

Abstract

This Request for Proposal (RFP) addresses the need for improved Deaf cyclist safety, especially those with profound hearing loss within the City of Toronto. There are members of the Deaf community who feel unsafe when riding a bicycle on busy city streets [1]. In general, there are inherent dangers for cyclists, but this is made worse for Deaf cyclists as they cannot hear auditory cues that can warn them of these dangers [2]. The Deaf cyclists are reliant upon their visual sense and the other road users in order to stay safe. However, the visual sense has a longer perception-reaction time than the auditory sense, resulting in decreased safety for the Deaf cyclists [3].

A design proposal is requested that allows for Deaf cyclists to become aware of these otherwise unheard auditory traffic alarms. The solution should remain relatively inexpensive and remain durable for a period of time as the majority of the Deaf community are either under-employed or unemployed [4]. The proposed solution must give the Deaf cyclists information about oncoming traffic hazards and allow the Deaf cyclists to stay safe on the road.

[1] "Deaf Cyclist/Pedestrian Safety," Google Drive, [Online]. Available: <http://goo.gl/ZsnR6>. [Accessed 16 February 2013].

[2] City of Toronto, Works and Emergency Services Department, Transportation Services Division, Transportation Infrastructure Management Section, "Bicycle/Motor-Vehicle Collision Study," 2003. [Online]. Available: http://www.toronto.ca/transportation/publications/bicycle_motor-vehicle/pdf/car-bike_collision_report.pdf. [Accessed 16 February 2013]

[3] Kosinski, Robert J. *A Literature Review*. September 2012. <http://biae.clemson.edu/bpc/bp/lab/110/reaction.htm> (accessed March 1, 2013).

[4] The Canadian Hearing Society, "Response of The Canadian Hearing Society to the Parliamentary Assistant to the Minister of Training, Colleges and Universities' Discussion Paper on Adult Education and Training Review," The Canadian Hearing Society, Toronto, 2002.

March 2nd, 2013

Request for Proposal

Improving Road Safety for Deaf Cyclists in the City of Toronto
Downtown Core

Revision 2.0

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1) Introduction

The purpose of this Request for Proposal (RFP) is to improve the safety of Deaf cyclists' with regards to sound-based warnings on the road. There are approximately 350,000 profoundly Deaf people in Canada, referring to those individuals who cannot rely upon their auditory senses [1]. In general, cycling has been increasing within the City of Toronto over the years [2]. In 2001, the City of Toronto implemented the Toronto Bike Plan, which aims to promote cycling within Toronto and reduce the number of biking collisions and injuries [2]. Many of these collisions occur at intersections and usually involve either the motor or cyclist attempting to turn. In particular, Deaf cyclists are at a unique security risk as they are unable to hear sound-based warnings of the road. Sound-based warnings refer to everyday traffic sounds including the following: car horns, cyclist-to-cyclist verbal communication, emergency vehicles, and engines of cars on the road. The purpose of this proposal is to request a solution that will improve the awareness of Deaf cyclists' to sound-based warnings on the road.

This proposal will provide more background on the Deaf community, discuss the Deaf cyclists' need for safety and its associated engineering problem, and identify the stakeholders influenced by or interested in this problem. In addition, it will provide engineering requirements for an ideal solution and discuss the current designs that attempt to solve the problem.

2) Community: The Profoundly Deaf in Downtown Toronto

Although there are various definitions of "deaf", in this proposal, "Deaf" will refer to those with profound hearing loss. People with profound hearing loss are defined as those who have little or no residual hearing [3]. This state of hearing loss can occur at birth, termed born deaf, or acquired later on in life, termed acquired deafness. In this proposal, those with mild hearing loss, those who use hearing aids consistently, and other classifications of deafness will not be considered part of the community by the RFP team's definition. Refer to Section 2 on the reason behind this exclusion. In addition, Appendix B provides more details about the Canadian Hearing Society's subcategories of the term deaf [3].

For the purposes of this document, community is defined as "a union of many elements" with the following traits [4]:

1. The elements are people
2. The basis of union is a common origin such as location, language, or common trait [5]
3. The union is connected to resources or infrastructure, such as government, religion, or economy, that support and sustain it [5]

In North America, several have identified themselves as "Culturally Deaf," or "Deaf," which encompasses the RFP team's definition of deaf. From now on, the term "Deaf," will be used to respect this culture. This community fits the above definition as follows:

1. The elements of this community are people.
2. Within the Deaf community, hearing loss is considered not a disability, but as a basis of union for individuals who share common experiences and values, and that depends largely upon American Sign Language as a method of communication [3][6].
3. To promote and sustain this culture, the union is supported by resources such as the following:
 - a. Organizations within Toronto and Canada: The Canadian Hearing Society, Toronto Association for the Deaf, and Ontario Association for Sign Language Interpreters
 - i. Organizations such as these connect the Deaf community to resources that sustain their language, provide financial and social security for individuals, provide education for children, and represent the community in interactions with the government and society [7].

As reported by the Participation and Activities Limitations Survey (PALS) in 2006, 5% of Canadians aged fifteen and older have hearing limitations, 16.8% of which are profoundly Deaf, equating to approximately 200,000 people [8]. The Canadian Association of the Deaf (CAD) approximates



Figure 1: The City of Toronto's definition of downtown core as defined in the 2010 Bike Count Report [14]

3) Note on the Community

All other definitions of the term “deaf” are excluded from the defined community to ensure that no proposed solutions which only assist those that still have residual hearing exclude the profoundly Deaf. Solutions that assist the profoundly Deaf will inherently assist those with milder hearing loss. However, it should be noted that certain solutions might be proposed that assist those with milder hearing loss but fail to address the needs of the profoundly Deaf. The purpose of excluding those with milder hearing loss from the defined community is to prevent the design team from making this error.

350,000 people, criticizing the survey methodology of the PALS as being insufficiently accessible to the Deaf respondents [1]. The City of Toronto, with over 5 million residents, is one of the largest cities in Canada; however, there is no feasible method to assess the population of the Deaf in Toronto due to the varying definitions of deaf as mentioned previously [1][9].

The City of Toronto has been identified as a “walkable” city, one that promotes and supports walking, cycling, and transit over driving automated vehicles [10]. Specifically, cyclists, are those who at a particular point in time use biking as their primary means of transportation. In this proposal, a “bicycle” excludes electronic bicycles, motorbikes, and similar non-mechanical vehicles. The RFP team will focus on the intersection of these two communities: **cyclists with profound hearing loss in the downtown core of the City of Toronto.** Using the City of Toronto’s definition from the 2010 Bike Count, the downtown core is bounded by Bloor Street West in the North to Queen’s Quay in the South, from the Jarvis Street in the East to Spadina Avenue in the West as shown in Figure 1. Their needs will be discussed in the following section [14].

