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## Evaluation of three pedestrian phasing with audible pedestrian signals configurations in Quebec City (Canada): an exploratory study of blind or visually impaired persons' sense of safety, preferences, and expectations

François Routhier, Josiane Lettre, Caroline Pigeon, David Fiset, Valérie Martel, René Binet, Véronique Vézina, E. Owen Waygood, Mir Abolfazl Mostafavi, Ernesto Morales

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1 **TITLE**

2 **Evaluation of Three Pedestrian Phasing with Audible Pedestrian Signals Configurations in**  
3 **Quebec City (Canada): An Exploratory Study of Blind or Visually Impaired Persons' Sense**  
4 **of Safety, Preferences, and Expectations**

5

6 **RUNNING HEAD**

7 Pedestrian Phasing with APS Configurations for Blind or Visually Impaired Persons

8

9 **ARTICLE CATEGORY**

10 Research Article – double anonymous peer review

11 **Abstract**

12 *Purpose:* This exploratory study aimed to evaluate the preferences, expectations, and sense of  
13 safety of blind or visually impaired persons regarding three types of pedestrian phasing with  
14 audible pedestrian signals configurations that exist in Quebec City (Canada). These include: 1)  
15 exclusive phasing with non-directional audible pedestrian signals; 2) exclusive phasing with  
16 directional audible pedestrian signals; and 3) concurrent phasing with directional audible  
17 pedestrian signals. *Methods:* Thirty-two blind or visually impaired persons were asked to  
18 complete a survey. Their preferences and expectations regarding audible pedestrian signals were  
19 documented through a series of simulations. Their sense of safety regarding the three existing  
20 configurations were also documented. Subsequently, semi-directed, individual interviews with 11  
21 of the individuals who had completed the survey were conducted to build off the collected  
22 information. *Results:* No formal consensus regarding many of the issues discussed were  
23 established as participants' responses varied too significantly. However, findings suggest that the  
24 exclusive phasing with directional audible pedestrian signals configuration is perceived to be the  
25 safest option by the participants. *Conclusion:* This study may have practical implications on the  
26 design of intersections (e.g., selection of a type of pedestrian phasing with audible pedestrian  
27 signal) and the training of blind or visually impaired pedestrians.

28

29 **Keywords:** Visual impairment, Audible pedestrian signals, Accessibility, Inclusive city,  
30 Participatory research

## 31 **Introduction**

32 The ability to get around independently and safely plays a key role in any individual's social  
33 participation. However, blind or visually impaired persons face countless mobility barriers and  
34 challenges, particularly when crossing intersections— even those equipped with pedestrian  
35 signals [1-4]. These individuals must negotiate these dangerous points with little or no visual  
36 input. They have to interpret certain environmental cues, such as the sound of traffic, to analyze  
37 intersections and traffic signal cycles and to establish and monitor alignment during crossings  
38 [1,5,6,]. However, these cues do not necessarily guarantee it is entirely safe to cross due to  
39 various “permitted” vehicular movements such turning across pedestrian crosswalks [3,6].  
40 Facilitating the autonomy of different parts of the population is an important equity goal of many  
41 cities. Audible pedestrian signals (APS) are placed at certain intersections to enhance safety and  
42 accessibility for blind or visually impaired persons [2,6,7,8]. APS have been commonly  
43 implemented in the USA, Japan, Australia and some European countries for the past several  
44 years. In the province of Quebec (Canada), the provincial transport department enacted  
45 legislation in 2003 that detailed how these types of devices should operate [9-11]. This standard  
46 specified a series of requirements, including the use of directional sound sources, which use  
47 alternating APS that are located at each end of a crosswalk. This aims to help blind or visually  
48 impaired pedestrians establish and maintain a straight line when crossing [12,13]. The efficacy  
49 and usefulness of these alternating APS from one side of the intersection to the other to guide  
50 blind or visually impaired pedestrians in the right direction before and while crossing a street  
51 have been documented in the literature [14]. The standardized system in the province of Quebec  
52 uses the Canadian Melody for east-west crosswalks and a high-pitched bird tweeting for north-  
53 south crosswalks of intersections [6,7]. However, an alternative to the high-pitched bird tweeting  
54 is currently being considered because it does not offer the same alignment accuracy for users as

55 the Canadian Melody [6,7]. The provincial standard also stipulates that a pushbutton locator tone  
56 must be set to activate and confirm the signal. This type of device has been installed in Australia  
57 and Sweden, among other locations [4,8,15].

58  
59 APS are usually installed at selected intersections with pedestrian crosswalks and are  
60 paired with traffic signals. Several years ago, Quebec City (capital of the province of Quebec,  
61 Canada), which has approximately 540,000 inhabitants, and several other small- and medium-  
62 sized provincial municipalities, adopted a traffic management system with exclusive pedestrian  
63 phases (also known as all-pedestrian phases, scramble crossing, or “Barnes dances”). A phase  
64 refers to a part of a traffic light signal dedicated to certain traffic movements such as East-West  
65 traffic and then North-South traffic in a two-phase system. For exclusive phasing, automobile  
66 traffic is completely halted for one phase and only pedestrians are allowed to circulate. Most  
67 intersections in Quebec City do not technically apply a true exclusive phase, as vehicles are  
68 allowed to turn right on a red vehicle signal. However, turning right on a red is not permitted in  
69 Quebec City in intersections with APS. The duration of exclusive phases is calculated based on  
70 the width of the widest crosswalk at the intersection. The duration of the phase includes both the  
71 “walk” and “don’t walk” signal indications. Traffic volumes at these intersections are variable.  
72 However, peak hours are relatively short and generally, one of the two streets will have more  
73 traffic than the other. A non-directional APS was implemented at several of these intersections  
74 (i.e., with exclusive pedestrian phases) prior to the 2003 legislation and remains in place. Unlike  
75 directional APS, non-directional APS is emitted by a single source located at one corner of the  
76 intersection. It gives audible cues similar to the visual “walk” (constant sound) and “don’t walk”  
77 (intermittent sound) signal indications. Due to changes in standards over the years, there are  
78 currently three different pedestrian phasing with APS configurations for blind or visually

79 impaired pedestrians in Quebec City. These configurations include: 1) exclusive phasing with  
80 non-directional APS; 2) exclusive phasing with directional APS; and 3) concurrent phasing  
81 (pedestrians served concurrently with adjacent traffic movement by way of an on-demand  
82 pushbutton) with directional APS (figure 1).

