[2] However, as autonomous vehicles progress beyond level 3 and as humans play a lesser role in controlling the vehicle, existing strategies may no longer prove safe.

Autonomous vehicles promise to reduce road fatalities and injury caused by human error. As indicated in Professor Wall Emerson's research, from 2014 to 2015, motor vehicle fatalities in Canada rose from 1,852 to 1,858; a rise of only 0.3%, but serious injuries were about 10 times that amount, totaling 10,280 in 2015. We do not have data on how many of the victims of road injury were vulnerable road users.

More comprehensive data capturing protocols would clarify the future impacts of vehicles and vulnerable road users. While general demographics are captured like gender and age, we are unaware of any characteristics on disability that are recorded.

Therefore, CNIB recommends demographic profiles of victims of collisions between pedestrians and vehicles, regardless of degree of autonomy, should be expanded to better understand characteristics such as degree of sight loss and perceptual abilities. Our research reaffirms that the leading cause of vehicle and human collisions are directly attributable to human error. We hope streets will become safer as vehicles become increasingly less reliant on human judgement and response times.

As municipalities start adopting smart city technologies, they will have access to a significant amount of rich data which can be leveraged to the benefit of everyone. Achieving this will require a less disparate architecture in which autonomous vehicles operate. Will onboard algorithms be able to alter behavior based on provincial or even municipal traffic rules? Human and vehicle interactions transpire at street corners and may differ based on municipal traffic rules. For example, a car turning right on a red light is expected to yield, in many municipalities, but not all. Will connected and autonomous vehicles be able to react based on rules which differ from municipality to municipality?

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[1] The International Society of Automotive Engineers has established a catigorization protocol for various levels of vehicle automation. See Appendix A for details.

[2] Society of Automotive Engineers
https://www.sae.org/about/

How will vulnerable road users be able to anticipate vehicle behaviour when deciding to enter an intersection?

In order that vulnerable road users can maintain a level of confidence when navigating streets and sidewalks, vehicle behavior must be unambiguous. Removing the driver from the pedestrian vehicle interaction will introduce new risks if vehicle algorithms cannot anticipate and react accordingly when pedestrians with disabilities come across their path.

To ensure consistency for vulnerable road users, CNIB recommends provincial transportation authorities adopt more uniform and consistent traffic regulations.

For pedestrians with sight loss, their understanding of how vehicle interactions will impact them in their daily lives may prove regressive. As such, policy development will need to ensure that vulnerable pedestrians are provided with ample information about the changing nature of infrastructure. At the same time, historical approaches to automotive development must be altered to ensure that design considerations for persons who are blind or partially sighted or who have other disabilities are not left to post deployment.

Understanding Sight Loss in Canada

The 2017 Canadian Survey on Disability indicates there are 1.5 million Canadians with a seeing disability.[3] The leading cause of sight loss is caused by aging, meaning that more pedestrians with low or no vision will become increasingly common on Canadian streets and roads. Before discussing the potential impacts of autonomous vehicles, either in isolation or as connected vehicles, it is important to understand how someone with sight loss currently navigates the built environment. While individual techniques and strategies vary greatly, influenced primarily by degree of sight loss and visual condition, constants do exist. These include accessible pedestrian signals (APS), textured and colour contrasted tactile warning or way finding surface indicators, orientation and mobility training, guide dogs and low vision aids.

Accessible Pedestrian Signals

Accessible pedestrian signals were standardized in the early 1970's when first introduced into the Manual of Uniform of Traffic Control Devices (MUTDC). Later, in partnership with CNIB, the Transportation Association of Canada published guidelines on deployment and operation for Canadian roads.

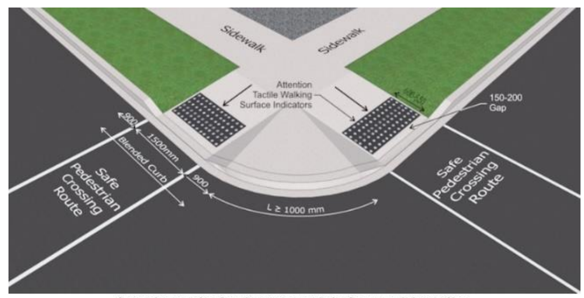
Accessible pedestrian signals provide persons who are blind or partially sighted with audible and tactile indications when traffic lights change

rvey on Disability Reports: A demographic, employment and income profile of Canadians with disabilities aged 15 years and over, 2017 https://www150.statcan.gc.ca/n1/pub/89-654-x/89-654-x2018002-eng.htm from red to green. In ideal installations, the audible signal will be distinct for each direction of travel and be easily discernable from other sounds. Accessible pedestrian signals were standardized in the early 1970's when first introduced into the Manual of Uniform of Traffic Control Devices (MUTDC). Later, in partnership with CNIB, the Transportation Association of Canada published guidelines on deployment and operation for Canadian roads.

Accessible pedestrian signals provide persons who are blind or partially sighted with audible and tactile indications when traffic lights change from red to green. In ideal installations, the audible signal will be distinct for each direction of travel and be easily discernable from other sounds. Accessible pedestrian signals are activated using a push button or by using proximity detectors.

Textured and Colour Contrasted Tactile Warning or Way Finding Surface Indicators (TWSI)

These plates made of various materials can be found at a variety of installations. As they pertain to this discussion, they are typically placed at curb cuts, providing a pedestrian with sight loss with both tactile and visual indication that they are about to enter a crosswalk. Directional tactile indicators can be installed on sidewalks or large open areas where audible or visual cues to facilitate wayfinding may prove more difficult. [4]



A good example of curb ramps used at a four-way intersection.

Orientation and Mobility Training (O&M)

Navigating one's environment without sight is a daunting task. Skills and techniques are provided through one-on-one training by certified professionals. Skills are taught by assessing an individual's residual vision, if any, and then customizing a training program based on the person's lifestyle and physical ability. Orientation and mobility instructors provide training on white cane skills or sight enhancement strategies. While an O&M instructor typically does not provide guide dog mobility training, a specialized area of rehabilitation unto itself, they do provide general orientation support to persons choosing to work with a guide dog post graduation. As at time of writing, 3,075 certified orientation and mobility instructors were registered with the Academy for Certification of Vision Rehabilitation & Education Professionals (ACVREP) in North America.

Guide Dogs

Guide dogs are highly trained animals, spending the first 20 months of their lives under the oversight of accredited organizations. In North America, there are twenty

[4] For more information on TWSI and their benefits to pedestrians who are blind, visit Clearing our Path.

organizations which provide guide dogs; all of whom are accredited by the International Guide Dog Federation.

Contrary to public perception, guide dogs do not navigate for their handlers who are blind. Rather, their role is to maneuver through crowded sidewalks, stop at intersections and provide their handler with ample warnings about possible hazards or obstacles. As it pertains to this discussion, guide dogs do not know when a traffic light cycles to green. Rather, they are trained to respond appropriately based on a handler's instructions, proceeding only when no perceived danger exists.

Low Vision Aids

Total blindness represents only a small proportion of the population of people with sight loss. Most persons have some residual vision ranging from light perception in one or both eyes to high visual acuities. Again, few common denominators exist as sight loss is unique to an individual's life experience.

Coping strategies taught by O&M instructors or acquired independently are as unique as the people who adopt them. Where one person may rely on a monocular to decide when a street crossing is safe, others may observe traffic patterns. Still others may simply follow other pedestrians, counting on others to determine when a safe crossing is possible.[5]

Regardless of the degree of sight loss, one constant exists today. Pedestrians with sight loss rely on drivers to react, even if they are reacting contrary to signals from traffic lights. Persons who are unable to see traffic signals will often listen for or watch for traffic patterns to decide when a street crossing is safe. When this places them into an intersection against a traffic signal, drivers react accordingly and will stop even if they have a green light.

The fundamental question behind this project is: will autonomous vehicles respond correctly in similar circumstances? Will onboard algorithms be able to anticipate and respond accordingly if someone enters an intersection against a traffic light? This will need to be tested and CNIB encourages industry to incorporate similar scenarios into their use cases.

CNIB recommends any new algorithms be developed and tested to anticipate and react accordingly when vulnerable road user or other pedestrian crosses contrary to a traffic signal.

[5] More information on blindness, accessible environments and related information can be found both on CNIB's website as well as at clearing our path.

What We Learned - Global Best Practices and Relevant Research

What are the Forecasted Impacts on Vulnerable Road Users with Sight Loss?

Professor Wall Emerson's research demonstrates that, in short, we simply don't know. The research revealed that a review of 432 documents relevant to automated vehicles conducted by Cavoli, Phillips, Cohen and Jones (2017), the theme of mobility for people with disabilities appeared in only 19 documents. In fact, one of the least frequently appearing topics was accessibility related to automated vehicles.

A brief from the Social Sciences and Humanities Research Council of Canada (SSHRC) revealed that from 2007 to 2016, NSERC awarded $40,249,696 as part of 327 individual grants to Canadian researchers working on developing and testing AV technologies.[6] What is conspicuously absent from the research identified by Professor Wall Emerson and that funded by SSHRC is an absence of any accessibility considerations. Standards do exist or are being developed but these seem not to speak clearly to the human vehicle interface as it pertains to vulnerable road users. SAE's existing standards as they pertain to persons with disabilities which we were able to identify include:

- SAE J1725 Structural Modification for Personally Licensed Vehicles to Meet the Transportation Needs of Persons with Disabilities;
- SAE J2092 Testing of Wheelchair Lifts for Entry to or Exit from a Personally Licensed Vehicle;
- SAE J2093 Design Considerations for Wheelchair Lifts for Entry to or Exit from a Personally Licensed Vehicle;
- SAE J2249 Wheelchair Tiedown and Occupant Restraint Systems for Use in Motor Vehicles;
- SAE J2395 ITS In-Vehicle Message Priority;
- SAE J2831 Development of Design and Engineering Recommendations for In-Vehicle Alphanumeric Messages;
- SAE J2988 Guidelines for Speech Input and Audible Output in a Driver Vehicle Interface;

[6] Taken from "Driving Change" page 42, a report issued by the Senate of Canada. https://sencanada.ca/content/sen/committee/421/TRCM/Reports/COM_RPT_TRCM_AutomatedVehicles_e.pdf

- SAE J3016 Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles;
- SAE J3163 Taxonomy and Definitions for Terms Related to Shared Mobility and Enabling Technologies.

These and SAE's existing standards are available at www.sae.org.

CNIB recommends accessibility considerations and impacts on vulnerable road users must be incorporated in all future research initiatives. Outcomes should be assessed using a disability lens and ensure that persons who are blind or who have other perceptual disabilities are engaged early and throughout research projects.