4) The Need for Deaf Cyclist Safety

Need is any aspect of life that, if not satisfied, will diminish an individual's personal well-being. Psychologist Abraham Maslow further subdivides this definition by specifying five levels of need as displayed in Figure 2 [12]. These levels range from those required for mere survival to those required for self-actualization [12]. In this proposal, *quality of life* is defined as the extent to which the levels of Maslow's hierarchy of needs are fulfilled. As each successive level of the hierarchy, displayed in Figure 2, is fulfilled in ascending order, the quality of life improves. In the case of the Deaf community, the identified level of focus is in safety, specifically physical security. The RFP team defines the safety of Deaf cyclists as the removal or reduction in the likelihood of hazards that can harm the cyclist's physical well-being.

This section establishes the importance of general cyclist safety within the City of Toronto, then details the specific need of Deaf cyclists.

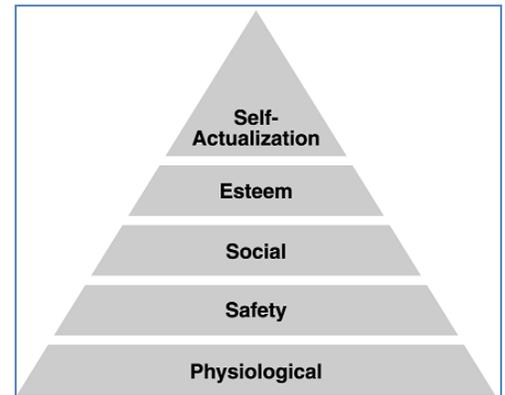


Figure 2: A visual view of Maslow's Hierarchy of Needs. [13]

4.1) Overview of General Cyclist Safety in the City of Toronto

The number of cyclists is increasing within the City of Toronto, and as such, the City of Toronto regards cyclists' safety as a genuine need [2]. In 2001, the City of Toronto implemented the Toronto Bike Plan whose vision is "to create a safe, comfortable and bicycle friendly environment in Toronto..." [14]. One of the primary goals of the Toronto Bike Plan is to lower the risk of a bicycle injury or collision and thus improve cyclist safety [14]. In the latest collision study, published in 2003, the majority of collisions occurred at the following areas, in order of highest prevalence:

- At intersections
 - The majority of these involved either a motorized vehicle or cyclist turning at intersections [15]
- Away from intersections
 - Involved motorized vehicles overtaking cyclists [15]
 - Drivers opening the passenger side of the door and hitting a cyclist [15]

Further statistical percentages are provided in Appendix D.

4.2) Situations involving Deaf Cyclists

Deaf cyclists, however, have an additional issue: they cannot hear the sounds of traffic that indicate an issue. A road-safety site for kids, created by Road Safety Scotland, identified some of the following "traffic and everyday sounds" [16]:

- Sirens (Police and Emergency Vehicles)
- Cars - horns
- Cars, motorbikes and other vehicles - engines starting up
- Bicycle bells
- Cars, motorbikes and other vehicles – speed as it passes by

These sounds are examples of the many ways of communication that exist on the road, and will be referred to as **sound-based warnings** for the rest of the document.

An empirical study involving 45 Deaf individuals, 29 of whom are profoundly Deaf, reports testimonies that emergency vehicles, traffic while cycling, and approaching vehicles from behind are examples of situations that bring about a feeling of insecurity [17]. Even more direct evidence can be found from Deaf forums online, where posts that ask for advice in regards to Deaf individuals who wish to cycle safely are common [18] [19] [20].

In addition, the RFP team designed and distributed a survey over several internet forums for the Deaf. The survey asks members of the Deaf community about their experiences as a Deaf cyclist and their opinions on Deaf cyclist safety. The survey primarily follows a multiple choice format, but also contains a section where respondents are encouraged to openly provide a brief testimony on their opinions and experiences. All questions are labelled as optional to ensure that no respondent is made to feel uncomfortable. Refer to Appendix A for a compilation of relevant statistics and notable testimonies from this survey.

At this time, there are 23 respondents, 17 of whom are profoundly deaf, with three partially deaf and three abstaining. There were 17 respondents who mentioned that there are situations that make them feel unsafe, and one respondent has been involved in a road accident while cycling. When asked if there was room for improvement in regards to deaf cyclist safety, 16 respondents responded “yes.” These results show that Deaf cyclists personally feel unsafe while on the road and are dissatisfied with the current state of Deaf cyclist safety. Many respondents, when prompted, provided details in regards to situations that make them feel unsafe when cycling.

Testimony 1 in Appendix A involves an individual who grew up an avid cyclist, but as a result of further hearing loss, and upon moving to the Greater Toronto Area, seldom cycles any longer. She mentions not trusting drivers, and feels that the city is not a ‘bike friendly’ area for the Deaf. Other respondents also mention being unaware of vehicles approaching from behind, and feel uncomfortable with the close proximity. Generally, road users primarily rely upon sound-based warnings to convey messages to fellow road users in an emergency situation. The audio cues that many road users rely upon are ineffective with regards to the Deaf community. As a result, Deaf cyclists are not given the same warnings in times of emergency, where a fast response is required. These are scenarios which, for hearing cyclists, would not pose as great of a threat, but for those with profound hearing loss, become serious security issues. The Ontario Human Rights Commission states the following for persons with disabilities:

- ...Disabled persons[...]have the same fundamental rights as their fellow citizens of the same age, which implies first and foremost the right to enjoy a decent life, as normal and full as possible [22].
- Disabled persons are entitled to have their special needs taken into consideration at *all stages of economic and social planning*” [22]

The current state of affairs with regards to Deaf cyclist safety does not provide these individuals with the same right to personal security as their hearing counterparts, or the right to enjoy a “normal and full” life[22].

Further details into the problem of cyclist safety for those with profound hearing loss are provided in the following section.

5) The Engineering Problem

This RFP focusses on the following problem statement: **Improve Deaf cyclists’ awareness of sound-based warnings on the road.**

The proposed design should focus on the need as outlined in Section 3 of this document. This section of the document will provide justification as to why this is a significant problem.

5.1) A Brief Outline

In order to improve the quality of life and safety of Deaf cyclists, this document will focus on the specific problem that Deaf cyclists are unable to hear sound-based warnings on the road. By alerting Deaf cyclists to these traffic warnings, their safety can be improved. While there is a lack of current research into the safety of Deaf cyclists specifically, there is evidence that non-Deaf people listening to music players when on the road results in a significant decrease in safety [23]. A study by Lichenstein, Smith,

Ambrose, and Moody in 2012 showed that a warning was sounded in 29% of crashes where victims were wearing headphones [24]. The authors of the study state that the deprivation of the hearing sense is one of two likely reasons that explains the link between headphone use and injury [24]. The other reason is the element of distraction, however it is indisputable that the deprivation of the sense of hearing is important in the study of safety for road users[24]. In addition, in the survey the RFP team conducted, 17 of the 23 respondents stated that they felt unsafe [25]. The most frequently cited reason as to why they felt unsafe is the fact that they cannot hear car horns, bicycle bells, emergency vehicle sirens, the revving of engines and other traffic warnings [25]. Road users primarily rely upon sound-based warnings to convey messages to fellow road users in an emergency situation [26] [27] [28]. Thus, the audio cues that many road users rely upon are ineffective with regards to the deaf community.