83

84 [Insert figure 1 here]

85

86 During a consultation process in Quebec City on APS upgrading, advocacy groups for the  
87 rights of individuals living with disabilities expressed concerns about the implementation of the  
88 standard-conforming signals. These concerns were mostly about adaptation-related challenges for  
89 blind or visually impaired persons. Due to such changes, additional intensive training with  
90 orientation and mobility specialists was then required. The advocacy groups also raised questions  
91 about the effective safety of the non-standardized system, especially in an area where the  
92 configurations can vary dramatically. Moreover, if blind or visually impaired persons do not trust  
93 the systems in place, this can negatively impact their daily mobility (e.g., by preventing them  
94 from independent travel), which can likely impact their quality of life. Even though Canada and  
95 other countries have been using various types of pedestrian phasing with APS for some years  
96 now, to our knowledge, there is limited evidence on the behavior and perception of blind or  
97 visually impaired persons regarding these types of configurations. The situation in Quebec City  
98 poses a unique experimental context for examining such questions, as other possible modifiers  
99 such as cultural influences (e.g., driving behavior) or general street/sidewalk design are held  
100 constant. Also, the questions raised by the community organizations in Quebec City provided a  
101 unique opportunity to investigate the advantages and disadvantages of different types of  
102 pedestrian phasing with APS configurations.

103  
104 In this respect, the overall purpose of this exploratory study was to investigate the various  
105 types of pedestrian phasing with APS configurations found in the Quebec City area so as to help  
106 improve the autonomy of blind or visually impaired persons. Based on the concerns raised by  
107 various partners, our research sought more specifically: 1) to identify the preferences and  
108 expectations of blind or visually impaired persons regarding pedestrian phasing with APS  
109 configurations; and 2) to estimate the extent to which the different configurations influence the  
110 sense of safety of blind or visually impaired persons. In this research project, sense of safety  
111 refers to the participants' perceived level of safety (based on their characteristics and personal  
112 experiences) and comfort (e.g., ease of mobility, accessibility, traffic noise, audible signal  
113 volume) [16-18].

114

## 115 **Methods**

116 This exploratory study was broken down into two different phases to meet its objectives, namely  
117 a survey and interviews. A monitoring committee was also set up to support the completion of the  
118 research project and the research team. The monitoring committee was made up of community  
119 stakeholders (n=3), orientation and mobility specialists (n=2), and municipal and provincial  
120 agents (n=2). The monitoring committee's role consisted of validating the project milestones,  
121 advising on the content of the data collection tools, participating in the recruitment process,  
122 monitoring project progress, and proposing courses of action. The study was approved by the  
123 Research Ethics Board in rehabilitation and social integration at the [REDACTED]  
124 [REDACTED] (REB number: 2018-435, RIS\_2017-  
125 571). All participants provided written informed consent.

126

127 *Phase 1: Survey*

128 *Recruitment*

129 For the first phase of this exploratory study, blind or visually impaired persons were recruited: 1)  
130 with the help of a regional non-profit organization, [REDACTED]  
131 [REDACTED]  
132 [REDACTED], in particular via their newsletter; 2) with the help of the Blindness and Visual  
133 Impairment Program of the [REDACTED]  
134 [REDACTED], specifically program stakeholders provided project information to their  
135 clients; and 3) through snowball sampling.

136

137 A varied representation of profiles was sought, namely in terms of the degree of visual  
138 impairment and assistive technologies used, the level of independence (autonomy) when getting  
139 around in familiar and non-familiar areas, and experience using APS. More specifically,  
140 individuals needed to comply with the following inclusion criteria: 1) be between the ages of 18  
141 and 65 (inclusively); 2) be visually impaired as defined by Quebec legislation; 3) be familiar with  
142 pedestrian crossing signals; 4) use audible pedestrian crossings; and 5) live in the eastern part of  
143 the province of Quebec.

144

145 *Variables and Data Acquisition Procedure*

146 A survey was developed to document the preferences, expectations, and sense of safety that blind  
147 or visually impaired persons have regarding pedestrian phasing with APS configurations. A  
148 survey methodology approach was selected because specific situational aspects can be examined  
149 [19] and specific behaviours or attitudes can be described or explained [20]. Based on a co-  
150 construction approach, the survey was developed in collaboration with members of the



151 monitoring committee. A pre-test with three individuals with different visual impairment profiles  
152 was also conducted to ensure that survey questions were understandable and accessible.

153  
154 Participants first completed a sociodemographic and clinical questionnaire. Then, the  
155 following variables were documented: 1) the sense of safety experienced when crossing  
156 intersections with APS for each of the three types of configurations (figure 1); and 2) the sense of  
157 safety experienced when crossing an intersection equipped with APS based on the length of the  
158 crosswalk (one lane in each direction vs. two lanes in each direction) and amount of traffic (light  
159 vs. heavy). Length of the crosswalk and amount of traffic were not further described in the  
160 survey. Participants were simply asked to think about their pedestrian commutes over the course  
161 of a year. A six-point Likert-type rating scale with an additional “I do not know” option to  
162 evaluate the sense of safety was used. Participants were asked to indicate if they agreed (three  
163 categories) or disagreed (three categories) with a statement about their sense of safety.