Quiet Cars: A Possible Solution

Blindness organizations around the world have been undertaking efforts to ensure that vehicle and human interactions remain safe, but these efforts have focussed primarily around quiet cars. While quiet, electric, and hybrid vehicles are an important consideration, they are beyond the scope of this research. We are aware of efforts being undertaken by our colleagues with Guide Dogs for the Blind and Jaguar who have collaborated in developing a noise emitting protocol[7]. CNIB is of the view that this represents a significant step in the right direction to ensure that quiet vehicles are detectible by persons who are blind or partially sighted

The Opportunities Afforded by CAV Technology

Autonomous vehicles hold a significant promise for Canadians with disabilities who currently are unable to drive. Professor Wall Emerson estimates that there were over 9.5 million Canadians who did not hold a driver's licence in 2017. This group consists of women, children, people with disabilities, people with low income, and the elderly; all of whom stand to benefit from autonomous vehicle deployment. If autonomous vehicles are made accessible and affordable, this group will benefit from the independence afforded by driving a vehicle, either as a first/last mile transportation solution or private ownership.

CNIB's research consistently finds that Canadians who are blind or partially sighted tend to be vastly under employed with before tax household incomes of $54,000.[8] Combined with the known cost of disability, estimated to be twenty five percent of a person's or families gross annual income, persons who are blind or partially sighted will likely encounter economic barriers as well as any accessibility challenges if autonomous vehicles fail to adequately accommodate their needs.

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[7] https://media.jaguar.com/news/2018/10/sound-jaguar-i-pace-protects-road-users Retrieved June 2019

[8] International levels of employment study undertaken by CNIB's research department https://cnib.ca/en/sight-loss-info/research/international-levels-employment-study?region=ab

Onboard Interfaces

To date, very little is known about the onboard interfaces which will make their way into autonomous vehicles. Touch screen technology has become universally accessible with both Google's Android and Apple's iOS platforms. However, there are no indications that the human interface for autonomous vehicles will be layered over top of either of these operating systems. In fact, given the proprietary nature of vehicle manufacturing, we suspect that it is not unreasonable to see operating systems unique to each manufacturer. We would hope that with the growing importance of accessibility considerations and attention given to disability issues that manufacturers would not forgo either adoption of or development of their own accessibility protocols. Any development of onboard accessibility interfaces must incorporate user acceptance testing throughout the entire software development life cycle. While beyond the scope of this project, standards maintained by the World Wide Web Consortium (W3C), do speak to internet of things (IOT) which may prove helpful in developing any new onboard systems.[9]

Regardless of which ownership model becomes prevalent, shared or individual ownership, autonomous vehicles must be independently usable by anyone, including persons with visual or perceptual disabilities.

CNIB recommends onboard vehicle interfaces be accessible to and usable by persons who are blind or partially sighted regardless of the underlying operating system. These interfaces should incorporate user acceptance testing early on and run throughout the software development life cycle, so inaccessible systems do not have to be retrofitted after deployment.

Smart Cities for All

There are no universally accepted definitions of what constitutes a smart city. It can include waste receptacles that trigger a collection call when full, or traffic lights which are responsive to vehicle counts. Municipalities have deployed real time transit services accessed via mobile devices. These systems, mostly accessible using assistive technology, provide on-demand scheduling information for public transit. Smart cities, however defined, will certainly extend both the capture and availability of robust data sets. These data sets will need to be leveraged by connected autonomous vehicles to reduce congestion on Canadian roads.

Municipal infrastructure will need to convey the presence of road closures or temporary barriers to vehicles on the road. Though some of this data is already available through GPS systems, it merely detects vehicle congestion based on tracking devices

[9]The Internet of Things refers to a virtual representation of a broad variety of objects on the Internent and their integration into Internet or Web based
systems and services.
https://www.w3.org/WAI/RD/wiki/Internet_of_Things

embedded into mobile phones. Autonomous vehicle systems will need to access this data in order to navigate efficiently on Canadian streets.

The wealth of data which smart cities will have access to holds considerable potential to improve the wayfinding experience for pedestrians who are blind or partially sighted. This cannot take place unless data infrastructures required to support autonomous vehicles are designed to facilitate seamless integration with non-vehicular applications.

An example of such an interface is a proof of concept experiment undertaken by CNIB, Blind Square and Transnomis. Appendix C provides a brief description of this proof of concept, which is still under investigation.

CNIB recommends data created to facilitate autonomous vehicle operations must be available via open platforms. The architecture of these platforms must support third party applications which can enhance way finding for pedestrians who are blind.

The vehicle-to-infrastructure interface is going to require considerable deployment of new technologies, including 5G networks and internet of things (IOT) devices. As these new technologies are being developed, their design, including use case development, cannot be considered complete if accessibility considerations are not factored into the product life cycle.

Without setting this expectation, autonomous vehicle deployment will fail to realize the true potential afforded by smart city ecosystems. For instance, traffic lights capable of altering their cycles based on vehicle counts must continue to be responsive, either through conventional or proximity activation. A truly smart city deployment would see accessible pedestrian signals whose cycles were responsive to the individual needs of pedestrians. For example, this could benefit someone who walks at a slower speed, giving them more time to complete their crossing safely.[10]

The Pivotal Issue with Autonomous Vehicle Technology

We have yet to find any evidence that the algorithms which are being developed will respond accordingly when a pedestrian with a white cane, a guide dog or someone living with an invisible disability starts to cross in front of an autonomous vehicle. Humans operating a vehicle will react accordingly if a vulnerable road user appears uncertain about beginning a crossing. How will autonomous vehicles react when someone begins a crossing against a light?

Of concern to CNIB is the protocols adopted by some vehicle manufacturers

[10] A lengthened pedestrian cycle using a health card. https://www.scmp.com/news/hong-kong/community/article/2130546/smart-device-gives-elderly-and-disabled-more-time-cross?

which will use light bars to indicate a vehicle's intent. One such example is the Ford Motor Companies experiment conducted in 2017.[11] The company conducted user experiments by driving an autonomous vehicle using various light sequences to indicate the vehicle's intent, like the existing signals such as hand waves or head nods by drivers. Should this protocol be accepted by industry, then pedestrians who are blind or partially sighted will face real and serious risks when crossing a street.

CNIB does not have a viable solution to this challenge as we have been unsuccessful in any dialogue with Ford or other vehicle manufacturers despite numerous attempts and presentations to industry.

CNIB recommends that vehicle intent cannot rely on interfaces which depend exclusively on visual cueing.

Regulators at all levels will need to require accessibility as a procurement expectation for us to see an emphasis on accessibility. For instance, as internet of things devices are piloted across Canada, their possible benefit on pedestrians with sight loss must not be omitted.

The photograph to the right depicts the light bar system developed by Ford. The lights flash across the top of the windshield depending on the intent of the vehicle. For example, solid white lights indicate the vehicle is moving autonomously, while rapidly blinking white lights indicate the vehicle is beginning to accelerate from a stop.[12]

Stakeholder Perception

A key component of this project was to assess the strategies and perceptions currently being used or held by persons who are blind or partially sighted to navigate the built environment. Appendix (B.1) to this report includes analysis and description of the survey instrument developed by Professor Habib at the University of Toronto.

Our goal in executing this survey was two-fold: first, we sought to better understand the way finding strategies currently being used by pedestrians who are blind. Secondly, we wanted to document perceptions of how autonomous vehicle technology could impact navigating the built environment.

The stakeholder survey, developed in partnership with Professor Habib and Dr. Sukhai, was distributed internationally. CNIB invited organizations from the United States, the

[11] https://media.ford.com/content/fordmedia/fna/us/en/news/2017/09/13/ford-virginia-tech-autonomous-vehicle-human-testing.html
Retrieved spring 2019

[12] https://media.ford.com/content/fordmedia/fna/us/en/news/2017/09/13/ford-virginia-tech-autonomous-vehicle-human-testing.html
Retrieved spring 2019

United Kingdom, Australia and New Zealand to share the survey with their stakeholders. In total, 352 responses were completed between the end of January 2019 and April 30. Appendix C describes in detail the responses received and the demographics of respondents.

The key findings of the stakeholder survey are as follows:

- Participants who have been using a combination of mobility aids and digital wayfinding devices and apps are more likely to embrace autonomous vehicle technology when it becomes available.
- Most respondents indicated that their trust level for autonomous vehicles was high with respondents under 18 expressing a high receptivity to autonomous vehicles.
- Participants who have been in proximity to an accident involving a quiet or electric vehicle expressed greater concern about increased numbers of vehicles which did not omit engine sounds. As a result, they are less likely to trust autonomous vehicles and have a lower preference rate for using them.

Participants who travel more frequently by car and public transit are more likely to be users of autonomous vehicles. Of the 352 completed responses, 82 percent had received orientation and mobility training and of this group, 45 percent had adopted some digital way finding solutions. In order of preference, respondents indicated that their preferred mobility aids are as follows:

- White cane;
- Google maps;
- Guide dog;
- Seeing AI; and
- Blind Square.[13]

Based on these findings, vehicle to pedestrian interfaces facilitating navigation for people with sight loss may not be adopted quickly. However, as sited in Professor Habib's report, the sample size is small given the actual number of persons living with sight loss both in Canada and abroad.

The strategies currently adopted and preferred for navigating intersections are traffic detection using hearing and accessible pedestrian signals. Sixty five percent of

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[13] Seeing AI is a Microsoft app which provides OCR, facial recognition, currency identification and scene descriptions. The app is free and runs on iOS devices.
Blindsquare, provides users with announcements of near by amenities such as coffee shops, stores and other services. The app relies on cloud-based information and is used in conjunction with conventional navigation apps such as Google, Waze or Apple maps.

Canadian respondents indicated that they can distinguish between on or off-road vehicles such as bicycles and cars.

We suspect that the unpredictability of mobile wayfinding devices and apps is why they are not identified more often as a preferred mode of navigation. As the technology becomes more robust, accurate and more reliable, we believe that this may change. After all, accessible mobile devices have only been available for approximately 10 years. Combined with affordability and a steep learning curve, it is no surprise that this segment of the population is lagging somewhat behind adoption of mobile technology.

Awareness of autonomous vehicle technology was high, with 98 percent of Canadians and 96 percent of foreign respondents aware of the technology prior to responding to the survey. The number of respondents who were optimistic that autonomous vehicle technology would positively impact their independence was high, at 80 percent and 72 percent respectively. Thirty one percent of Canadians and 42 percent of foreign respondents somewhat trust autonomous vehicle technology.

Professor Habib's conclusion is that pedestrians will tend to rely on vehicles and infrastructure over mobile devices.

Accessible pedestrian signals (APS) have been prevalent as far back as the 1920s. To some extent, mobile devices may still be perceived as novel but, as the reliability and functionality of mobile apps continues to grow, this could alter existing perceptions.