In the survey the RFP team conducted, four of the respondents specifically noted that they have to use their sense of sight in order to see the hazards on the road and be more attentive of them [25]. One respondent mentioned that she specifically cycles on the opposite side of the road to see oncoming traffic as detailed in testimony 5 on Appendix A. However, testimony 10 mentions that the Deaf have an heightened visual sense and a wider field of view. This idea is called the concept of sensory compensation by the philosopher Diderot in 1749 [29]. Despite the testimony, empirical studies have proved inconclusive, and there is even evidence to show that that sensory compensation is false [29] [30]. According to testimony 9 in Appendix A, the respondent answered saying that he does not always have a wide enough view of the road and, as a result, feels unsafe. Furthermore, there have been studies showing that the time taken to react to auditory stimuli, at 140-160 milliseconds, is shorter than the time taken to react to visual stimuli, at 180-200 milliseconds [31] [32]. An auditory stimulus takes only 8-10 milliseconds to reach the brain while a visual stimulus takes 20-40 milliseconds to reach the brain [32]. In conclusion, the studies and the RFP team's survey seem to agree that there are varying degrees upon which a person's visual sense can be relied upon. In allowing for a better alert system for Deaf cyclists, their safety can be much improved.

6) Stakeholders

A stakeholder is any party that has an interest in the project at hand. It also encompasses all parties who will have an effect on the project and those who will be affected by the project [33]. Some of the stakeholders that will be directly influenced by this project include the drivers in the downtown core, cyclists with profound hearing loss, the City of Toronto, the Ontario Government and organizations that represent the Deaf in Toronto, listed in order of largest stake in the project.

6.1) Cyclists with Profound Hearing Loss

- The primary stakeholders of this project are cyclists with profound hearing loss, as the solutions are being created to improve their awareness to traffic signals.
- According to a 1998 survey, 85% of Deaf Ontarians are under-employed or unemployed [34], and according to the Canadian Association for the Deaf, this value has likely remained stagnant [1]. Thus, it is important to consider economical solutions that will fit the budget of the majority of the population.
- The Deaf cyclists would want solutions that respect their inherent human right to dignity in a manner that does not cause undue harm as outlined in the Duty to Accommodate under the Canadian Human Rights Act and in the United Nations' Declaration of the Rights of Disabled Persons [35] [36] [37].

6.2) Motorists and Other Road Users

For driver-centric solutions to the problem, the driver of a motorized vehicle would be the main stakeholder as their use of the solution will directly impact Deaf cyclist safety.

- Another interest drivers have is in being more aware of Deaf cyclists to avoid accidents.

6.3) The City of Toronto – Transportation Services

- The City of Toronto Transportation Services is interested in promoting cyclist safety and lowering the amount of traffic accidents involving cyclists [38]. Since Deaf cyclists make up a proportion of this group, any solution that contributes to lowering the accident rates will be of interest.
- Solutions that require a change in the city’s current infrastructure (such as changes in traffic signaling) will directly involve the City of Toronto Transportation Services, which would be involved in implementing these solutions.

6.4) The Ontario Provincial Government - Ministry of Transportation

- The Ontario Provincial Government has an interest in ensuring that solutions follow the established laws under the Highway Traffic Act

6.5) Representative Organizations for the Deaf

- As mentioned in Section 2.1, several organizations have been established that voice concerns of the Deaf community, some of which include the Deaf Culture Centre, Silent Voice, and Bob Rumball Centre. As such, they directly embody the stakeholders described in section 4.1. Details on some of these organizations are listed below:
 - The Canadian Hearing Society - headquartered in Toronto, it provides services for the Deaf and hard-of-hearing, including selling and distributing communication devices [40]. As such, the organization would be interested in distributing and/or promoting any solutions that improve the safety of its members.
 - The Toronto Association of the Deaf (TAD) – a subdivision of the Ontario Association for the Deaf, part of TAD’s mission statement is to promote “the rights, living standards, and well-being of Deaf people...” [39], which also coincides with the goal and target community of this proposal.
 - In addition, other local organizations such as the Deaf Culture Centre, Silent Voice, and Bob Rumball Centre are interested in promoting and protecting the Deaf Community.

7) Engineering Requirements:

This section will review the requirements to which all solutions should adhere. First, a list of high-level objectives and constraints will be presented. Second, there will be a table showing the detailed objectives, constraints and criteria.

7.1) High-Level Objectives and Constraints:

The proposed solution must:

1. Increase Deaf cyclists’ awareness to sound-based traffic warnings
2. Be made accessible to the majority of the community

7.2) Project-Level Constraints

The proposed solution must:

1. Not infringe upon the Duty to Accommodate nor the right to dignity as outlined in section 5.1
2. Not break any laws set out by the City of Toronto and the Ontario Government
3. Both cyclists and drivers cannot see electronic displays unless it is a GPS or specifically a vehicle avoidance system [41]

7.3) Detailed Objectives and Constraints:

Table 1: Detailed Objectives, Criteria and Constraints

	Objectives	Criteria		Constraints
		Metrics	Gradient	
Primary objectives	Increase deaf cyclists' awareness to sound-based traffic warnings			
	Minimize the time it takes the user to become aware of an emergency situation and react to it when a threat is normally in the field of view	Average perception-reaction time	Lower is preferred	Less than 2.5 s (1)
	Improve the area around the user for which they are aware of sound-based warning on the road	Average angle of the sector centered around the user that the product can detect hazards (See figure 3)	Greater is preferred	Greater than 170° (2)
	Improve the amount of information the product gives for each specific warning	The number of the following points the product communicates to the user: <ul style="list-style-type: none"> • Location of the source of threat • Speed of threat • Direction of threat 	Higher is preferred	The product must be able to tell the general location from where the warning comes from
	It is preferable that the product can differentiate between the sources of the warning	The number of different warnings that it can differentiate	Higher is preferred	N/A
Secondary objectives	To create a product that is accessible to the majority of the community			
	To maximize the affordability of the product	Approximate price	Lower is preferred	Less than \$45 (3)
	To design a product that is intuitive to use (4)	Beta-testing on the ease of use with the scale: <ol style="list-style-type: none"> 1. Excellent 2. Good 3. Satisfactory 4. Unacceptable 	Excellent is preferred	Average response must be higher than 3 or better than satisfactory
	To maximize the durability of the product (5)	Number of years the product can function under regular operating conditions	Higher is preferred	No less than 5 years (6)