164  
165 At their convenience, participants could complete the survey online (written and/or  
166 audio), via an electronic file (sent by email), in paper format (sent by mail), or by phone with the  
167 support of a research team member.

168  
169 *Data Analysis*

170 The participant characteristics, obtained through the sociodemographic questionnaire, were  
171 compiled using descriptive statistics (means, frequencies). Descriptive statistics were also used to  
172 document participants’ sense of safety regarding the different types of configurations and  
173 variables (i.e., the length of a crosswalk and amount of traffic).

174

175 A non-parametric, repeated measures ANOVA model, that is also applicable to  
176 multifactorial designs (*R software, package nparLD, version 2.1*), was used to compare the  
177 differences between the sense of safety participants experienced for all three configurations [21].  
178 This particular ANOVA model was developed specifically for small sample pools and does not  
179 require any specific distribution of data, allowing for repeated measures distribution to be  
180 modified. It also does not require that missing data be imputed and is particularly robust in terms  
181 of marginal data (outliers). By not making assumptions in terms of the structure of the covariance  
182 matrix among the repeated measures, this model accepts variance heterogeneity. However, since  
183 this is a non-parametric ANOVA model, it does not provide an effect size estimate. Using  
184 Wilcoxon tests for post hoc comparisons, it is still possible to calculate Vargha and Delaney's A  
185 (VDA) statistic and Cliff's delta ( $\Delta$ ) effect sizes [22]. The VDA statistic oscillates between zero  
186 and one, with a value of 0.5 corresponding to the null hypothesis. Although there is not really any  
187 absolute criterion available to qualify effect sizes, a value greater than or equal to 0.64 is  
188 considered a moderate effect size. The Cliff  $\Delta$  is a concept similar to the correlation coefficient  
189 ( $r$ ) which varies between minus one and one, where the zero value corresponds to the null  
190 hypothesis. As an absolute value, a number that is higher than or equal to the estimate of 0.28 is  
191 deemed to reveal an effect size that is at least moderate. Software packages to calculate these two  
192 statistics are included with the R software (*package rcompanion, version 2.3.21, 2020-01-09*).

193

## 194 ***Phase 2: Interviews***

### 195 *Recruitment*

196 For the second phase of the study, blind or visually impaired persons who had completed Phase 1  
197 were recruited. The same participant profile was sought.

198

199 *Variables and Data Acquisition Procedure*

200 Semi-directed, one-on-one interviews were conducted to further document the preferences,  
201 expectations, and sense of safety that blind or visually impaired persons have regarding APS.  
202 Interviews were the preferred qualitative research tool because they allow direct access to an  
203 individual's lived experiences [23]. An interview guide was developed based on the data collected  
204 from the survey. The interview guide was then submitted to the monitoring committee for  
205 validation and approval (see supplemental material).

206

207         Participants were first asked about their sociodemographic profile and commuting habits.  
208 With their consent, the information collected from the surveys was then supplemented with data  
209 collected during the interviews. In-person and over-the-phone interviews were conducted with  
210 the participants (subject to their preference). They were recorded for analysis purposes.

211

212 *Data Analysis*

213 The participant characteristics, obtained through the sociodemographic questionnaire, were  
214 compiled using descriptive statistics (means, frequencies). The content from the semi-structured  
215 interviews was transcribed and then analyzed using NVivo software (QSR International Pty Ltd).  
216 More specifically, a thematic analysis was performed [24]. An early coding template was created  
217 to start data categorization. The coding template was data-driven, which is specific to an  
218 inductive approach, and therefore no theoretical framework was used for its design [25]. As the  
219 process progressed, the coding guide was adjusted and refined according to the themes and  
220 subthemes that were discussed, which is characteristic of a continuous thematic analysis. This

221 analysis was led by a research assistant who was supervised by two members of the research  
222 team to ensure the work was thoroughly conducted.

223

## 224 **Results**

### 225 *Phase 1: Survey*

#### 226 *Participants*

227 Thirty-two individuals completed the survey. Most respondents were between 46 and 55 years of  
228 age (n=12; 37.5%) and 56 to 65 years of age (n=13; 40.5%). Women made up 62.5% of the  
229 sample pool (n=20). Most respondents had been living with visual impairments since birth (n=24;  
230 75%).

231

232 Respondents mostly use a cane (always or occasionally) (n=25; 78.1%). The majority of  
233 respondents use their residual sight when getting around outdoors (n=23; 71.9%) and 18 (56.3%)  
234 use their residual sight at all times. See table 1 for an overview of the participants' travel  
235 characteristics. Most respondents were trained by an orientation and mobility specialist,  
236 regardless of the type of intersection (without an APS: n=27; 84.4%, with an APS: n=24; 75.0%).  
237 Table 2 provides an overview of the characteristics of audible and non-audible pedestrian signals  
238 used by participants. Almost 60% of participants (n=19) stated that they use non-audible  
239 pedestrian signals at least once a day or week, and almost 85% of participants (n=27) stated that  
240 they use APS at least once a day or week. The participants were thus generally active users.

241

242 [Insert table 1 here]

243 [Insert table 2 here]

244

245 *Sense of Safety*

246 Table 3 provides an overview of the findings regarding the use of different pedestrian phasing  
247 with APS configurations. The most commonly used configuration is the exclusive phasing with  
248 non-directional APS. Almost all participants stated that they use this type of configuration (n=31;  
249 96.9%). Fourteen participants (43.8%) stated that they use or had already used all three types of  
250 configurations.

251

252 [Insert table 3 here]

253

254 Participants' sense of safety regarding the various configurations and some variables (i.e.,  
255 the length of the crosswalk and amount of traffic) was documented. Figures 2 to 7 present the  
256 participant responses. For a clearer presentation of the results, the dichotomized scores from the  
257 six-point Likert-type rating scale used are shown.