External Stakeholder Engagement

Over the 16 months which this project ran, CNIB participated in or presented at several events. These include:

- Autonomous Vehicle Symposium - San Francisco, July 2018;
- Connected & Automated Vehicles Workshop: Identifying Gaps and Priorities in Codes and Standards - Toronto, November 2018;
- Ontario Good Roads Association Annual Meeting - announcing the Ontario autonomous vehicle corridor pilot - Toronto, February 2019;
- University of Ontario Institute of Technology, Autonomous Vehicle Integration Network - Oshawa, March 2019;
- Transport Canada and Innovation, Science and Economic Development Canada – Vehicle of the Future Expert Working Group conference calls;
- Transport Canada, Forum on Low Speed Shuttles - Ottawa, June 2019

Policy Considerations and Recommendations

The following are recommendations sited throughout this report which CNIB believes are a first and positive step towards realizing the benefits promised by autonomous vehicle technology.

Recommendation 1: CNIB recommends statistics on road fatalities must be expanded to better understand victim characteristics such as sight loss or other disabilities.

Recommendation 2: CNIB recommends provincial transportation authorities adopt uniform traffic rules across Canada.

Recommendation 3: CNIB recommends all future research initiatives need to be reflective of the needs of persons with perceptual disabilities.

Recommendation 4: CNIB recommends onboard vehicle interfaces should be accessible to and usable by persons who are blind or partially sighted. These systems should incorporate user acceptance testing throughout the entire software development life cycle.

Recommendation 5: CNIB recommends smart city data must operate under open data governance and be usable by third party systems which enhance way finding for pedestrians who are blind or partially sighted.

Recommendation 6: CNIB recommends automotive engineers develop and test vehicle algorithms which will respond accordingly when vulnerable road users enter an intersection against a red light.

Recommendation 7: CNIB recommends protocols which rely exclusively on visual queues must be avoided.

Conclusion

Disruptive technologies are all around us and the pace of change continues to escalate. History has never witnessed such transformative change in a comparatively small instance of time.

Canadian streets are about to redefine the transportation paradox as humans begin to give control to autonomous vehicles. The infrastructure considerations required to achieve level 5 fully autonomous vehicles will require vast investments in deploying all kinds of devices and technologies. At the same time, the number of vulnerable road users will also increase as demographics witness another global first; more people living longer. Will these two firsts bring about the desired outcome of safer streets, enhanced mobility for marginalized groups, increased transportation efficiency and enhanced quality of life? There is no doubt that safer roads will do just that, but without a policy backdrop against which a disability lens is applied in a meaningful manner, these benefits will not be realized equally for vulnerable road users.

The CNIB Foundation appreciates the opportunity afforded to us by Transport Canada's ACATS program. We hope that our findings are helpful and that governments at all levels as well as industry continue to engage with persons with disabilities as the policy and technology landscapes continue to progress.

Appendix (A) Global literature review

Impacts of autonomous and connected vehicles on people who are blind

Robert Wall Emerson
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With a financial contribution from Transport Canada

Executive Summary

Autonomous and connected vehicles are currently being developed and tested in a range of scenarios across the globe. However, since the technology and its implementation is still being developed, implications for non-drivers have not been fully considered. The interaction of autonomous and connected vehicles with people who are blind or have low vision, either as passengers or as pedestrians, has particularly not been well explored. As municipalities, provincial agencies, and the federal government begins to explore how to incorporate autonomous and connected vehicles into existing infrastructure or how to create new infrastructures, needs of people with disabilities need to be addressed. Firstly, vehicles without drivers need to be designed so that people who are blind are able to interact with the vehicle as needed and the vehicle provides what information the passenger desires. Secondly, when people who are blind are pedestrians, autonomous and connected vehicles need to be able to interact with the pedestrians appropriately. Vehicles must be able to communicate their presence and intent to pedestrians who are not able to see. Thirdly, as transportations systems are developed to have vehicles communicate with infrastructure, pedestrians need to be able to access necessary information from the system as well in order to benefit their own travel. Finally, as such integrated transportation system are developed, municipalities and agencies need to be mindful of not further marginalizing portions of the population who are already marginalized in terms of access to transportation.

Current state of affairs

From 2014 to 2015, pedestrian fatalities in the United States rose 9.5% from 4910 to 5376 and then rose another 9% to 5,987 in 2016 (National Center for Statistics and Analysis, 2017; 2018). From 2014 to 2015, motor vehicle fatalities in Canada rose from 1,852 to 1,858; a rise of 0.3%, but serious injuries were about 10X that amount, totaling 10,280 in 2015 (Cutean, 2017). From 2015 to 2016, pedestrian fatalities in Canada rose from 284 to 334 (Transport Canada, 2018). Approximately 94% of traffic crashes are due, in part, to human error (Cutean, 2017; Singh, 2015). Pedestrians most at risk include children, older people, and people with disabilities (World Health Organization, 2014). Autonomous and connected vehicles could theoretically reduce risk inherent in pedestrian-driver interactions by assuming some or all of the tasks performed by the driver and reducing human error, thus increasing safety as well as reducing fuel consumption (Mersky & Samaras, 2016).

There are currently six levels of automation acknowledged by SAE International (National Highway Traffic Safety Administration, 2016). These levels are: SAE Level 0 (No automation) where the human driver controls the driving task; SAE Level 1 (Driver assistance) where the human driver performs all dynamic driving tasks but an automated system can assist the driver with either steering or acceleration/deceleration; SAE Level 2 (Partial automation) where the human driver performs all dynamic driving tasks but an automated system can assist the driver in one or more ways with both steering and acceleration/deceleration; SAE Level 3 (Conditional automation) where the automated driving system performs all aspects of mode-specific driving but the human driver must be ready to take back control when needed; SAE Level 4 (High automation) where an automated driving system performs all driving tasks, but only in certain environments and under certain conditions; and SAE Level 5 (Full automation) where the automated system performs all driving tasks, in any environment and under all conditions. The more advanced levels of automation are achieved by having vehicles that can sense the environment, and communicate with other vehicles and with travel infrastructure. Vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication can enhance individual vehicle performance and, to some degree, account for vehicles on the road that do not yet have such sophisticated technology. Technology that allows a vehicle to communicate with any potential useful entity (e.g., other vehicles, infrastructure, pedestrians) is known as vehicle to anything or V2X. While more automated vehicles may reduce certain aspects of the traffic infrastructure, it will almost certainly increase the need for more technologically advanced infrastructure to support V2I communication (Cavoli, Phillips, Cohen & Jones, 2017).

There are many vehicles currently operating that satisfy level 2 automation. Parking assistance, lane change warnings, and automatic braking are examples of level 2 automation. However, many people, when discussing "automated vehicles" are conceptualizing a vehicle operating at level 4 or 5. Even if the technology existed today for such levels of automation in the marketplace, it would take some time before noticeable impacts were made on the vehicle fleet. Bansal and Kockelman (2017) forecast that the current private vehicle fleet will have 24.8% penetration of level 4 technology by 2045 (assuming 5% annual price drop and constant willingness to pay values). The penetration level is 87.2% if the price drops 10% annually and the willingness to pay increases. Litman (2015) estimated 30% of the fleet to have level 4 automation by 2040 and 50% by 2050. A more recent document (Snyder, Torres & Wu, 2017) indicates that accelerated estimates have autonomous vehicles in common use by 2030 and more conservative estimates place the time at after 2050. It is estimate that about 66% of current vehicles in Canada have some connectivity and that by 2022 70% to 95% of new cars in Canada will have V2I, V2V, or similar technology on board (Nowak, 2017).

Level 4 and 5 automation will be most beneficial, however, for commercial fleets and higher income households where savings on drivers and the benefit from higher driving distances will be seen (Wadud, 2017). One study found that the average household is willing to pay $3,500 for partial automation and $4,900 for full automation, with some willing to pay above $10,000 for full automation technology (Daziano, Sarrias & Leard, 2017). However, Kyriakidis, Happee and de Winter (2015) found that 22% of their 5000 respondents across 109 countries would not pay anything extra for a fully automated vehicle while 5% indicated that they would pay more than $30,000. These results suggest that whatever level of automation technology is available, some households will be willing and able to take advantage of that technology while others will not.

General impacts

One review of 50,200 documents mentioning automated vehicles was narrowed to a body of 432 documents directly relevant to automated vehicles (Cavoli, Phillips, Cohen & Jones, 2017). These documents yielded 44 thematic codes, of which the most commonly appearing were road safety, legal/regulatory issues, public perception, drivers' interaction with automated vehicles and ownership models. Road safety was the most prevalent topic since one of the main impacts cited due to an increase of automated vehicles is crash reduction and increased road safety. Increasing use of automated vehicles show that fatal crashes could be reduced by up to 40% (Fagnant & Kockelman, 2015). However, simulations showed that restricting the acceleration and deceleration of autonomous vehicles to levels that optimize passenger comfort may decrease transportation capacity and increase delays (Le Vine, Zolfaghari & Polak, 2015).

There are also the issues inherent in introducing any new technology. Hopes and expectations may not be met, and performance lower than expectations may lead to slower adoption or less positive acceptance. There are also some areas that will remain unknown until more automated vehicles enter the active vehicle fleet. For example, there is uncertainty about how drivers in manually driven vehicles will interact with vehicles operating under some level of automation (Cavoli, Phillips, Cohen & Jones, 2017). It is possible that human drivers might be encouraged by how close autonomous vehicles are traveling to each other and being to approach other vehicles too closely, thus increasing risk (Brown, 2016; Gouy, Wiedemann, Stevens, Brunett & Reed, 2014). Also, if an increase in autonomous vehicles encouraged more people to walk and increased pedestrians' confidence in walking in front of vehicles, this change in behavior might impact traffic flow in unknown ways (Alessandrini, Campagna, Site, Filippi, & Persia, 2015; Begg, 2014). Until a significant number of autonomous vehicles are operating on public roadways, it is unclear whether or how exactly risk will be impacted (for drivers and pedestrians) or how the travel landscape will change.

Beyond impacts to the roadways in terms of congestion, parking, or driver interaction, the introduction of many autonomous vehicles has the potential for a range of impacts on other aspects of society. If large scale use of autonomous vehicles led to greater fuel economy, one impact could be lower greenhouse gas emissions (Snyder, Torres & Wu, 2017). In fact, Greenblatt and Saxena (2015) estimate that autonomous vehicles could reduce greenhouse gas emission by 87% to 94% below 2014 conventional vehicle levels. It makes sense that introducing autonomous vehicles would lead to some fuel savings since simply optimizing platooning in the trucking industry could reduce fuel use by 1.5 billion gallons annually (saving 15.3 metric tons of carbon dioxide) (Hsu, 2017).