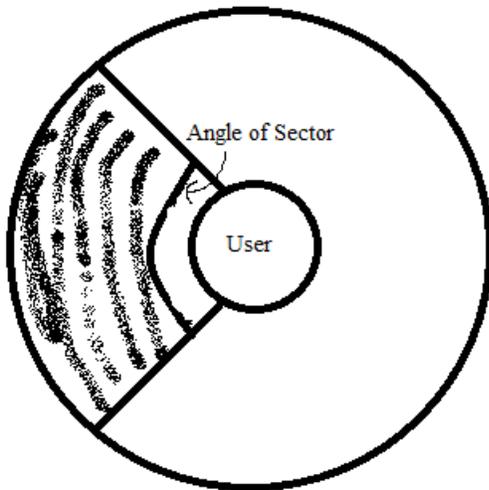


Figure 3: A Visual Description of the Angle of the Sector Centered about the User that the Product can Detect Hazards

The justifications for the choices in the above table are as follows:

1. The value of 2.5 seconds was used as a standard visual perception and brake reaction time of a cyclist in Guide for the Developing of Bicycle Facilities [42]. The visual perception and brake reaction time is the time taken for the user to perceive a visual stimulus and react by braking [42]. If the perception-reaction time when using the product is greater than this value, then the device is not effective, since the user would have the same reaction-perception time relying on purely visual perception without the product.
2. The normal field of view of people is approximately 160° [43]. The solution must increase this value by at least 10° .
3. The approximate price of the bicycle helmets is slightly below \$30 [44]. Prices for bicycle bells range widely from about \$5 to over to slightly over \$40 [45]. Based on these values, the RFP team chose the price of \$45 as the maximum price that people should pay for a bicycle safety product.
4. A product that is not intuitive to use may result in the users returning the product. "The rule of thumb (is that) every dollar invested in ease of use returns \$10 to \$100" [46]. Therefore in order to maximize profit for the company making the product, it should be ensured that devices are intuitive to use.
5. This is listed under the high-level objective of increasing the accessibility of the product as it lowers the long-term cost for the Deaf cyclists. As a result, more Deaf cyclists should be able to afford the product.
6. Some of the fire alarms that have prices within the constraints for the proposed solution have warranties of 5 to 10 years [47] [48] [49] [50] [51] [52]. Since fire alarms are safety related products, this range was taken as a standard for our product. Proposed solutions should last a minimal of 5 years because the lower bound of the warranties is 5 years. However, ideal solutions should last longer as the service life of most products is greater than the warranty coverage.

8) Reference Designs

The following four reference designs will be examined: Deaf bike signs, Mirrors, Deaf child signs, and Cochlear Implants. The reasons why each of these designs fails to meet our requirements for an ideal solution will be explained.

8.1) Deaf Cyclist Signs:



Figure 4. A picture showing the deaf cyclist sign used by deaf cyclists [53]

These deaf bike signs are used to warn drivers and other cyclists that the individual in front is Deaf.

Why it helps:

- The signs will warn an otherwise unaware driver who is behind the cyclist that honking the horn will not help in an emergency situation, and may cause the driver to keep more distance with the cyclist.

Where it falls short:

- These signs are only a very slight precaution, and will not be effective in the circumstance when a vehicle is unable to stop and must warn the cyclist.
 - Fails the requirement to minimize the time it takes the user to become aware of an emergency situation and react to it.
- The use of signs can help to improve nearby drivers of deaf cyclists, but the cyclists themselves are still unaware of nearby hazards.
 - Fails the requirement to improve Deaf cyclists' awareness of sound-based warnings on the road.
- Some members of the Deaf community may not feel that it is socially appropriate to wear a Deaf cyclist sign, as not all

8.2) Mirrors



Figure 5. Rearview mirrors on bikes that expand the field of view for a cyclist. Even though these are not aimed at the problem discussed in this RFP, they are often given as a common suggestion on Deaf forums

threads on cycling [18] [19]. Mirrors are commonly mounted on the handlebars, glasses, or helmets [21]. Why it helps:

- Rearview mirrors allow individuals to see behind them. Since Deaf cyclists rely primarily upon their vision to be aware of their surroundings, mirrors enhance the ability to see their surroundings.

Where it falls short:

- Handlebar mirrors require the user to tilt the handlebars to see specific angles, which limits the benefit to the user's field of view [21].
 - This fails the requirement to design a product that is intuitive to use.
- All mirrors require the user to take their focus off of the road ahead for a brief moment in order to make use of the mirror. Handlebar mirrors require the user to further deviate their eyes from the road when compared to helmet or glasses mirrors [21].
 - This fails the requirement to design a product that is intuitive to use.
- Handlebar mirrors have a tendency to be knocked off or knocked loose by nearby objects [21]. Mirrors in general tend to be fragile and a collision will cause them to break.
 - This fails the requirement to maximize durability.

8.3) Deaf Child Signs



Figure 6. An Example of a Deaf Child Sign[54]

These signs are posted in neighbourhoods or areas where Deaf children are often present. Similar to the school zone or animal crossing signs, these signs will inform motorists of a special circumstance that they should be aware of.

Why it helps:

- Much like other road signs warning of a special area, drivers are expected to adjust behaviour to fit the circumstance, and be more aware of their surroundings and prepared to react to a problem.

Where it falls short:

- The fundamental issue behind all manners of road signs is that too often, motorists either ignore them or do not see them. The assumption on the part of Deaf children and their families however, is that this area of the road is now safe. This may in fact result in increased danger to the children in question [54].

- This does not aim to solve the problem to improve Deaf cyclists' awareness of sound-based warning on the road. The solution may aggravate the situation instead of solving the problem.
- A concept known as "sign pollution", where signs that are no longer relevant are not removed, reducing the overall effectiveness of each road sign [54].
 - This does not aim to solve the problem to improve Deaf cyclists' awareness of sound-based warning on the road.

8.4) Cochlear Implants

A cochlear implant is a surgical device that is placed within the ear and allows those with certain types of hearing loss to regain part or all of their auditory senses. The issue with this device and other hearing aids is that they are a major area of controversy for the Deaf community [55]. The controversy of cochlear implants can be seen on internet forums, with a warning posted by the administrators of the forum alldeaf.com and can be found in Appendix C. Since the subject of cochlear implants is controversial, design proposals must avoid these devices when considering solutions.