258

259 Figure 2 demonstrates that the participants, for the most part, feel safe when they cross  
260 intersections with exclusive phasing, regardless of whether or not they are equipped with non-  
261 directional (n=28; 87.5%) or directional (n=30; 93.8%) APS. Compared to the other two  
262 configurations, participants' sense of safety seems to be lower with concurrent phasing that uses  
263 directional APS; 68.8% (n=22) stated that they feel safe when crossing a pedestrian crosswalk  
264 with this type of configuration.

265

266 [Insert figure 2 here]

267

268 A statistical comparison (nparLD-type ANOVA on the ordinal variable in six categories)  
269 identified a significant statistical difference among the configurations ( $p=0.000038$ ). The post hoc  
270 tests indicated that the first two configurations inspire a similar sense of safety ( $p=0.657$ ;  
271  $VDA=0.534$ ;  $Cliff \Delta=0.067$ ) while the third configuration inspires less safety than the first  
272 configuration ( $p=0.012$ ;  $VDA=0.688$ ;  $Cliff \Delta=0.377$ ) and the second configuration ( $p=0.0004$ ;  
273  $VDA=0.676$ ;  $Cliff \Delta=0.353$ ). The VDA and Cliff  $\Delta$  statistics revealed significant differences in  
274 magnitude (moderate effect or more).

275  
276 To determine the impact residual sight might have, an additional nparLD-type ANOVA  
277 was performed by adding this independent variable to the type of configuration. The differences  
278 regarding the type of configuration were still observed ( $p=0.004$ ). However, the findings did not  
279 indicate a main effect of residual sight, albeit the p value is very close to the alpha threshold  
280 ( $p=0.053$ ). However, if we accept the p value of 0.053 as being worthy of interest, a slight effect  
281 of residual sight is systematically present in all the configurations. Lastly, the interaction of  
282 configuration x residual sight is statistically significant ( $p=0.036$ ), which indicates that residual  
283 sight has a significant effect for at least one configuration. Post hoc tests for each configuration  
284 with Wilcoxon signed-rank sample tests were performed. It was found that residual sight had a  
285 considerable effect for the first configuration (i.e., exclusive phasing with a non-directional APS)  
286 ( $p=0.002$ ;  $VDA=0.807$ ;  $Cliff \Delta=0.614$ ). More specifically, this means that for this type of  
287 configuration, participants without residual sight have a heightened sense of safety compared to  
288 participants with residual sight. Nonetheless, the effect of residual sight was not observed for the  
289 second configuration ( $p=0.484$ ;  $VDA=0.374$ ;  $Cliff \Delta=-0.251$ ) or for the third configuration  
290 ( $p=0.773$ ;  $VDA=0.457$ ;  $Cliff \Delta=-0.087$ ).

291  
292 A second additional analysis was performed in which gender was included as an  
293 independent variable to residual sight and the type of configuration. It clearly found that gender  
294 does not influence one's sense of safety [principal effect:  $p=0.795$ ; interactions:  $p=0.639$  (gender  
295 x residual sight);  $p=0.884$  (gender x configuration);  $p=0.642$  (gender x residual sight x  
296 configuration)].

297  
298 As displayed in figure 3, 59.8% of respondents ( $n=19$ ) indicated that they feel safe when  
299 crossing with different types of APS (i.e., non-directional and directional) when getting around.  
300 However, almost one-third of participants ( $n=10$ ; 31.3%) stated that they do not feel safe when  
301 faced with more than one type of APS. These proportions are inverted when respondents come  
302 across different types of pedestrian phasing (i.e., concurrent and exclusive). In fact, 56.3% ( $n=18$ )  
303 of the participants feel unsafe when crossing different types of pedestrian phasing, while 40.6%  
304 ( $n=13$ ) of the participants do feel safe while crossing.

305  
306 [Insert figure 3 here]

307  
308 Residual sight may have an effect in the case of different types of APS, although the  
309 effect would be small ( $p=0.051$ ;  $VDA=0.594$ ;  $Cliff \Delta=0.188$ ). In this case, participants without  
310 residual sight would have a higher sense of safety than participants with residual sight. However,  
311 it was found that there was a higher sense of safety when pertaining to different types of  
312 pedestrian phasing ( $p=0.028$ ;  $VDA=0.676$ ;  $Cliff \Delta=0.353$ ). Participants without residual sight feel

313 safer than participants with residual sight when faced with more than one type of pedestrian  
314 phasing.

315

316 Figure 4 illustrates that regardless of the type of pedestrian phasing with APS  
317 configuration, the majority of participants indicated that they feel safe when crossing an  
318 intersection with one lane in each direction during light traffic. However, the exclusive phasing  
319 with directional APS configuration stands out in particular because participants were almost  
320 unanimous: 97% (n=31) of participants feel safe when crossing under these conditions.

321

322 [Insert figure 4 here]

323

324 Figure 5 illustrates that more participants stated that they do not feel safe when crossing  
325 an intersection with one lane in each direction and heavy traffic. Concurrent phasing with  
326 directional APS configuration is perceived as the most unsafe in this type of situation, with 38%  
327 (n=12) of participants feeling unsafe. In comparison, 22% (n=7) of participants stated that they  
328 do not feel safe when crossing this type of intersection with the other two types of configurations.  
329 It is important to mention that most participants reported feeling safe when crossing an  
330 intersection with one lane in each direction during heavy traffic for all three types of  
331 configurations.