From a more human perspective, widespread adoption of autonomous vehicles could reduce accidents and fatalities, reduce stress, increase physically active lifestyles, increase access to transportation for people of all income levels and walks of life (Snyder, Torres & Wu, 2017). Of course, all of these potential benefits depend on how autonomous vehicles are implemented and how they are integrated with existing transportation systems. Canada is currently not as far along in the development and exploration of automated vehicles as many other countries. The 2016 AV Index (a measure of a country's technological advancement in the field of automated vehicles), Canada did not enter the list of the top 9 countries. The list included Germany, the United States, Sweden, the United Kingdom, Japan, France, China, Italy, and South Korea (Cutean, 2017). Only 26% of Canadians are positive about the concept of fully autonomous vehicles with most responding that they feel anxious and powerless when riding in one (Cutean, 2017).

Public perception and acceptance

Little of the research into automated vehicles deals with public acceptance or impact on pedestrians. In Cavoli, Phillips, Cohen and Jones' (2017) review of 50,200 documents relevant to automated vehicles, less than 6% dealt with social science aspects. The 432 documents analyzed yielded 44 thematic codes, of which public acceptance/perception/expectations was the third most prevalent, appearing as a topic in 70 documents.

In a survey of 347 people in Austin, Texas, the primary benefit predicted from an increase in autonomous vehicles was a reduced number of crashes and the primary concern was equipment failure (Bansal, Kockelman & Singh, 2016). In terms of how much respondents were willing to pay for differing levels of automation, it seems that people were willing to pay more for higher levels of automation. This might be indicative of respondents' willingness to pay for more novelty than for simply enhancing already existing technological trends. In general, respondents who had higher incomes, were more technologically adept, were male, lived in urban areas, and had experienced more crashes previously were more interested in the technology and were more willing to pay for acquiring autonomous and connected vehicle technology (Bansal, Kockelman & Singh, 2016; Kyriakidis, Happee & de Winter, 2015; Schoettle & Sivak, 2014). People in California, people who enjoy driving, and technology enthusiasts are also more likely to be interested in purchasing autonomous vehicles (Cavoli, Phillips, Cohen & Jones, 2017). Although Bansal, Kockelman and Singh (2016) hypothesized that younger road users might be more accepting of new technologies, limited connection has been shown of age with autonomous vehicle acceptance or perceptions of safety in autonomous vehicles (Kyriakidis, Happee & de Winter, 2015). Brechin, Farr, Hurley, King and Willis (2017) found that in a survey of 448 people, respondents over 50 years old were slightly more negative towards the idea of driverless vehicles than younger people. However, after 88 participants took part in trials with an autonomous vehicle, 98% of the participants, who ranged in age from 20 to over 80, felt safe in the autonomous vehicle.

Other surveys have found similarly positive perceptions of autonomous vehicles. Hyde, Dalton and Stevens (2017) found that of 233 people surveyed, 81% believed that driverless cars were a good idea. Beyond this basic positive perception, however, only 55% indicated trust in a driverless vehicle with 23% somewhat agreeing that they could trust a driverless vehicle. As was seen in the Brechin, Farr, Hurley, King and Willis study (2017), direct exposure to autonomous vehicles might increase acceptance. Responses in the Hyde, Dalton and Stevens survey indicated that providing up to date information about autonomous vehicles did not impact the level of positive perceptions of such vehicles but that factors such as vehicle manufacturer and safety record would impact level of trust.

Not all surveys, however, have found such positive perceptions. Schoettle and Sivak (2015) found that out of 500 drivers, a majority had concerns about driving in a driverless vehicle. In a larger sample of 3,184 drivers in the U.S., China, and Germany, McKinsey (2015) found that only 61% were in favor of legalizing vehicles with automated functions. Concerns regarding autonomous vehicles include safety and reliability of the system (Bansal & Kockelman, 2016; Cavoli, Phillips, Cohen & Jones, 2017; Howard & Dai, 2014; Schoettle & Sivak, 2014), software security (Kyriakidis, Happee & de Winter, 2015; Schoettle & Sivak, 2014), cost (Bansal & Kockelman, 2016; Cavoli, Phillips, Cohen & Jones, 2017; Howard & Dai, 2014), perceived usefulness (Cavoli, Phillips, Cohen & Jones, 2017; Choi & Ji, 2015; Clark, Parkhurst & Ricci, 2016a; 2016b), trust (Choi & Ji, 2015; Frisoni, Dall'Oglio, Nelson, Long, Vollath, Ranghetti & McMinimy, 2016) and liability (Howard & Dai, 2014; Kyriakidis, Happee & de Winter, 2015). Within Canada, the highest level of trust in autonomous vehicles is in Quebec and Ontario while the lowest levels of trust are in Manitoba and Saskatchewan (Cutean, 2017).

Surveys discussed thus far have tended to focus on the perceptions of potential drivers or passengers in autonomous vehicles. For drivers, receptivity to the new technology refers to their likelihood of using it. For pedestrians, receptivity would refer to the likelihood of them walking in front of an autonomous vehicle. Differences in perceived risk with regard to autonomous vehicles exist between vehicle passengers and pedestrians with passengers typically perceiving autonomous vehicles as more risky than pedestrians (Hulse, Xie & Galea, 2018). Deb, Strawderman, Carruth, DuBien, Smith and Garrison (2017) surveyed potential pedestrians in the

United States regarding attitudes toward autonomous vehicles. Factors including attitude, social norms, trust, compatibility, and system effectiveness were used to model a pedestrian's likelihood in crossing a road in front of an autonomous vehicle. Of 482 respondents, the main components of pedestrians' receptivity towards autonomous vehicles were safety, interaction, and compatibility. "Safety" explained 24% of the variance in the predictive model and was made up of items regarding attitude, social norm and effectiveness. "Interaction" explained 22% of the variance in the predictive model and was made up of items regarding trust, crossing related attitude, and social norm. "Compatibility" explained 14% of the variance in the predictive model and was made up of items regarding the ability to successfully integrate autonomous vehicles into the current traffic framework. While limited effects of age have been shown in terms of drivers' receptivity towards autonomous vehicles, this study showed that younger and more urban pedestrians tended to be more positive toward autonomous vehicles.

Travel inequality

In the review of 432 documents relevant to automated vehicles conducted by Cavoli, Phillips, Cohen and Jones (2017), the theme of mobility for people with disabilities appeared in only 19 documents. In fact, one of the least frequently appearing topics was accessibility to automated vehicles. Nevertheless, connected and autonomous vehicles have the potential to greatly increase independence for people who do not or are not able to drive (Fagnant & Kockelman, 2015; Harper, Hendrickson, Mangones & Samaras, 2016; Ticoll, 2015). The section of the U.S. population that do not drive is estimated to be 30% (Smith, 2012). In Canada, there were 25,580,000 licensed drivers in 2016 and the total population was 35,151,728 (Statista, 2018; Statistics Canada, 2017). This suggests that Canada has up to 9,571,728 non drivers. The World Health Organization notes that the group of non-drivers is made up largely of vulnerable road users including women, children, people with disabilities, people with lower income, and the elderly; all who might have limited access to jobs, education, services, and recreational opportunities as a result of limited mobility (World Health Organization, 2016). The 9,571,728 non-drivers in Canada probably overlaps significantly with the 13.7% of the adult population in Canada that reports being limited in their daily activities due to a disability (Statistics Canada, 2018).

In Canada, as elsewhere, transportation equality has been an ongoing issue. Jacobs (2018) explored this issue from 1976 to 2016 and found that the basic human right for access to transportation for people with disabilities was often lessened due to a lack of adequate legislation. In many instances, transportation systems are altered to improve efficiency in a way that decreases how well people with disabilities can access the system (e.g., fewer buses on a route, less wait times at stops). As technology develops, more technologically based solutions to both transportation efficiency and transportation access have been developed. A primary field for this endeavor is the application of intelligent transportation systems (ITS). However, the range of potential technologies and the speed at which they change has not led to a unified approach or to a large scale implementation of ITS to address the needs of vulnerable road users (Mans et al, 2017; Vaa, 2018). It is estimated that the introduction of autonomous vehicles would impact the lives of 57 million people with disabilities in the U.S., 6 million of whom have difficulty getting the transportation they need (Claypool, Bin-Nun, & Gerlach, 2017). These authors further indicate that approximately 1.9 million people with disabilities never leave their homes. The number of Canadians with disabilities impacted by automated vehicles would be smaller but still be approximately 5,500,000.

People who are elderly, people with disabilities, and people who do not own a vehicle and are not connected to a robust transportation network might all be able to increase their independent travel and do so more flexibly if autonomous vehicles are designed with accessibility in mind (Begg, 2014; Bohm & Hager, 2015). In order to do so well, municipalities need to plan for future mobility not simply as a modification of current mobility routes and modalities but as an entirely new modality. If the majority of vehicles are not owned or leased but exist to provide a service to any who request that service, cars and vans on the road become an extension of the bus, metro, and train transportation system. As such, the entire system would need to be integrated. Instead of walking to a bus stop, a person with a mobility impairment might request a vehicle to pick them up at their home and take them to the metro or train depot to begin a longer trip.

Harper, Hendrickson, Mangones and Samaras (2016) estimate that increased mobility for people who are elderly and other current non-drivers due to autonomous vehicles could add up to 295 billion or a 14% increase in annual vehicle miles traveled. People living in areas not well supported by public transport might also benefit from the advent of autonomous vehicles (Alessandrini, Campagna, Site, Filippi, & Persia, 2015). If autonomous vehicles are to be leveraged to increase mobility for all members of society, then an integrated mobility framework needs to be designed that will reach all geographic areas. Simply adding to well traveled arteries or modifying the most well used transit routes will not achieve the economic or societal gains possible form autonomous vehicles. Infrastructure needs to be designed and implemented that allows autonomous vehicles to be the link between different modes of travel as well as a seamless part of the total transport picture.

However, many people who do not drive might not be able to take advantage of the benefits of autonomous vehicles until level 4 or 5 automation is prevalent. Further, many members of groups that are non drivers also tend to be in lower socio-economic groups and might not be able to afford access to autonomous vehicle systems (Wagner, Baker, Goodin, & Maddox, 2014). There are some arguments that as connected vehicle systems are slowly developed, it is the affluent in society that will benefit the most; both from being able to afford high priced connected and autonomous vehicles and by living in areas that are more likely to have sophisticated technology installed in transportation infrastructure (Bierstedt, Gooze, Gray, Peterman, Raykin & Walters, 2014; Enoch, 2015; Frisoni, Dall'Oglio, Nelson, Long, Vollath, Ranghetti, & McMinimy, 2016). Depending on how autonomous and connected vehicle technology is introduced, especially in regards to mass transit systems, there is the potential for it to exacerbate social inequity issues (Thomopolous & Givoni, 2015) or to lift all members of a society to greater access (McCarthy, Bradburn, Williams, Pieckocki & Hermans, 2015) and reduce overall costs (Beggs, 2014).