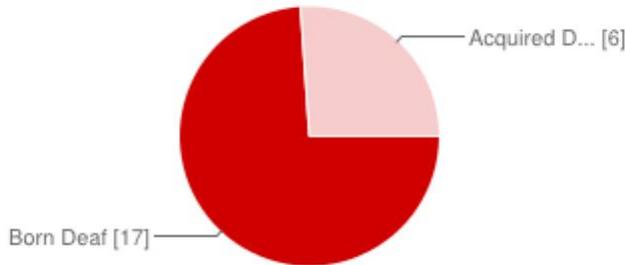
9) Concluding Remarks

Thus, the proposal team requests a design that improves Deaf cyclists' perception of sound-based warning systems. The proposed design will be accessible to all members of the community by minimizing cost, maximizing ease of use and durability, and provide more information on hazards within the field of view. Improving the safety of cyclists will support the City of Toronto's overall goal to promote cycling within the City of Toronto and reduce the number of biking collisions and injuries [14].

Appendix A: Summary of Survey Results

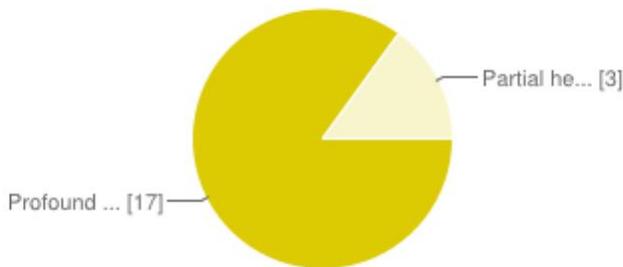
Total Number of People Surveyed: 23

Which of the following options best describes the nature of your hearing loss:



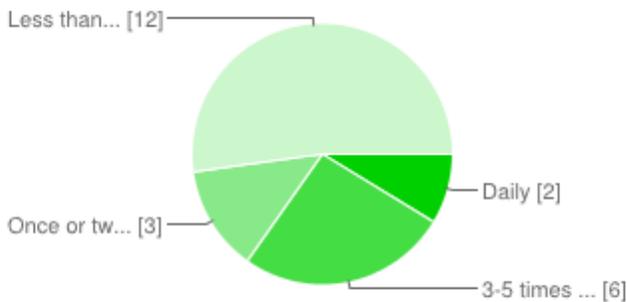
Born Deaf	17	74%
Acquired	6	26%
Deafness		
Total	23	

Which of the following options best describes the extent of your hearing loss:



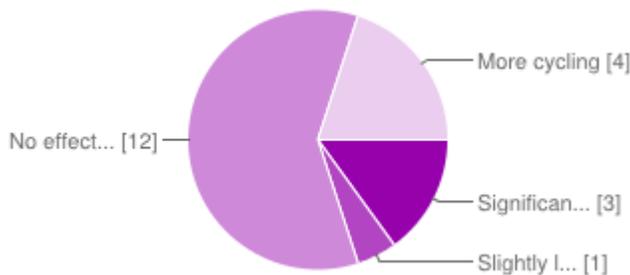
Profound hearing loss	17	85%
Partial hearing loss	3	15%
Total	20	

How often do you cycle?



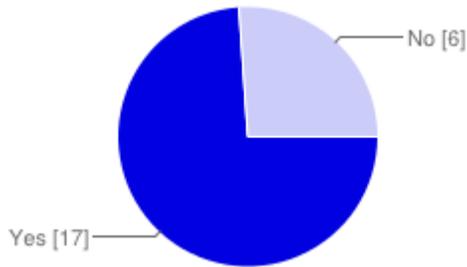
Daily	2	9%
3-5 times a week	6	26%
Once or twice a week	3	13%
Less than once a week	12	52%
Total	23	

If you have acquired deafness, how did your hearing loss affect the frequency of your cycling?



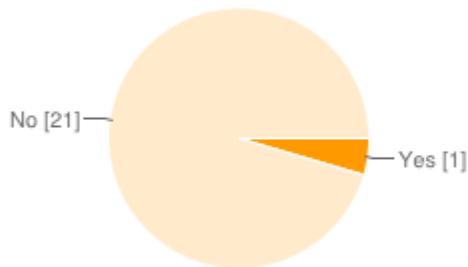
Significantly less cycling	3	15%
Slightly less cycling	1	5%
No effect on cycling	12	60%
More cycling	4	20%
Total	20	

When cycling, are there situations that make you feel unsafe?



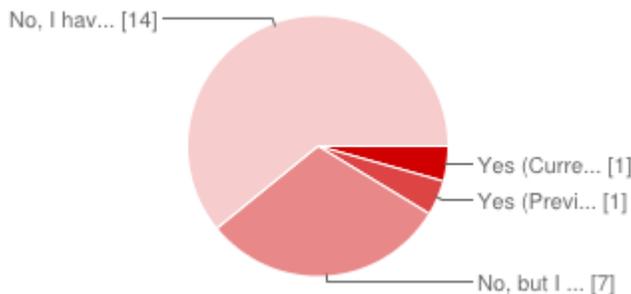
Yes	17	74%
No	6	26%
Total	23	

Have you been involved in a road accident while cycling?



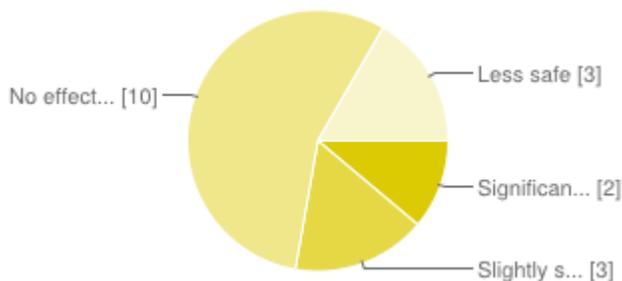
Yes	1	5%
No	21	95%
Total	22	

Do you currently or have you ever worn a deaf cyclist sign?



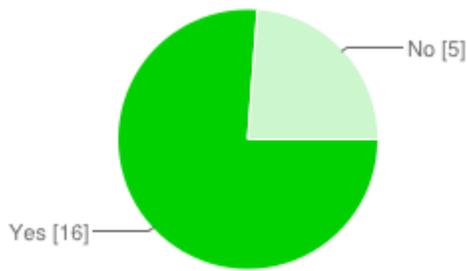
Yes (Currently)	1	4%
Yes (Previously)	1	4%
No, but I am aware of them	7	30%
No, I have never heard of them	14	61%
Total	23	

If so, how much safer do you feel when wearing the sign?



Significantly safer	2	11%
Slightly safer	3	17%
No effect on safety	10	56%
Less safe	3	17%
Total	18	

Do you feel that there is room for improvement for Deaf cyclist safety?