332

333 [Insert figure 5 here]

334

335 Figure 6 illustrates that most respondents feel safe when crossing an intersection with two  
336 lanes in each direction during light traffic, regardless of the type of pedestrian phasing with APS



337 configuration. However, fewer participants stated feeling safe when crossing a concurrent  
338 phasing intersection with directional APS in this type of situation in comparison to the other two  
339 types of configurations. The exclusive phasing with directional APS configuration is especially  
340 notable since 90.6% (n=29) of participants stated that they feel safe crossing an intersection with  
341 two lanes in each direction during light traffic with this type of configuration.

342

343 [Insert figure 6 here]

344

345 Figure 7 illustrates that in the case of an intersection with two lanes in each direction  
346 during heavy traffic, the number of participants who do not feel safe (n=15; 46.9%) is slightly  
347 higher than the number of participants who feel safe (n=14; 43.8%) when crossing a concurrent  
348 phasing with directional APS configuration. The findings for the other two types of  
349 configurations are identical: 75% (n=24) of participants stated that they feel safe when crossing  
350 this type of intersection.

351

352 [Insert figure 7 here]

353

## 354 ***Phase 2: Interviews***

### 355 *Participants*

356 Eleven individuals took part in the interviews. Most respondents were between 56 and 65 years  
357 of age (n=6; 54.5%) and women made up 54.5% of the sample pool (n=6). Table 4 illustrates that  
358 a large majority of respondents had been living with visual impairments since birth (n=8; 75%).  
359 A large majority use their residual sight (n=8; 72.7%) and a cane (n=9; 81.8%).

360

361 [Insert table 4 here]

362

363 *Main Themes Discussed during Interviews*

364 Following the interviews, the most relevant information was grouped into the following three  
365 main themes: 1) participants' expectations regarding pedestrian phasing with APS; 2) positive  
366 and negative aspects of each of the three pedestrian phasing with APS configurations, as well as  
367 of the exclusive phasing and of the directional APS; and 3) factors that influence participants'  
368 sense of safety. Table 5 illustrates the sub-themes associated with each of the three main themes.  
369 In the following, each of these sub-themes is presented in detail.

370

371 [Insert table 5 here]

372

373 ***Participants' expectations regarding pedestrian phasing with APS.*** Several participants  
374 discussed the addition of APS and uniformity-related challenges. Most participants (n=8; 72.7%)  
375 would like to see an increase in the *number of intersections equipped with APS*. In fact, some  
376 mentioned that they should be installed everywhere: "Well, maybe it is wishful thinking [...], but  
377 as soon as there is a traffic signal, that an audible signal be [...] already in place, operational [...],  
378 it should become the norm, but not just for Quebec City, but everywhere." Thoughts about the  
379 need for *uniformity* were more mixed. Five participants (45.5%) stated that it is essential to  
380 standardize pedestrian phasing with APS into a single configuration: "[...] given that it is not  
381 standardized, I have to start assessing each intersection I am not familiar with. It's an issue. If  
382 everything was standardized, I would not have to ask questions". However, four participants  
383 (36.4%) said that it did not have an effect and that they were satisfied with the presence of APS,

384 regardless of the configuration: “For me, on one hand, it doesn’t bother me [...]. What matters to  
385 me is to have a system in place, whether it be one or any of the three configurations”.

386  
387 Two participants (18.2%) expressed their thoughts on *what type of configuration would be*  
388 *the most adequate based on the characteristics of an intersection*. For example, one participant  
389 explained that: “For smaller intersections, the old system [exclusive phasing and non-directional  
390 audible signals] is appropriate [...] because the pole is located at the corner of a street at smaller  
391 intersections and that's ok. For larger, more complex intersections, it is best to have the new  
392 system [directional audible signals]”.

393  
394 Participants expressed other expectations regarding *pedestrian pushbuttons* (this is not  
395 APS specific; nearly all pedestrian signals in Quebec City have a pushbutton). Two participants  
396 (18.2%) stated that the location of the pushbuttons is not standardized, despite the existing  
397 standard, and that they accidentally press the wrong pushbutton. However, the participants  
398 indicated that the addition of a pushbutton locator tone to help identify the location of the  
399 pushbutton is very useful, as stated by the following individual: “Some intersections are now  
400 equipped with a pole that emits a sound so it can be located. [...] this should be the case  
401 everywhere”.

402  
403 One participant (9.1%) stated that *APS volumes* are not loud enough or standardized:  
404 “[The audible signal sound volume] varies greatly from one place to the next; it should be  
405 standardized. [...] I have to admit that there are places where [...] the audible signals are close to  
406 residential [areas] [...], but we must be able to hear them”.

407  
18

408           Lastly, one participant (9.1%) stated that Quebec City, among others, should raise  
409 awareness to foster a *better understanding of APS among other road users*: “We need to raise  
410 awareness to explain to people what audible signals are and what they do. [...] people don’t know  
411 and might think it is useless noise”.

412  
413 ***Positive and negative aspects of each of the three types of configurations, exclusive phasing,***  
414 ***and directional APS.*** Six participants (54.5%) stated that they felt safe when crossing an  
415 intersection with *exclusive phasing with non-directional APS*. Among these participants, one has  
416 no residual sight, one never uses their residual sight, and four have and use their residual sight.  
417 However, five participants (45.5%) stated that it was more difficult to locate the pushbutton and  
418 to monitor a straight line of travel when crossing: “Me, I do [not] feel comfortable [using this  
419 type of configuration] because it is only a *bi bi bi bi bip*. It tells us when to cross, but since I no  
420 longer see enough to walk in a straight line, [the non-directional audible signal] doesn’t help me  
421 walk straight when I am crossing”. Among these participants, one has no residual sight and four  
422 have and use their residual sight.