Inequalities in access to independent travel already exist in society (Bradshaw-Martin & Easton, 2014; Claypool, Bin-Nun & Gerlach, 2017). Many people with disabilities are forced to schedule multiple forms of transportation such as private drivers, public transportation, shared rides, etc. to accomplish what drivers are able to accomplish by simply getting in a car and driving somewhere. What accessible forms of transportation do exist can also be unreliable or inconvenient due to paratransit scheduling requirements, elevator outages in metros, broken sidewalks, and buses that do not kneel (Claypool, Bin-Nun & Gerlach, 2017). This can lead to increased cost, reduced access to aspects of life, lower employment, and a focus on transport simply as utility (Bradshaw-Martin & Easton, 2014). If social inequity currently exists in terms of access to public transportation, autonomous vehicle technology used to alter public transportation might magnify such inequities. There are two other potential drawbacks of increased use of autonomous vehicles by current non drivers. The possible increase in vehicle miles traveled estimated by Harper, Hendrickson, Mangones and Samaras (2016) could lead to increased road congestion and the increased use of transportation systems not reliant on vehicle ownership could lead to increased urban sprawl (Meyer, Becker, Bosch & Axhausen, 2017). Both of these potential impacts could be alleviated with a forward thinking plan of adoption of autonomous vehicle technology by all levels of government, especially in regards to public transport systems. While many approaches to the implementation of autonomous and connected vehicle technology have been discussed, there is the potential for this technology to radically reshape the travel landscape. An approach that explores this possibility is treating mobility as a service (MaaS) with an emphasis on shared mobility and integration of multiple modes of transportation (Hensher, 2017; Mulley, 2017; Wong, Hensher & Mulley, 2017).

Designing for interaction with pedestrians with disabilities

The lack of a driver in an automated or connected vehicle means that the vehicle must be able to communicate with not only infrastructure and other vehicles but with other road users, especially pedestrians. Since pedestrians who are blind cannot see lights that might be outfitted on vehicles, a range of communication modalities needs to be employed (e.g., Clamann, Aubert & Cummings, 2015; Dey, Martens, Eggen & Terken, 2017; Hulse, Xie & Galea, 2018; Mahadevan, Somanath & Sharlin, 2018; Merat, Louw, Madigan, Wilbrink & Schieben, 2018; Owens, Greene-roesel, Habibovic & Head, 2018; Parkin, Clark, Clayton, Ricci, & Parkhurst, 2016; Rasouli & Tsotsos, 2018; Straub & Schaefer, 2018; Zimmerman & Wettach, 2017). The range of communicative options includes options such as external lights on the vehicle, haptic feedback fed to a hand held device, and auditory feedback presented from a smart phone. Any option pursued for providing information to vulnerable road users, including those with visual impairments, should be a part of a broad infrastructure communication strategy so that all users of the transportation system can access a broad range of information when needed. However, it should be noted that many pedestrians eschew feedback from devices in favor of their own perception of a vehicle's speed and time to arrival (Clamann, Aubert & Cummings, 2015; Dey, Martens, Eggen & Terken, 2017; Mahadevan, Somanath & Sharlin, 2018; Merat, Louw, Madigan, Wilbrink & Schieben, 2018; Rasouli & Tsotsos, 2018).

There is a long history of development of technological tools designed to assist people who are blind with the task of navigating the built environment. Many devices dedicated for use by people who are blind have been based on ultrasonic waves and provided auditory or vibrotactile feedback about objects in the environment (Smith & Penrod, 2010). Some of these devices were worn on a person's body, some attached to a long cane, and some were held in a person's hand. Few of these have seen widespread adoption. Those still in production and limited use are the Sonic Pathfinder, the Hand Guide, the Miniguide, and the K Sonar (Smith & Penrod, 2010). More recently, GPS devices have seen grater use. GPS based units dedicated to people who are blind include the Trekker Breeze, the Trekker Maestro, and the Kapten. However, since GPS based devices and phone applications are also widely used by people who are not blind, the range of options for such devices and applications is much wider than previous technologies. In the same manner, ways that a pedestrian might communicate with automated vehicles or smart infrastructure needs to be developed so that it will be used by all pedestrians but also designed so that pedestrians who are blind can access the same information.

Currently, there are many approaches being explored for providing people who are blind information about the built environment. The majority of these projects either use the widespread availability of smartphones or provide auditory or haptic information through a dedicated hand held or body worn device. However the specific technology is structured, some of the information a pedestrian who is blind might potentially want to know includes their location, the status of lights at an intersection, distance to a given location, presence of a vehicle, time to arrival of the nearest vehicle, alignment to a crossing, time to arrival of a bus, and presence of construction. There are projects underway in many locations exploring isolated components of the range of information a pedestrian who is blind might need to know but no project currently proposes to develop a transportation system that provides all potentially useful information. A system that seeks to integrate automated and connected vehicles as a way of enhancing transportation for all would need to develop such a broad based approach.

For travelers who are blind, there are certain design features that need to be addressed to ensure access to autonomous vehicles. First, the person needs to be able to ascertain that an autonomous vehicle has arrived, is ready for the person who is blind to enter, and where exactly the vehicle is. These information requirements are slightly more demanding than the current information available via services such as Lyft and Uber. For those services the human driver is able to stop a car where a passenger appears to be waiting and is also able to verbally indicate that they have arrived and are the vehicle the passenger is waiting for. Options that are possible include the transmission of a key code to the waiting passenger who then must enter the code to enter the vehicle. If the vehicle announces itself as arriving for person X, and repeats that message occasionally until the person arrives or until a maximum time, that would give a person who is blind time to go to the vehicle and enter the code. Note that autonomous vehicles arriving for a person with a disability, especially a person who is blind, would need to be able to arrive not only at an address but at a specific location relevant to that address, such as “the north side of the building” or “the side entrance”. These requirements would be communicated by the person calling for the vehicle when the ride was requested.

Next, an autonomous vehicle needs to be designed to allow room for dog guides and to ensure that a person who is blind is able to interact reliably with the vehicle to input commands (Javelosa & Marquart, 2016). Some developers of autonomous vehicles have elected to focus on vans since they currently allow the greatest variety of users to most easily use the vehicle. By having side doors that slide open, a large opening is available for people with dogs or people in wheelchairs to use the vehicle. A button on the outside of the vehicle might allow a wheelchair user to deploy a ramp from within the vehicle in order to enter without assistance. Similarly, people using an autonomous vehicle will want to have a large enough space to open and use laptop computers, books, or other materials. This is more easily accomplished in a van than in a passenger sedan.

The vehicle must also be able to reliably communicate to the passenger the vehicle’s location, surroundings, and what the immediate environment is when the passenger is disembarking (Claypool, Bin-Nun & Gerlach, 2017). Once a person with a disability has recognized that a vehicle has arrived, has arrived for them, and has gotten into the vehicle, communication between the passenger and the vehicle is important. The communication interface needs to be able to handle people speaking with a broad range of accents and speech impediments or to accept typed input. It would also be useful to have the passenger be able to load a destination via their smart phone. If a passenger has a device with which they can communicate (through speech, an adaptive keyboard, etc.) and they can send information to the vehicle from that device, that will allow a passenger to communicate with the vehicle through an existing adaptive device. The vehicle should then keep a passenger alerted to what is happening in the surroundings, the trip progress, and time to destination. A choice can be offered to a passenger for how much information they want or how often they want to be updated.

Taken partly from the literature and partly from a U.S. government report (United States Government Accountability Office, 2017), in order to minimize the potential drawbacks and optimize the potential benefits, especially for vulnerable travelers or non-drivers, there are a series of broad areas to be taken into consideration.

- integrate autonomous vehicle use in mass transit applications with current systems
- do not simply update current systems or update the most commonly used routes
- ensure that autonomous vehicles are introduced across geographical areas, instead of doing spot introduction (requires first that the required infrastructure is put in place)
- ensure that autonomous vehicles are able to accept users with wheelchairs, dog guides, etc. and can input and output information through a variety of modalities
- consider how the physical built environment might be adapted to accommodate increased autonomous vehicle use (e.g., less parking, different traffic flow, different links between pedestrian and vehicle flows, less signage)
- rather than focusing on automated vehicles in isolation, automated vehicles need to be considered as part of a more integrated "smart" transportation system that includes V2V, V2I and V2P elements
- include a sizeable component of public education in the deployment of autonomous and connected vehicles

- allocate sufficient resources to make use of big data that will be possible from connected vehicles and infrastructure

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Appendix B University of Toronto survey analysis

Notice to reader: The report prepared by Professor Habib has been split into two sections; the narrative analysis, below, and appendices containing detailed data analysis. The latter can be found on CNIB's website.

Understanding the Impacts of Connected and Automated Vehicles (CAVs) on Pedestrians with Visual Impairment

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Abstract

A fully autonomous transportation system allows vehicles to communicate with each other and with the world around them. There is no question that municipal streets will function very differently once connected autonomous vehicles (CAVs) become commonplace. When this occurs, interactions between vulnerable groups such as persons with visual impairment will also be transformed. This project identifies the impacts and accessibility barriers posed by CAV technology for pedestrians with visual impairment.

A comprehensive survey of Canadians and non-Canadians with visual impairment was conducted in collaboration with the Canadian National Institute for the Blind (CNIB). The survey was designed to evaluate perceptions of pedestrians with visual impairment regarding communicating with CAV. In the first part of the survey, participants were asked about their current approaches and relevant issues regarding navigating through transportation networks. Pivoting on current experience, a series of hypothetical scenarios that involve communicating with CAVs was created.

Overall, we received almost 400 records from inside and outside Canada, of which around 350 are usable. Approximately half of the observations are from Canada and the other half from outside the country.

Key findings:

1. Participants who have been using a combination of tools and applications that integrate technologies for navigation purposes are more likely to be CAV users.
2. Most participants “somewhat” trust CAVs.
3. Participants who acknowledged being near an accident involving an electric vehicle are more concerned about the quietness (i.e., quiet impact) of electric and autonomous vehicles. As a result, they are less likely to trust CAVs and have a lower preference rate for using them.
4. Participants who travel more frequently by car and public transit are more likely to be CAV users.

Introduction:

According to the World Health Organization, “the road users most at risk are pedestrians, children, cyclists, and people with various types of disabilities, all of whom can be considered vulnerable road users [VRUs]” (1). However, providing safety and mobility improvements for VRUs compared to drivers and car passengers has traditionally been less of a priority (2), despite statistics indicating a clear need. For example, Transport Canada reported that 18.9% (or nearly one-fifth) of road fatalities in 2016 involved pedestrians (3).

Pedestrians with disabilities in particular have a higher risk of experiencing road accidents compared to pedestrians without disabilities. In particular, people with visual impairment face issues around communicating with drivers and cyclists on roads and sidewalks. Therefore, investigating the perceptions of people with visual impairment regarding automated vehicles and learning their preferences for communicating with these emerging technologies would be more beneficial than simply waiting for after-the-fact solutions.

This report is organized as follows: section 2 summarizes some descriptive results from the survey; and the final section recaps the study’s key findings.