Yes	16	76%
No	5	24%
Total	21	

Notable Testimonies:

1. I grew up in a small town with more hearing than I have now. I loved to bike everywhere. Now with my hearing loss and living in a larger city, I rarely ever cycle. The only time I do is with a group of family members in small town Ontario. I really don't trust drivers around my area and it is hardly bike friendly.
2. Cars assume I can hear them coming up from behind me. I used to have a mirror on my bike but it broke. Sometimes the cars come very close and I could get hit if I had to swerve to avoid something on the street.
3. Usually at intersection when cars rushed around corners [creates an unsafe situation].
4. Traffic noise (i.e. horn, police siren, etc) will be missed out as I won't be able to hear them.
5. Because I can't hear cars behind me, I prefer to cycle the opposite direction so I can see them coming.
6. Other cyclists not being friendly as they would honk their horns and try to get by me if I'm riding too slow and that sometime put us at risk.
Drivers who make last minute changes in their driving (turning without signaling).
7. Heavy traffic where people are honking. Other cyclists nearby who need to pass because I can't hear them coming up behind me.
8. The new e-bikes are so quiet and you don't notice them coming from behind until they are upon you. Cars make noise and you are aware of them coming from behind.
Not always being able to hear the siren of ambulances or fire trucks(high-frequency hearing loss).
Other bikers coming from behind and using their bells - not able to hear them.
9. Unable to see the car passing by, limited of space to bike as bad vision- ushers cause more feeling of unsafe ride.
10. Again, need to inform you that we have higher sense of visually and turn our heads more frequently. Most important " use common sense" and don't assume that everyone will move out of the way for you.

Appendix B: Definitions of deaf types by CHS

Hearing loss ranges from mild to profound. The distinctions between the terms “deaf”, “Deaf”, “deafened” and “hard of hearing” are based principally on the individual’s preferred language (spoken or sign) rather than on the actual degree of hearing loss. Deaf, deafened and hard of hearing individuals may use hearing aids, cochlear implants or other assistive listening devices.

Deaf

This term is generally used to describe individuals with a severe to profound hearing loss, with little or no residual hearing. Some deaf people use sign language, such as American Sign Language (ASL) or Langue des signes québécoise (LSQ) to communicate. Others use speech to communicate using their residual hearing and hearing aids, technical devices or cochlear implants, and/or speechreading.

Culturally Deaf

This term refers to individuals who identify with and participate in the language, culture and community of Deaf people, based on sign language. Deaf culture does not perceive hearing loss and deafness from a pathological point of view, but rather from a socio-cultural point of view, indicated by a capital D as in “Deaf culture”. Culturally Deaf people may also use speech, residual hearing, hearing aids, speechreading and gesturing to communicate with people who do not sign.

Deafened or late-deafened

These terms describe individuals who grow up hearing or hard of hearing and, either suddenly or gradually, experience a profound loss of hearing. Late-deafened adults usually cannot understand speech without visual clues such as captioning/computerized notetaking, speechreading or sign language.

Hard of hearing

This term is generally used to describe individuals who use spoken language (their residual hearing and speech) to communicate. Most hard of hearing people can understand some speech sounds with or without hearing aids and often supplement their residual hearing with speechreading, hearing aids and technical devices. The term “person with hearing loss” is increasingly used and preferred.

Appendix C. Quotation from Aldeaf.com Forum on Cochlear Implants [56]

We, the moderators, are very well aware that Cochlear Implant issues are VERY controversial and sensitive amongst the deaf community. We do understand the severity of this issue and it do invoke frustrations, anger and the world of negativity in our souls, however We are NOT here to declare war on one's personality, one's experience or one's whatever. We are here to DISCUSS the subject itself.

For example I would express my opinion as:

"I think Deaf child should not have an implant because it doesn't allow that child a freedom to...."

Rather than saying:

"I think you are a misfit because you forced your deaf child to have an implant...."

or

"your credentials doesn't qualify you to.."

If we see this negative activities continue in any thread, we will start to track users who do that and will start handing out warnings and eventually ban if our warnings are ignored.

We want this place to be a good resource for those who wanted to listen to both sides and to express their experience and to allow unknowns to make a decision on their own rather than to attack them away. We are here to provide the positive image of the deaf culture, not to make it look like a war machine!

Appendix D: Car-Bike Collision Types and Road Types

From http://www.toronto.ca/transportation/publications/bicycle_motor-vehicle/pdf/car-bike_collision_report.pdf [C]

Table I: Car-Bike Collision Types — Number of Cases, Cyclists' Position, Major Injuries and Fatalities (1997- 98)

<u>Collision Type</u>	Number of Cases	% of Total	Cyclist's Position		Major Injuries	Fatal
			Sidewalk	Road		
Drive Out At Controlled Intersection	284	12.2%	51%	49%	8	0
Motorist Overtaking	277	11.9%	0	100%	7	4
Motorist Opens Vehicle Door	276	11.9%	0	100%	8	1
Motorist Left Turn – Facing Cyclist	248	10.7%	18%	82%	11	0
Motorist Right Turn (Not at Red Light)	224	9.6%	35%	65%	3	0
Motorist Right Turn At Red Light	179	7.7%	86%	14%	4	0
Drive Out From Lane or Driveway	179	7.7%	81%	19%	3	0
Ride Out At Controlled Intersection	65	2.8%	0	100%	3	2
Wrong Way Cyclist	59	2.5%	0	100%	2	0
Ride Out At Mid-block	51	2.2%	100%	0	4	1
Motorist Left Turn – In Front Of Cyclist	48	2.1%	48%	52%	2	0
Ride Out From Sidewalk	44	1.9%	100%	0	5	0
Cyclist Lost Control	44	1.9%	11%	89%	2	0
Cyclist Left Turn In Front Of Motorist	41	1.8%	0	100%	6	0
Cyclist Strikes Stopped Vehicle	39	1.7%	0	100%	1	0
Motorist Reversing	37	1.6%	46%	54%	0	0
Cyclist Overtaking	31	1.3%	0	100%	0	0
Cyclist Caught in Intersection	30	1.3%	3%	97%	0	0
Ride Out From Lane or Driveway	29	1.3%	Unknown		1	0
Drive Into/Out of On-Street Parking	28	1.2%	0	100%	0	0
Cyclist Left Turn – Facing Traffic	11	0.5%	0	100%	2	0
Other (Not classifiable)	101	4.3%	Unknown		9	2
Unknown (Insufficient Information)	247	-	Unknown		4	0
Totals:	2572		30%	70%	85	10

References

- [1] The Canadian Association of the Deaf, "Statistics on Deaf Canadians," 23 July 2012. [Online]. Available: http://www.cad.ca/statistics_on_deaf_canadians.php. [Accessed 12 February 2013].
- [2] City of Toronto, "Cycling Statistics," [Online]. Available: <http://www.toronto.ca/cycling/reports/statistics/statistics.htm>. [Accessed 1 March 2013].
- [3] The Canadian Hearing Society, "Get Connected to Deaf, Deafened and Hard of Hearing