423  
424           Participants’ views on the *concurrent phasing with directional APS* configuration are  
425 rather polarized. Five participants (45.5%) only mentioned the following negative aspects: “With  
426 parallel traffic [...], it is a lot of information to process at the same time. I have to focus on the  
427 audible signal to cross, but at the same time I have to make sure I don’t get distracted by the  
428 sounds of vehicles around me”. Among these participants, one has no residual sight, one never  
429 uses their residual sight, and three have and use their residual sight. Other participants brought up  
430 some positive aspects, such as shorter waiting periods (n=6; 54.5%): “Exclusive phasing slows  
431 down traffic”. Four participants (36.4%) also indicated that this type of configuration allows for

432 proper alignment due to parallel circulation: “With concurrent phasing signals, we can self-  
433 correct our path if we realize by the sound that we are not heading in the right direction”.

434  
435 Five participants (45.5%) greatly appreciated the *exclusive phasing with directional APS*  
436 configuration because there is no traffic present when crossing and there is an APS to help them  
437 monitor a straight line of travel. Only one negative aspect was mentioned by one participant  
438 (9.1%): “Audible signals [...] are not present on all four sides”. As we observed in Quebec City,  
439 this type of configuration does not always cover all four corridors of the intersection, but only  
440 two or three.

441  
442 The participants also discussed exclusive phasing signals and directional APS, without  
443 referring to any particular configuration. Participants did not criticize *exclusive phasing signals*.  
444 The fact that automobile traffic is for the most part halted (right turns on red are permitted if there  
445 is no APS) gives them a heightened sense of safety (n=5; 45.5%). One individual stated that: “If  
446 everything is stopped around me, I am not worried”. Lastly, *directional APS* is especially  
447 appreciated because these include a pushbutton locator tone that indicates where the pushbutton  
448 is located and emits a sound confirming the audible sound command (n=5; 45.5%): “Knowing  
449 that there is a sound that locates [the pole] and confirms that the system is operational, that is  
450 helpful”. Furthermore, according to some participants (n=3; 27.3%), directional APS enables  
451 proper alignment: “What helps is the sound: the tweeting sound or the Canadian Melody,”  
452 depending on which crosswalk they are travelling. However, this view is not shared by all. Some  
453 participants (n=2; 18.2%) stated that they sometimes felt confused by the fact that there are two  
454 different types of directional APS.

455  
20

456 ***Factors influencing one's sense of safety.*** There are several factors that influence one's sense of  
457 safety. Participants sometimes mentioned the same factors, but their views sometimes diverged  
458 and were nuanced.

459  
460 All participants discussed *intersection characteristics* (n=11; 100%). Regarding the length  
461 of crosswalk, some participants (n=6; 54.5%) indicated that the risk of deviating decreases when  
462 the crosswalk is short and there is less exposure time: "Shorter crosswalks are better because it  
463 takes less time to cross". However, for other participants (n=4; 36.4%), the length of the  
464 crosswalk has no influence: "[...] for me, it's OK because I can walk and get around easily". The  
465 position of the pedestrian pushbutton was an issue that two participants raised (18.2%): "When  
466 you have to select a button, and the signal starts to sound, and it's a new standardized signal, but  
467 we don't know if we pressed the right button". Lastly, the inconsistent crossing times was a  
468 stressful factor for some participants (n=5; 45.5%) because they cannot see the number of  
469 seconds that are displayed.

470  
471 Almost all participants discussed *traffic levels* (n=10; 90.9%). Three participants (27.3%)  
472 indicated that they needed to be extra careful when crossing intersections with higher volumes of  
473 traffic: "I will be more alert [and] I will be more careful". Furthermore, two participants (18.2%)  
474 stated that the presence of motorists is helpful because they can determine where vehicles are  
475 located.

476  
477 All participants discussed *noise* at intersections, which is most often traffic-related (n=11;  
478 100%). Three participants (27.3%) indicated that the sound of cars allows them to get aligned and  
479 adjust their trajectory accordingly when crossing: "By listening to the traffic [...] when there is a

480 lot of noise, it is easier to orient yourself”, “It's clear that I prefer to listen to the cars to know  
481 what direction [they are heading in], [...] [when there isn't] any sound, [we] don't know if there  
482 are cars or not”, and “Before crossing [we listen] to determine if we are correctly aligned”.  
483 However, several participants (n=9; 81.2%) qualified the pros and cons of sound: “too much is  
484 like not enough, [you] need the right balance”. Cyclists are also a disruptive variable that impacts  
485 some participants' sense of safety (n=4; 36.4%): “Cyclists are a bit irritating because [we] don't  
486 hear them”. Although not studied here, this is a potential future issue as electric vehicles do not  
487 make much noise.

488  
489 If one is *familiar with an intersection*, it increases the sense of safety. Many participants  
490 (n=10; 90.9%) stated that they analyze an intersection before crossing it for the first time: “I am  
491 going to be more careful, I will listen more, I will be more attentive. I will closely examine the  
492 intersection”.

493  
494 Participants (n=11; 100%) also discussed *external conditions*, such as light and wind.  
495 Some participants (n=2; 18.2%) explained that cloudy conditions and the lack of sunlight at night  
496 optimizes their residual sight: “I can see the traffic signals [...] [and] I can see them clearly at  
497 night”. Some participants (n=4; 36.4%) stated that their vision is better when it is sunny: “during  
498 the day, if it is sunny, it helps me because of my peripheral vision”. Four participants (36.4%)  
499 indicated that wind has a negative impact on their sense of safety because the APS is less audible  
500 and seems diverted.

501  
502 Participants mentioned *road sign compliance* on several occasions during the interviews  
503 (n=6; 54.5%), mainly because they fear right turns on red. Three participants (27.3%) deplored

504 how little motorists complied with road signs that forbid right turns on a red signal. This has a  
505 significant impact on one's sense of safety. One participant stated: “You always have to be on  
506 guard because there are [motorists] that run lights even when pedestrians have the right of way”.  
507 Another participant added: “the problem lies with individuals who do not comply with traffic  
508 laws”.