Descriptive Analysis:

We received 421 records from inside and outside Canada. After cleaning the data (i.e., removing inaccurate, incomplete, and irrelevant records from the dataset), we discovered that 352 records were usable for further analysis; of these, 181 were from inside Canada and 171 from outside. We also found that the dataset was slightly overrepresented for Ontario and British Columbia and slightly underrepresented for Quebec. Furthermore, we found that around 50% of the participants were blind or partially-sighted prior to the age of 18, and that 30% and 18% of the participants had experienced visual impairment onset between the ages of 18 and 65 and before the age of 18, respectively. Around 82% of the participants had received O&M (orientation and mobility) services, with almost 45% using integrated technologies in their programs.

According to the results, most participants used their smartphones for multitasking recreation purposes, such as reading, watching movies, etc. The non-Canadian responses indicated that the second most common purpose for using smartphones was for “getting around”, whereas Canadian responses indicated that the second most popular use for smartphones was as a calendar. Interestingly, the application “Seeing AI” was listed as the most popular app by participants both inside (45%) and outside (43%) Canada. Similarly, BlindSquare and KNFB Reader applications were also popular among the participants. However, BlindSquare was more commonly used for navigation. BlindSquare and the Classic Text to Speech Engine were more popular among Canadian participants, compared to KNFBReader, Ultra Magnifier +, Messageease Keyboard, iBlink Radio, Learning Ally, and LookTel Money Reader, which were more common among participants from outside Canada.

In terms of technologies and aids that are used for navigation purposes and getting around, it was found that white canes are still the most popular tool for this purpose. However, Google maps is the second most popular aid after white canes among both Canadian and non-Canadian participants, followed by built-in GPS on smartphones. Interestingly, Seeing AI and BlindSquare are placed fourth and fifth, after guide dogs.

In terms of mode choice behavior, the results are very similar for both Canadian and non-Canadian responses. Another observation is related to the poor para-transit systems both in and outside Canada. It was found that more than 60% and 40% of participants had never used para-transit. However, almost 20% of non-Canadian participants had used para-transit 2 to 5 times per month. Cars were chosen as the most frequent mode of travel (2 to 5 times per week) for both Canadian and non-Canadian participants. Similarly, public transit was used more frequently by Canadian participants than non-Canadian participants, with walking being the second most common travel mode.

Both Canadian and non-Canadian survey respondents had similar perceptions when choosing alternatives for traveling in familiar and unfamiliar places. However, GPS devices were more popular among non-Canadians for navigating in familiar places (almost twice as Canadians). Other than that, for navigating in familiar and unfamiliar places, nearly similar results were observed for both Canadians and non-Canadians. Together with white canes, smartphone applications play a major roles for navigation.

Furthermore, regarding para-transit, the majority of Canadian participants (44%) do not have access to this travel mode, compared to 28% of non-Canadian participants. Among participants who have access to paratransit, 24% of non-Canadians are “somewhat” satisfied with the system compared to only 18% of Canadians.

In terms of satisfaction rates regarding accessibility to the public transit system, Canadian participants have more positive views, with 37% and 25% being “somewhat satisfied” or “very satisfied” with the system, respectively. On the other hand, only 25% of non-Canadian participants are “somewhat satisfied” with the public transit system.

In terms of agreeing/disagree statements regarding different scenarios on the importance of hearing as a pedestrian, it was found that interacting with other road users (e.g., cyclists or motorists on roads and sidewalks) via hearing audible alerts is an important concern. Again, it was found that both Canadian and non-Canadian participants have very similar perceptions regarding the use of headphones while walking on sidewalks or crossing streets. It was found that approximately 20% of Canadian and non-Canadian participants with visual impairment use headphones while walking on sidewalks or crossing streets. It was also found that more than 50% of them use headphones for navigation purposes while walking. On the other hand, among participants who did not use headphones while walking, the majority believe that safety issues and isolation from surroundings are major concerns that prevent them from using these devices.

Furthermore, the participants indicated that they were more likely to rely on their sense of hearing for deciding to cross compared to using technologies, applications, or tools. Currently, the Accessible Pedestrian Signal (APS) systems are considered to be the second most helpful alternative after the sense of hearing.

According to the results, 65% of Canadian and 60% of non-Canadian participants can distinguish noise from on/off road traffic, such as motorists on roads and cyclists on sidewalks. More than 98% of the participants are familiar with electric vehicles. Approximately 18% of Canadian and 24% non-Canadian participants have already experienced being near an accident with an electric vehicle. Note that the question asked to participants was whether they were near an accident with an electric vehicle, not whether they were personally involved in such an accident.

Similarly, it was found that 98% of Canadian and 96% of non-Canadian participants had heard about CAVs before participating in the survey. Moreover, almost 80% of Canadian and 72% of non-Canadian participants believe that CAVs will impact their future independence for traveling. However, when participants were asked about how much they trust CAVs, only 30% and 41% of Canadian and non-Canadian participants "somewhat" trust these vehicles, respectively. On the other hand, regarding whether or not they prefer to be CAV users, the results are more counterintuitive. It was found that almost 36% of Canadian participants either "highly preferred" or "somewhat preferred" to be users of these vehicles compared to almost 27% who did "not [prefer] at all' to use CAVs. The results are more balanced among non-Canadian records, as almost all three options ("not preferred at all", "somewhat preferred" and "highly preferred") were chosen equally by one-third of the total participants.

According to the results for communication preferences with CAVs, 37% of the participants prefer to get alerts. On the other hand, almost 30% prefer not to communicate at all. Overall, it can be concluded that participants prefer to get alerts from vehicles or infrastructure rather than use personal devices that connect to these vehicles, such as smartphones.

Descriptive results of combined records of Canadians and non-Canadians according to age, employment status, and sight-loss experience:

In this section, the aggregated dataset developed from Canadian and non-Canadian participants represents additional descriptive results, as in most cases there are limited differences between Canadian and non-Canadian records. In this regard, some of the demographic information was chosen for evaluation of relationships concerning other observed variables.

Descriptive data broken down by sight-loss experience:

Nearly 60% of participants have experienced sight loss or have been partially sighted all their life. Most of the participants in this group show that they "somewhat" trust CAVs, with the second largest group (25%) also "somewhat" trusting CAVs. This second group first experienced visual impairment between the ages of 18 and 65. Similarly, most participants from the remaining respondents who experienced visual impairment before the age of 18 "somewhat" trust CAVs as well.

Interestingly, the results show that most of the participants (16.3%) who are partially sighted or have been blind all their life "somewhat preferred" to be CAV users, while 15.4% of the same group "highly preferred" to be a user. On the other hand, 8% of the second largest group (i.e., those who experienced sight loss between the ages of 18 and 65) "highly preferred" to be CAV users, whereas 5.8% of the same group indicated that CAV user-ship was "not preferred at all' or only "somewhat preferred".

In terms of concerns about sharing roads with CAVs, the results indicate that technological failures and lack of proper communication techniques are the two main concerns acknowledged by the participants. Regarding the stated preferences for communication techniques with CAVs, participants were given three response options: preferred not to communicate at all, preferred to get alerts from CAVs about their current status, and preferred to get feedback from infrastructure similar to the operation of Accessible Pedestrian Signal systems. It was found that most participants prefer to receive alerts from CAVs about their current status (e.g., "about to stop"). Preference to not communicate at all with CAVs was the second most chosen option, with the highest number among participants who are blind or partially sighted all their life.

In terms of the chosen technologies, aids, and tools that participants use on a daily basis, the study found that those most commonly used by participants who have been blind all their life are braille note-taker (85%), a refreshable braille display (82%), and AIRA (77%). On the other hand, artificial vision products such as eSight or OrCam, intervenors for the deafblind, and sign language interpreters are the most common applications used by 33% of participants who experienced sight loss prior to age 18. For participants who experienced visual impairment between the ages of 18 and 65, the most commonly used tools were screen magnifying programs such as ZoomText, an assistive listening device such as a hearing aid o an FM system, a CCTV or closed-circuit television, and a tablet other than iPad.

Descriptive data broken down by employment status:

The study indicated that some participants with different employment statuses have almost the same thoughts regarding concerns about sharing roads with CAVs. Specifically, their concerns centered on technology failures of CAVs, lack of proper communication with CAVs, and the possibility of new (unknown) disastrous situations.

Most of the study participants are full-time employees or retired, while the remainder are either students or unemployed. In terms of how employment status affected their preference for communicating with CAVs, there were four available options, as follows: prefer to not communicate at all, prefer to get feedback and alerts from CAVs, prefer to get feedback from infrastructures such as Accessible Pedestrian Signal systems, and prefer to have a device that is connected to CAVs for communication. The majority of participants of all employment statuses preferred to get alerts and feedback from vehicles. However, as their second choice, participants indicated they would choose to not communicate at all with CAVs.

Conclusion:

The overall aim of the study was to evaluate the perceptions of people with visual impairment regarding CAV technology and how they would choose to communicate with these vehicles if they had a range of options. Based on the key findings from the pilot test, a comprehensive survey was designed to examine the impacts of CAVs on pedestrians with visual impairment. Participants were asked about their sight loss experience as well as the severity of their sight loss. This was followed by general questions about different applications and tools they use daily. In the next step, they were asked about their travel behavior as well as any navigation tools or applications they use regularly. This was then followed by questions about their perceptions of electric vehicles, including some hypothetical scenarios on CAVs and how they might want to communicate with these vehicles.

Overall, the majority of participants have been partially sighted or blind all their life. Also, most participants are aged 21 to 64 years. The advantage of having higher participation from the younger generation is that they are the likeliest to someday become CAV users. In general, it was found that most participants "somewhat" trust CAVs. However, the results associated with the preference of participants to be CAV users are slightly counterintuitive, in that among the three options regarding their preference to use CAVs (i.e., "not preferred at all', "somewhat preferred", and "highly preferred"), the majority of participants chose the first two options. These counterintuitive results are not significantly problematic, as CAVs have not yet been tested on a large scale.

Moreover, the major purpose of this study is to move a step forward in filling the research gap on this topic. Further research will be required to mitigate the upcoming issues of CAVs in terms of how pedestrians and other road users prefer to communicate with these types of vehicles. Furthermore, guidelines, standards, and law enforcement should be developed that take these preferences into consideration.

Another key finding from the survey is related to the importance of the sense of hearing in relation to both roads and sidewalks. The study results found that most participants have concerns about the "quietness" (i.e., the quiet impact) of electric vehicles on roads as well as the same factor in cyclists on sidewalks. The majority of participants acknowledged that they would like to hear some sort of feedback or alerts from vehicles on roads as well as cyclists or scooters on sidewalks.