- People: A Guide for Service Providers and Businesses," [Online]. Available: http://www.chs.ca/index2.php?option=com_docman&task=doc_view&gid=90&Itemid=267. [Accessed 16 February 2013].
- [4] S. Keller, *Community, USA*: Princeton University Press, 2003.
- [5] S. E. Hyland, *Community Building in the Twenty-First Century* (School of American Research Advanced Seminar), Santa Fe, New Mexico: School of American Research Press, 2005.
- [6] L. M. Harmer, "Health Care Delivery and Deaf People: Practice, Problems, and Recommendations for Change," *Journal of Deaf Studies and Deaf Education*, pp. 73-110, 1999.
- [7] Ontario Association of the Deaf, "OAD's Five Years Strategic Plan 2008-2013," [Online]. Available: <http://www.deafontario.ca/strategic.html>. [Accessed 14 February 2013].
- [8] S. Brennan, I. Gombac and M. Sleightholm, "Participation and Activity Limitation Survey 2006, Facts on Hearing Limitations," Statistics Canada, Ottawa, 2009.
- [9] Government of Canada, "Population of census metropolitan areas," Statistics Canada, 6 February 2013. [Online]. Available: <http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/demo05a-eng.htm>. [Accessed 15 February 2013].
- [10] K. Perrotta, M. Campbell, S. Chirrey, L. Frank and J. Chapman, "The Walkable City: Neighbourhood Design and Preferences, Travel Choices and Health," April 2012. [Online]. Available: http://www.toronto.ca/health/hphe/pdf/walkable_city.pdf. [Accessed 16 February 2013].
- [11] Road Safety Scotland, "Streetsense Resources," [Online]. Available: <http://www.road-safety.org.uk/education-and-families/primary/streetsense2/streetsense-resources/>. [Accessed 1 March 2013].
- [12] A. H. Maslow, "A Theory of Human Motivation," *Classics in the History of Psychology*, 1943. [Online]. Available: <http://psychclassics.yorku.ca/Maslow/motivation.htm>. [Accessed 15 February 2013].
- [13] TJ, "Maslow's Hierarchy of Needs for a Small Scale Business," *SHYEntrepreneur.com*, 2011 October 2011. [Online]. Available: <http://www.shyentrepreneur.com/pre-business/maslow%E2%80%99s-hierarchy-of-needs-for-a-small-scale-business/>. [Accessed 15 February 2013].
- [14] City of Toronto, "City of Toronto Bike Plan: Shifting Gears," June 2001. [Online]. Available: http://www.toronto.ca/cycling/bikeplan/pdf/bike_plan_full.pdf. [Accessed 1 March 2013].
- [15] City of Toronto, Works and Emergency Services Department, Transportation Services Division, Transportation Infrastructure Management Section, "Bicycle/Motor-Vehicle Collision Study," 2003. [Online]. Available: http://www.toronto.ca/transportation/publications/bicycle_motor-vehicle/pdf/car-bike_collision_report.pdf. [Accessed 16 February 2013]
- [16] City of Toronto: Transportation Services, "2010 Bicycle Report," December 2010. [Online]. Available: http://www.toronto.ca/cycling/reports/pdf/bicycle_count_report_2010.pdf. [Accessed 1 March 2013].

- [17] M. Hersh, J. Ohene-Djan and S. Naqvi, "Investigating Road Safety Issues and Deaf People in the United Kingdom: An Empirical Study and Recommendations for Good Practice," *Journal of Prevention & Intervention in the Community*, pp. 290-305, 2010.
- [18] "Deaf Cyclist," vBulletin Solutions, Inc, 11 September 2011. [Online]. Available: <http://www.bikeforums.net/showthread.php/767338-Deaf-Cyclist>. [Accessed 13 February 2013].
- [19] "Deaf cyclist needs advice," alldeaf.com, 03 March 2010. [Online]. Available: <http://www.alldeaf.com/deaf-products-technologies/76058-deaf-cyclist-needs-advice.html>. [Accessed 13 February 2013].
- [20] "Is there any restrictions of deaf people riding bikes on main roads?," cycle-route.com, 15 October 2012. [Online]. Available: <http://www.cycle-route.com/forum/General-Chat-Is-there-any-restrictions-of-deaf-people-riding-bikes-on-main-roads-Thread-3325.html>. [Accessed 13 February 2013].
- [21] "How to choose and use a bike mirror," Practical Biking, 30 June 2013. [Online]. Available: <http://practicalbiking.org/2010/06/how-to-choose-and-use-a-bike-mirror.html/>. [Accessed 1 March 2013].
- [22] Ontario Human Rights Commission, "The duty to accommodate," December 2009. [Online]. Available: <http://www.ohrc.on.ca/en/policy-and-guidelines-disability-and-duty-accommodate/4-duty-accommodate>. [Accessed 16 February 2012].
- [23] A. Jamieson, "'Pedestrians' involved in one in 10 road accidents," *The Telegraph*, 8 October 2008. [Online]. Available: <http://www.telegraph.co.uk/news/uknews/3156499/Pedestrians-involved-in-one-in-10-road-accidents.html>. [Accessed 13 February 2013].
- [24] R. Lichtenstein, D. C. Smith, J. L. Ambrose and L. A. Moody, "Headphone use and pedestrian injury and death in the United States: 2004–2011," 16 January 2012. [Online]. Available: <http://injuryprevention.bmj.com/content/early/2012/01/03/injuryprev-2011-040161>.
- [25] "Deaf Cyclist/Pedestrian Safety," Google Drive, [Online]. Available: <http://goo.gl/ZsnR6>. [Accessed 28 February 2013].
- [26] J. M. Owen, "Quiet Vehicle Avoidance Systems for Blind and Deaf-Blind Pedestrians," VCU Bioinformatics and Bioengineering Summer Institute, Richmond, 2008.
- [27] D. K. Stein, "Stop, Look, and Listen: Quiet Vehicles and Pedestrian Safety," *The Braille Monitor*, June 2005. [Online]. Available: <https://nfb.org/images/nfb/publications/bm/bm05/bm0506/bm050605.htm>. [Accessed 1 March 2013].
- [28] "Hybrid Cars Are Harder to Hear," Regents of University of California, 28 April 2008. [Online]. Available: <http://newsroom.ucr.edu/1803>. [Accessed 1 March 2013].
- [29] B. Roder and F. Rosler, "Compensatory Plasticity as a Consequence of Sensory Loss," in *The Handbook of Multisensory Processes*, Cambridge, The MIT Press, 2004, pp. 719-723.
- [30] D. Bavelier, M. W. G. Dye and P. C. Hauser, "Do deaf individuals see better?," *TRENDS in Cognitive Sciences*, vol. 10, no. 11, pp. 512-518, November 2006.