509  
510 *Stress and unexpected events* are aspects that have a negative effect on some of the  
511 participant's sense of safety (n=6; 54.5% and n=3; 27.3%, respectively). One participant  
512 explained how she reacts to unexpected events: “Yes, if there are large trucks or if there is  
513 anything unusual, I wait, I don’t risk it”. This means that this type of individual may spend more  
514 time at an intersection to ensure they begin crossing only when they feel it is safe.

515  
516 Lastly, participants discussed the impact of APS on their trajectories. Most participants  
517 (n=7; 63.6%) stated that they mostly head to locations equipped with APS. In fact, one  
518 participant even said that they do not travel if there is no APS: “Intersections without audible  
519 signals, I don't really use them [intersections]”. However, other participants (n=5; 45.5%) stated  
520 that it does not stop them from getting out, but that the presence of APS is still a key element:  
521 “For me personally, the lack of audible signals doesn’t stop me, but it is true that for locations  
522 with heavier traffic [it is particularly important]”.

523

## 524 **Discussion**

525 Through a survey and **individual** interviews, this exploratory study appraised the preferences,  
526 expectations, and sense of safety of blind or visually impaired persons regarding three types of  
527 pedestrian phasing with APS configurations that exist in Quebec City (Canada).



528

529 *Sense of Safety*

530 The results tend to demonstrate that the addition of APS to pedestrian signals heightens the sense  
531 of safety of blind or visually impaired persons, regardless of the type of APS. The presence of  
532 APS was desired more than the uniformity of such systems. However, a preference for directional  
533 APS could be seen. Several participants indicated that it would be helpful if more APS were  
534 installed. Participants also suggested that increasing the number of crosswalks with APS  
535 increases route choices, thereby improving accessibility. This is in line with what is found in the  
536 literature regarding the advantages of using APS to ensure safe crossing at intersections  
537 [2,8,26,27].

538

539 On the whole, the traffic control system with an exclusive pedestrian phase that uses the  
540 directional APS appears to provide a higher sense of safety than the other two types of  
541 configurations (i.e., exclusive phasing with non-directional APS and concurrent phasing with  
542 directional APS). As also documented in the existing literature [28,29], many participants from  
543 this study indicated that they had a heightened sense of safety when: a) there is an absence of car  
544 movement, b) there is a pushbutton locator tone, and c) there is the emission of a sound  
545 confirming that the sound signal command has been activated. Participants also discussed how  
546 they adjust their trajectory when crossing an intersection when they hear alternating APS at either  
547 end of the intersection. Some studies demonstrated how this type of alternation is beneficial for  
548 the alignment of blind or visually impaired persons [12-14], while a similar study was unable to  
549 demonstrate such findings [2]. Lastly, some participants stated that the Canadian Melody signal  
550 helped them achieve better alignment than the bird tweet signal. These statements concur with the

551 existing literature which indicates that it is more challenging for pedestrians to remain aligned  
552 with the bird tweet signal than with the Canadian Melody [6,7].

553  
554 The exclusive phasing with non-directional APS configuration has the advantage of being  
555 widely familiar; participants are accustomed to it since it has been common in the Quebec City  
556 area for a long time. However, almost half of the participants pointed out the disadvantages of the  
557 non-directional APS, namely due to the challenges locating the pushbutton and maintaining  
558 proper alignment when crossing.

559  
560 The survey found that the concurrent phasing with directional APS was generally  
561 perceived as the least safe. Opinions expressed in the interviews on the concurrent phasing with  
562 directional APS configuration were polarized. For almost half of the interviewed participants, the  
563 fact that vehicles are circulating at the same time as pedestrians makes them feel unsafe.  
564 Participants expressed that adaptation is more complex because of the risk associated with a  
565 possible deviation when crossing and the increase in the number of stimuli they need to manage.  
566 In the same vein, an earlier study showed that blind or visually impaired persons experienced a  
567 higher cognitive load when navigating complex, obstacle-ridden environments when travelling  
568 [30]. Furthermore, attentional abilities of blind or visually impaired persons significantly impact  
569 their performance [30]. These abilities refer to the process of selecting information and  
570 processing it efficiently. This is consistent with the fact that the concurrent phasing with  
571 directional APS configuration was appreciated by participants from the current study who were  
572 familiar with it and had a good risk tolerance. The literature documents some of the advantages of  
573 concurrent phasing, namely the shorter interruption periods of pedestrian and vehicular traffic,

574 and the possibility for blind or visually impaired persons to use parallel traffic sounds to begin  
575 crossing and maintain alignment [28,31]. This was reflected in a few participants comments.

576

### 577 *Uniformity*

578 Participant views on the uniformity of APS was somewhat split. While almost half of the  
579 participants stated that they wished for more coherent pedestrian phasing with APS  
580 configurations, a little over one-third of participants expressed a more nuanced view. These  
581 participants explained that it would be easier for them to adapt if the same pedestrian phasing  
582 with APS configuration was used throughout the city. However, because their main hope is for  
583 there to be more APS-equipped intersections in general, they reported that they would be satisfied  
584 with any APS, regardless of configuration. The costs associated with the standardized system  
585 most likely represent a significant challenge because it could lead to installation delays and have  
586 an impact on the number of installed devices.