Similarly, it was found that most participants prefer to get feedback and alerts from CAVs other than in reference to infrastructure. Some indicated a willingness to use Accessible Pedestrian Signal systems or wearable devices such as smartwatches or smartphones when communicating with CAVs. However, most participants chose the option "prefer to not communicate at all" after getting feedback from CAVs. The remaining option (i.e., "prefer to get alerts from infrastructure and wearable devices that connect to CAVs") was the least preferred for communicating with these vehicles.

It was also found that participants who received orientation and mobility (O&M) training that used integrated technologies are more likely to be CAV users and to "somewhat" trust CAVs. Similarly, participants who acknowledged that they use navigation applications and tools that employ integrated technologies are more likely to be CAV users and to "somewhat" trust these vehicles. On the other hand, participants who acknowledged that they use more traditional tools for navigation purposes, such as white canes or guide dogs, are less likely to be CAV users.

Another key finding is related to the quietness of electric engines. It was realized that most participants worry about the noise reduction of electric and autonomous vehicles. In this regard, having previous experience of being near an accident with an electric vehicle (not necessarily being involved in one) impacted negatively on their perceptions about CAVs. It also had a negative impact on the extent to which they preferred to use CAVs or how much they trusted these vehicles.

It is not surprising that this is an issue because, according to the results, it was found that most participants (almost 97%) had acquired some information about CAVs before participating in the survey. Therefore, they probably knew that there are major differences between electric vehicles and CAVs in terms of operation and functionality, as CAVs are supposed to have the ability to detect many different obstacles on roads, including other road users, such as specifically pedestrians. However, the participants still had concerns about sharing roads with vehicles that run too quietly. One solution to this issue is law enforcement, which has already been implemented in the European Union (EU) (21). In the EU, it is now mandatory that all new electric vehicles have an Acoustic Vehicle Alert System (AVAS) for travel below 12 mph (19 km/h) (21). This new regulation could be applied to CAVs as well.

However, some limitations of this study should be noted. The sample size for Canadian records (181 records) is relatively small compared to the total population of blind or visually impaired people across Canada estimated by CNIB, which is around half a million (22).

Another limitation is related to the data collection methodology. Because an online survey was the only reasonable way to collect data (given the time and budgetary constraints), there is some bias in our conclusions, as not everyone who experiences visual impairment had access to the internet to participate. Also, the online platform that was used for this study has some accessibility issues with common screen readers for people with visual impairment.

The main purpose of this project is to obtain a better understanding of the possible impacts of CAVs on pedestrians with visual impairment. Overall, we can conclude that as technology has been improved prominently in terms of connectivity and communications among road users and infrastructure, it is inevitable to have some sorts of communication with autonomous vehicles and other road users, whether motorized or non-motorized. As a result, governments could develop the accessibility of autonomous vehicles for underserved road users, such as visually impaired people in terms of navigation perspectives. They could also develop better communication techniques with these vehicles by implementing new legislation that specifically takes into consideration the needs of visually impaired road and sidewalk users.

Appendix (C.1) Survey instrument

The following are the questions asked of the 352 respondents. The survey was made available from January through April 2019 and was provided in both English and French.

Understanding the impact of connected and automated vehicles for pedestrians with sight loss

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Informed Consent

Introduction

An "Electric Vehicle (EV)" uses one or more electric motors for propulsion. These vehicles consume electricity as their major fuel. A "self-driving" car (sometimes called an autonomous vehicle/ driverless vehicle/ automated vehicle) is a vehicle that uses a combination of technologies to travel and guide itself without human conduction. To qualify as fully autonomous, a vehicle must be able to navigate without human intervention to predetermined destinations over roads that are or are not designed for these vehicles.

Next step will be "Connected Automated Vehicles" which are vehicles that can use any of a number of different communication technologies to communicate with the driver, other cars on the road (vehicle-to-vehicle [V2V]), roadside infrastructure (vehicle-to-infrastructure [V2I]), and the "Cloud" [V2C]. Both "self-driving" and "connected automated vehicles" are supposed to be run entirely on electricity.

Consent Form

With partial funding support from the Government of Canada, Transport Canada, Advance Connectivity and Automation in the Transportation System (ACATS), CNIB, in collaboration with the University of Toronto, is undertaking a project to understand the perceptions about connected and automated vehicles for pedestrians with sight loss. Your responses will help form CNIB's policy recommendations as to how to ensure that when implemented, connected and autonomous vehicles enhance the mobility experience of pedestrians with sight loss.

Responses are captured in aggregate meaning that individuals participating in the survey cannot be identified. We are not asking for personally identifiable information and as such, your candid and honest responses are greatly appreciated. The postal code data will be used in aggregate not individual for the analysis purposes.

Once you have successfully completed the survey, your answers will be saved. We will then invite you to provide contact details should you wish to receive a copy of either the survey analysis or CNIB's final report which we will submit late in 2019.

As a part of the project, the research team is conducting a survey to accurately identify the level of understanding about using navigational aids/tools, smartphones' applications, perceptions about connected and automated vehicles, and areas where people who are blind or partially sighted feel higher risks for ground transportation. This research will provide up-to-date data on technology use and navigation skills for pedestrians with sight loss to better inform our program development and advocacy efforts. To achieve our goal of better understanding levels of perceptions for persons with sight loss, we are asking that you complete this survey. All data collected will be kept anonymous and confidential. Results will be reported in aggregate, without any identifying features associated with any individual. Data will not be shared except in aggregate, summary form with outside parties.

This survey should take approximately 35 minutes to complete. Please note that participation in this survey is entirely voluntary and confidential. Decisions you make around participation will have absolutely no impact on the services you receive from CNIB, either now or in the future. You can end the interview at any time, and you can choose not to answer certain questions. And, of course, there are no consequences to you if you choose not to participate.

If you have any questions about this survey, or have difficulty accessing or completing the survey, please contact Sina Soldouz by email at sina.azizisoldouz@mail.utoronto.ca or Professor Khandker Nurul Habib at khandker.nurulhabib@utoronto.ca.

This survey has been approved in accordance with the University of Toronto Research Ethics Board, which can be contacted at ethics.review@utoronto.ca or 416-946-3273.

1) By clicking "Yes I agree to participate in this survey" below, I acknowledge that I understand the purpose of the survey, and how my responses to the survey questions will be managed, analyzed, and used by the researchers.

( ) Yes I agree to participate in this survey

( ) No, I do not agree to participate in this survey

Your Location

2) Your Location:

What country do you live in?: ____

In which City/Town/Village are you living?: ____

What is your ZIP/Postal code?: ____

Your Experience with Sight Loss

3) Which of the following statements best describes you?

( ) I have been blind or partially sighted all my life

( ) I experienced sight loss in childhood, before the age of 18

( ) I experienced sight loss between the ages of 18 and 65

( ) I experienced sight loss after the age of 65

4) In your opinion, which of the following best describes the severity of your sight loss?

( ) Mild – I have most of my vision

( ) Moderate – I have some of my vision

( ) Significant – I can see very little

( ) Total – I am completely blind

( ) I have sight loss as well as some or significant hearing loss – I am deafblind

---

How You Get Around

5) Have you received orientation & mobility training?

( ) Yes

( ) No

( ) No, but waiting for service

( ) I prefer not to say

6) Has this orientation & mobility integrated technology use for the purpose of navigational aids?

( ) Yes

( ) No

( ) I prefer not to say

How You Use Technology

7) Which of the following technologies, aids, and services, if any, do you use on daily basis. Please check all that apply.

[ ] Screen reading programs such as JAWS, NVDA or Voice Over for Mac

[ ] Screen magnifying programs such as ZoomText

[ ] Large monitor

[ ] Custom computer/desk workstation

[ ] iPhone

[ ] iPad

[ ] A smartphone other than an iPhone

[ ] A tablet other than an iPad

[ ] Reader apps such as KNFB Reader or Seeing AI

[ ] Be My Eyes

[ ] AIRA

[ ] A CCTV or closed-circuit television

[ ] A DAISY or Digital Accessible Information System

[ ] Audio book player

[ ] A refreshable braille display device

[ ] A talking watch

[ ] Other talking products such as a kitchen timer or alarm clock

[ ] Artificial vision products such as eSight or OrCam

[ ] Braille note-taker

[ ] Brailler, Slate or Stylus

[ ] Intervenors for the deafblind

[ ] Sign language interpreters

[ ] Assistive listening device such as a hearing aid or FM system

[ ] Specialized transportation system

[ ] White cane

[ ] Guide dog

[ ] Mobility aid, such as crutches, walkers

[ ] Low-tech aids for mobility and independent living

[ ] Low-tech vision aids (monocular, bioptics, etc.)

[ ] Other (please specify): ____

How You Use Technology (Continued...)

8) Do you use a smartphone?

( ) Yes

( ) No

( ) I prefer not to say

9) How do you use your smartphone? Please check all that apply.

[ ] I use it for my job

[ ] I use it for getting around

[ ] I use it for recreation (reading, watching TV/movies, listening to music/podcasts, etc.)

[ ] I use it for household chores (grocery lists, etc.)

[ ] I use it as a personal calendar

[ ] Other (please specify): ____

10) Which of the following apps, if any, do you use on a daily basis. Please check all that apply.

[ ] LookTel Money Reader

[ ] SayText

[ ] Color Identifier

[ ] TalkingTag LV

[ ] Learning Ally

[ ] Visible Braille

[ ] Navigon MobileNavigator

[ ] Big Clock

[ ] The Talking Calculator

[ ] iBlink Radio

[ ] Ideal Accessibility Installer

[ ] ScanLife Barcode and QR Reader

[ ] Magnify

[ ] Messages Keyboard

[ ] Font Installer Root

[ ] Ultra Magnifier +

[ ] Walky Talky

[ ] Classic Text To Speech Engine

[ ] NoLED

[ ] BlindSquare

[ ] Key2Access

[ ] KNFBReader

[ ] Seeing AI

[ ] Other (please specify):
____

11) Which of the following apps or tools, if any, do you use on a daily basis for getting around. Please check all that apply.

[ ] Nearby Explorer for Android

[ ] The Seeing Eye GPS

[ ] BlindSquare

[ ] Open Street Maps

[ ] Yelp

[ ] Aira

[ ] Seeing AI

[ ] Google maps

[ ] Built-in GPS that comes as part of my smart phone

[ ] Identification cane

[ ] Support cane

[ ] White cane

[ ] Guide dog

[ ] Other (please specify): ____

Land Transport

12) What are your most common trip purposes? Please check all that apply.

[ ] Visiting family or friends

[ ] Grocery shopping

[ ] Shopping (for items other than groceries)

[ ] Walking for recreation

[ ] Exercise

[ ] Doctors appointments

[ ] Entertainment or leisure activities

[ ] Religious

[ ] School

[ ] Work

[ ] Other (please specify): ____

13) How often do you travel by car for daily trips?

( ) Never

( ) Rarely (once monthly or less)

( ) Sometimes (2 to 5 times per month)

( ) Frequently (2 to 5 times per week)

( ) All the time (every day)

14) How often do you take a Taxi, Uber, or Lyft for daily trips?