- [31] R. Cooper, "Visual Dominance and the Control of Action," in Proceedings of the Twentieth Annual Conference of the Cognitive Science Society, Mahwan, Lawrence Erlbaum Associates, 1998, pp. 250-255.
- [32] R. J. Kosinski, "Literature Review on Reaction Time," September 2012. [Online]. Available: <http://biae.clemson.edu/bpc/bp/lab/110/reaction.htm>. [Accessed 1 March 2013].
- [33] P. Townsley, "Social issues in fisheries: Stakeholder groups," Fisheries and Aquaculture Department, 1998. [Online]. Available: <http://www.fao.org/docrep/003/W8623E/w8623e05.htm#TopOfPage>. [Accessed 16 February 2013].
- [34] The Canadian Hearing Society, "Response of The Canadian Hearing Society to the Parliamentary Assistant to the Minister of Training, Colleges and Universities' Discussion Paper on Adult Education and Training Review," The Canadian Hearing Society, Toronto, 2002.
- [35] City of Toronto, "City of Toronto Bike Plan: Shifting Gears," June 2001. [Online]. Available: http://www.toronto.ca/cycling/bikeplan/pdf/bike_plan_full.pdf. [Accessed 1 March 2013].
- [36] Government of Canada. Canadian Human Rights Act. December 15, 2012.
- [37] United Nations Human Rights. (1975, December 9). Declaration on the Rights of Disabled Persons [Online]. Available: <http://www.ohchr.org/EN/ProfessionalInterest/Pages/RightsOfDisabledPersons.aspx>
- [38] City of Toronto, Transportation Services Division, Traffic Data Centre and Safety Bureau, "Pedestrian Collision Study," January 2007. [Online]. Available: http://www.toronto.ca/transportation/walking/pdf/ped_collision_study-full_report.pdf. [Accessed 16 February 2013].
- [39] Toronto Association of the Deaf, "TAD Vision, Mission and Core Value Statements," [Online]. Available: http://www.deaftoronto.ca/index.php?option=com_content&view=article&id=1:headline&catid=8:pages&Itemid=101. [Accessed 16 February 2013].
- [40] The Canadian Hearing Society, "Welcome to the Communication Devices Program," [Online]. Available: http://www.chs.ca/index.php?option=com_content&task=view&id=215&Itemid=216&ServiceID=4&OfficeID=25&lang=en. [Accessed 16 February 2013].
- [41] Province of Ontario. Highway Traffic Act. 2012.
- [42] American Association of State Highway and Transportation Officials, "Guide for the Development of Bicycle Facilities," 1999. [Online]. Available: <http://www.industrializedcyclist.com/aashto.pdf>. [Accessed 1 March 2013].
- [43] P. A. Lichtenberg, Handbook of Assessment in Clinical Gerontology, Academic Press, 2010.
- [44] Mountain Equipment CO-OP, "Cycling: Bells, Mirrors and Reflectors," [Online]. Available: <http://www.mec.ca/AST/ShopMEC/Cycling/BellsMirrorsReflectors.jsp>. [Accessed 28 2 2013].
- [45] Walmart, "All Helmets & Protective Gear," [Online]. Available: <http://www.walmart.ca/canada-estore/catalog/productlistingpagecontainer.jsp?inputId=31808>. [Accessed 1 3 2013].

- [46] IBM, "User-Centered Design," [Online]. Available: <http://www-01.ibm.com/software/ucd/ucd.html#costjustifying>. [Accessed 1 3 2013].
- [47] Canadian Tire, "Kidde Tamper-Resistant Smoke Alarm," [Online]. Available: <http://www.canadiantire.ca/AST/browse/3/HouseHome/SafetySecurity/SmokeAlarms/PRDOVR~0460016P/Kidde+Tamper-Resistant+Smoke+Alarm.jsp?locale=en>. [Accessed 1 3 2013].
- [48] Canadian Tire, "Garrison Battery Smoke Alarm with Hush Button," [Online]. Available: <http://www.canadiantire.ca/AST/browse/3/HouseHome/SafetySecurity/SmokeAlarms/PRDOVR~0460081P/Garrison+Battery+Smoke+Alarm+with+Hush+Button.jsp?locale=en>. [Accessed 1 3 2013].
- [49] Amazon, "Kidde PI9010 Battery-Operated Dual Ionization and Photoelectric Sensor Smoke Alarm," [Online]. Available: http://www.amazon.com/Kidde-PI9010-Battery-Operated-Ionization-Photoelectric/dp/B0007G71U4/ref=sr_1_3?s=hi&ie=UTF8&qid=1362277813&sr=1-3. [Accessed 1 3 2013].
- [50] Amazon, "Kidde i12040 120V AC Wire-In Smoke Alarm with Battery Backup and Smart Hush," [Online]. Available: <http://www.amazon.com/Kidde-i12040-Wire-In-Battery-Backup/dp/B0000CBHOR>. [Accessed 1 3 2013].
- [51] 1000 Bulbs, "Kidde 910 - Smoke Alarm," [Online]. Available: http://1000bulbs.com/product/3456/KIDDE-0910.html?utm_source=SmartFeedGoogleBase&utm_medium=Shopping&utm_term=KIDDE-0910&utm_content=Smoke+Detectors&utm_campaign=SmartFeedGoogleBaseShopping&gclid=CMfp3aq_37UCFY9AMgodQz4ALg. [Accessed 1 3 2013].
- [52] 1000 Bulbs, "First Alert SA340B - Smoke Alarm," [Online]. Available: http://1000bulbs.com/product/54506/BRK-SA340B.html?utm_source=SmartFeedGoogleBase&utm_medium=Shopping&utm_term=BRK-SA340B&utm_content=Smoke+Detectors&utm_campaign=SmartFeedGoogleBaseShopping&gclid=CNWtufe-37UCFYpDMgod5IAAnQ. [Accessed 1 3 2013].
- [53] C. Brewer, "DeafBikeSigns," [Online]. Available: <http://www.deafbikesigns.com/howto.html>. [Accessed 15 February 2013].
- [54] City of Fort Collins, Traffic Operations, "Question/Request: DEAF CHILD SIGNS," 9 April 2007. [Online]. Available: www.fcgov.com/traffic/pdf/ntsp-deaf_child.pdf. [Accessed 13 February 2013].
- [55] CBS Interactive Inc., "The Cochlear Implant Controversy," 11 February 2009. [Online]. Available: http://www.cbsnews.com/8301-3445_162-10794.html. [Accessed 16 February 2013].
- [56] "Hearing Aids & Cochlear Implants: Important!!," AllDeaf.com, 4 March 2008. [Online]. Available: <http://www.alldeaf.com/hearing-aids-cochlear-implants/49876-important.html>. [Accessed 16 February 2013].