( ) Never

( ) Rarely (once monthly or less)

( ) Sometimes (2 to 5 times per month)

( ) Frequently (2 to 5 times per week)

( ) All the time (every day)

15) How often do you walk for daily trips?

( ) Never

( ) Rarely (once monthly or less)

( ) Sometimes (2 to 5 times per month)

( ) Frequently (2 to 5 times per week)

( ) All the time (every day)

16) How often do you travel by bicycle for daily trips?

( ) Never

( ) Rarely (once monthly or less)

( ) Sometimes (2 to 5 times per month)

( ) Frequently (2 to 5 times per week)

( ) All the time (every day)

17) How often do you use public transport (Bus, Subway, LRT, etc.) for daily trips?

( ) Never

( ) Rarely (once monthly or less)

( ) Sometimes (2 to 5 times per month)

( ) Frequently (2 to 5 times per week)

( ) All the time (every day)

18) How often do you travel by para-transit for daily trips?

( ) Never

( ) Rarely (once monthly or less)

( ) Sometimes (2 to 5 times per month)

( ) Frequently (2 to 5 times per week)

( ) All the time (every day)

Land Transport (Continued...)

19) How do you usually find your way around in your own community? Please check all that apply.

[ ] Using Smartphone apps

[ ] Using GPS devices

[ ] Using a white cane

[ ] Using a guide dog

[ ] Asking friends or family to travel with you

[ ] Independently travel with memorizing routes

[ ] Mostly travel independently, but sometimes ask for help from others to make sure that I am on the right path

[ ] Other (please specify): ____

20) How do you usually find your way around in an unfamiliar area (other than your own community)? Please check all that apply.

[ ] Using Smartphone apps

[ ] Using GPS devices

[ ] Using a white cane

[ ] Using a guide dog

[ ] Asking friends or family to travel with you

[ ] Independently travel with memorizing routes

[ ] Mostly travel independently, but sometimes ask for help from others to make sure that I am on the right path

[ ] Other (please specify): ____

21) Please rate your satisfaction with public transport accessibility in your area?

( ) I don't have access to public transport

( ) Extremely dissatisfied

( ) Very dissatisfied

( ) Somewhat dissatisfied

( ) Somewhat satisfied

( ) Very satisfied

( ) Extremely satisfied

22) Please rate your satisfaction with para-transit system accessibility in your area?

( ) I don't have access to para-transit

( ) Extremely dissatisfied

( ) Very dissatisfied

( ) Somewhat dissatisfied

( ) Somewhat satisfied

( ) Very satisfied

( ) Extremely satisfied

Land Transport (Continued...)

23) As a pedestrian on a sidewalk, it is important to hear vehicle noise or other kinds of noise from traffic.

( ) Yes

( ) No

24) As a pedestrian, it is important to hear warnings from cyclists both on sidewalks and on roads.

( ) Yes

( ) No

25) As a pedestrian I think audible sounds from Accessible Pedestrian Signals (APS) are helpful for crossing streets.

( ) Yes

( ) No

26) As a pedestrian, it is important to hear vehicle noise when you and a vehicle approach an intersection?

( ) Yes

( ) No

27) Do you use headphones while walking on a sidewalk or crossing streets?

( ) Yes

( ) No

28) What is the most common purpose for using headphones while walking on a sidewalk or crossing streets?

( ) Listening to music

( ) Using navigational apps

( ) Other (please specify): ____

29) What are the reasons you do not prefer to use headphones while walking on a sidewalk or crossing streets? Please check all that apply.

[ ] Safety issues

[ ] Isolate from surrounding environment

[ ] Headphones are easy to be lost

[ ] Other (please specify)

30) When making the decision to cross, which of the following are most important to you: (Please check all that apply)

[ ] I prefer to rely on my sense of hearing when vehicles stop before deciding when to cross

[ ] I prefer to rely on audible sounds from Accessible Pedestrian Signals before deciding when to cross

[ ] I use my remaining eyesight to help me identify cars, bicycles, and other pedestrians

[ ] I prefer to use technologies or apps such as eSight, Be My Eyes, etc.

[ ] Other (please specify): ____

Electric Vehicles

31) Can you distinguish the noises made by individual motorized devices such as scooters or electric bikes on sidewalks versus motor vehicles on roads?

( ) Yes

( ) No

32) Have you ever heard about "Electric Vehicles"?

( ) Yes

( ) No

33) Have you ever had an accident or near accident with an "Electric Vehicle"?

( ) Yes

( ) No

34) Nowadays "Electric Vehicles" have become more popular on streets. As these vehicles operate quietly, do you think that they impact your safety as a pedestrian?

( ) Yes

( ) No

Self-driving/Automated and Connected Automated Vehicles

35) Have you ever heard about "Self-driving", "Automated", "Autonomous" and/or "Connected Autonomous" vehicles?

( ) Yes

( ) No

36) Do you think "Self-driving" vehicles impact your independence for traveling?

( ) Yes

( ) No

37) As a pedestrian, how much do you trust "Self-driving" vehicles?

( ) Not at all

( ) Barely

( ) Somewhat

( ) A lot

( ) Entirely

( ) I don't know

38) Consider as a passenger of a vehicle such as an Uber or an a bus that cruising without a driver. Please rate your preference for using these "Self-driving" vehicles in the near future?

( ) Not preferred at all

( ) Somewhat preferred

( ) Highly preferred

( ) I don't know

39) What, if any, concerns do you have about sharing the road with "Self-driving" vehicles? Please check all that apply.

[ ] Technology failures that will affect negatively the safety for walking areas.

[ ] Lack of proper communication techniques between "Self-driving" vehicles and other road users such as pedestrians.

[ ] The possibility of new disastrous situations with "Self-driving" vehicles. For example, in complex cases when self-driving vehicles have to decide to collide with pedestrians or other vehicles on the road or safety priority for the passengers.

[ ] Other (please specify):

____

Self-driving/Automated and Connected Automated Vehicles (Continued...)

40) Do you agree/disagree with the following statement:
I will use a navigation device which provides real-time information (such as smart watches, wearable cameras, etc.), if it is not connected to other devices or a third party.

( ) Agree

( ) Disagree

( ) I don't know

41) Do you agree/disagree with the following statement:
I prefer to have the option to use a navigation device whether it is connected to other devices or a third party or not. Transportation systems should support my safety and security regardless of whether I have or use an additional device or not.

( ) Agree

( ) Disagree

( ) I don't know

42) How do you prefer to communicate with "Connected Automated" vehicles or "Self-driving" vehicles when you want to cross streets?

( ) Audible alerts from the infrastructure such as Accessible Pedestrian Signal alerts.

( ) Alerts from the "Self-driving" vehicles that announce their current status, such as the "Self-driving" vehicle is about to stop for you.

( ) Alerts from wearable devices such as eSight about the "Self-driving" vehicle's current status, such as the vehicle is about to stop.

( ) I prefer not to communicate with "Self-driving" vehicles, their systems should be accurate in detecting pedestrians and stopping for them.

( ) Other (please specify): ____

Some Questions About You

43) Which of the following best describes your household?

( ) One adult

( ) Two adults

( ) One adult and a child

( ) One adult and more than a child

( ) Two adults and a child

( ) Two adults and more than a child

( ) Other (please specify): ____

44) How many individuals in your home hold a valid drivers license?

( ) Zero

( ) One

( ) Two

( ) Three

( ) More than three

45) How many vehicles are owned by persons living in your household?

( ) Zero

( ) One

( ) Two

( ) Three

( ) More than three

46) Would you identify as:

( ) I prefer not to say

( ) Male

( ) Female

( ) Another gender identity:

____

47) Age:

____

48) What is your highest level of education?

( ) I prefer not to say

( ) Less than a high school diploma

( ) High school diploma or equivalent

( ) CEGEP

( ) College

( ) Trade certificate or professional certification

( ) Bachelor's degree

( ) Master's degree

( ) Doctoral or Professional degree

49) What best describes your current employment status?

( ) I prefer not to say

( ) Employed full time

( ) Employed part time

( ) Unemployed

( ) Self-employed

( ) Retired

( ) Student

( ) Unable to work

( ) Other (please specify):

____

Future Research

50) Please rate the accessibility level of this survey?

( ) Excellent

( ) Very good

( ) Good

( ) Average

( ) Poor

51) Do you want to participate in further research conducted by the CNIB?

( ) Yes

( ) No

52) Your responses have been saved to our database.
On the next screen, we will invite you to provide your contact information should you wish to receive a copy of the survey analysis and CNIB's final report.
We hope to have this report completed late in 2019.
Contact us at advocacy@cnib.ca

Full Name: ____

Email Address:
____

Please send me future notices about CNIB advocacy, research or community events.

( ) Yes

( ) No

Appendix (D) Enhanced way finding experiment

Proliferation of digital navigation systems have radically transformed how people navigate city streets. While way finding solutions for persons who are blind are becoming increasingly more commonplace, there will always exist a lag between what is commercially available such as onboard GPS systems or the usability of main stream applications such as Google or Apple Maps. Some of these technologies do link to and provide enhanced navigation such as road closures or delays, but they are primarily focussed on vehicular applications.

It is our view that temporary street closures or sidewalk construction data already, or will shortly be maintained through the public domain that municipalities should be encouraged to continue open data initiatives which make sidewalk closures, festival/events readily available to mobile app developers; particularly those which stand to benefit wayfinding for persons who are blind.

CNIB in partnership with Blind Square and Transnomis, undertook a proof of concept project to demonstrate the viability of this concept. We identified Edmonton and Oshawa as prototype sites given the availability of municipal data and good connectivity. The project defined one virtual fence in each centre and within that fence, obstacles were defined. These obstacles would only be detectible by participants who were provided with a site specific URL. The URL provided the participant with access to a mapping solution provided by Transnomis via Blind Square.

Under current navigation options, anyone who is blind relying on mobile devices to navigate the built environment may not have any warning of temporary obstacles or sidewalk closures. In fact, currently, it is not unreasonable for someone who is blind to learn of a sidewalk closure or construction only after coming upon a hording. If these obstacles occure at a street corner then a pedestrian who is blind would only discover it after completing a crossing. The pedestrian would be stranded in an intersection surrounded by vehicular traffic possibly including trucks serving the construction site.

If, the existence of the above described hazard could be made available to someone working with an accessible mobile device would they be able to alter their root prior to entering an intersection? Could they plan an alternate root which would see them navigate away from a sidewalk closure? Would the same pedestrian, if notified in advance, also be able to participate in other cultural events such as music or heritage festivals?

This research will continue to be of interest to CNIB.

It is our hope that with the development of the data required to support CV/AV systems that enhanced navigation for persons who are blind can and will be enhanced through a more robust and rich data set. AVs should not be viewed as the only beneficiaries of V to X communications.