587

### 588 *Physical Characteristics of Intersections and other factors*

589 According to the participants from the current study, characteristics of intersections are among  
590 the main factors that impact their sense of safety when crossing a crosswalk. From the survey, the  
591 amount of traffic appears to have a larger impact on the sense of safety than the length of the  
592 crosswalk. From the interviews, further details could be found about the impacts of design and  
593 context. In particular, the results suggest that a short intersection seems to reduce the risk of  
594 losing one's alignment, thereby increasing participants' sense of safety. It also appears from the  
595 findings of this study that the different noises one hears at an intersection can have both a positive  
596 and negative effect on the sense of safety that blind or visually impaired persons experience. In  
597 fact, automobile sounds can help ensure a better alignment before and during crossing, but too

598 many noises can lead to confusion. It was demonstrated that ambient traffic noise buries the  
599 sounds emitted by APS [2], making it even more difficult for individuals to cross a crosswalk. To  
600 offset this issue, France installed devices that automatically adjust their volume based on ambient  
601 noise [32]. Finally, some participants reported fearing right turns on red. The Institute of  
602 Transportation Engineers (ITE) is likely to recommend against this practice [33].

603

#### 604 *Future Studies*

605 We identified several potential future studies in collaboration with the monitoring committee. To  
606 improve our understanding of how APS work across the world, a rigorous review of scientific  
607 and grey literature is required. In addition to the present study, an evaluation of the level of safety  
608 (objective safety) of each of the three configurations was carried out via experiments in real-use  
609 settings. A Global Positioning System (GPS) was used to document participants' trajectories.  
610 These findings will be published in another research article. In light of the importance that project  
611 participants gave to the presence of pedestrian pushbuttons, user tests could be conducted for  
612 other alternatives, such as automatic signals or APS remote controls or applications on smart  
613 devices that would allow the users to activate the APS without needing to search for the  
614 pushbutton.

615

#### 616 *Study Limitations*

617 While the measuring instruments that were used and developed with the monitoring committee  
618 were not scientifically validated, these instruments captured the subjective views of participants.  
619 Participants were few and mostly lived in the Quebec City area. More diversity among  
620 participants would have allowed us to see if the sense of safety is the same in areas where  
621 concurrent pedestrian phasing has been better established. Furthermore, again due to the small

622 sample pool, it was impossible to perform analyses for each of the variables documented by the  
623 survey comparing participants with functional residual sight to those without. Unfortunately, a  
624 detailed description of visual impairments (e.g., characteristics such as visual acuity and visual  
625 field) was not collected. However, considering the small sample pool, we would not have been  
626 able to conduct analyses documenting the impact of these difficulties on the participants' sense of  
627 safety, preferences, and expectations. Although generalizability is limited because the study was  
628 conducted in Quebec City, the unique experimental context of this area, including the use of the  
629 rather unique exclusive phasing with non-directional APS configuration, provides valuable  
630 contribution for documentation of advantages and disadvantages of different types of pedestrian  
631 phasing with APS configurations from the perspective of blind or visually impaired persons. This  
632 study demonstrates the complexity of evaluating these types of scenarios in that several factors  
633 must be considered in order to achieve a comprehensive overview. Given the large number of  
634 parameters and variables that need to be considered within the scope of this project, a larger  
635 sample pool would have allowed for further in-depth analysis.

636

## 637 **Conclusion**

638 In this study, the perceptions of blind or visually impaired persons on three different types of  
639 pedestrian phasing with APS configurations were documented, and more specifically, the effects  
640 these configurations have on the sense of safety of these individuals. A wide range of findings  
641 and statements were recorded using a survey (n=32) and walk-along interviews (n=11). Due to  
642 the size of the sample, the results are not definitive, but address a gap in knowledge with respect  
643 to APS paired with traffic signals and perceived safety by their target users. The survey results  
644 suggested that directional APS were believed to be safer. Exclusive pedestrian phases were  
645 consistently thought to be safer than concurrent phasing. The interviews provided rich findings

646 that allowed for further insight than the survey. Overall, a feeling that it is more important to have  
647 APS at intersections than having a uniform system. Participants had different opinions on some  
648 of the key items questioned, such as the concurrent phasing. This is certainly due to several  
649 factors that can influence the perceptions of blind or visually impaired persons, such as sight  
650 profile characteristics, in particular presence or absence of a residual sight, travel habits, such as  
651 comfort in moving in unfamiliar environments, and personal experiences, good or bad, with  
652 pedestrian crossings. As such, it is not possible to establish a formal consensus regarding many of  
653 the issues discussed. The findings from this project will contribute to the corpus of knowledge  
654 and development of expertise on accessibility for individuals living with disabilities. Specifically,  
655 this study may have practical implications on the design of intersections with APS, the selection  
656 of a type of APS based on intersection characteristics, the training of blind or visually impaired  
657 pedestrians by orientation and mobility specialists, and the importance of educating road users  
658 about blind or visually impaired pedestrians.

659

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663

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665

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760  
761

**Table 1.** Characteristics of participant commutes (n=32)

<b>Characteristics of commutes</b>	<b>n</b>	<b>%</b>
<b>Assistive technology used during commutes</b>		
Cane (always or occasionally)	25	78.0
Telescope/magnifying glass	7	21.9
Electronic assistance (e.g.: Breeze, smart phone)	6	18.8
Guide dog	4	12.5
Corrective glasses or contacts	1	3.0
Nothing	3	9.4
<b>Use of residual sight when getting around outdoors</b>		
Yes, at all times	18	56.3
Yes, most of the time	4	12.5
Yes, but only under specific circumstances	1	3.0
No, never	2	6.3
No, I have no residual sight	7	21.9
<b>Outdoor travel frequency</b>		
At least once a day	22	68.8
At least once a week	9	28.1
At least once a month	1	3.1
<b>Help/support required</b>		
Yes, at all times	1	3.0
Yes, each time I cross an intersection	0	0.0
Yes, when crossing intersections I am not familiar with	10	31.3
Yes, when crossing challenging intersections	10	31.3
No, never	11	34.4
<b>Travel frequency in unfamiliar environments</b>		
At least once a day	4	12.5
At least once a week	8	25.0
At least once a month	5	15.6
Less than once a month	7	21.9
At least once per season	4	12.5
Never	4	12.5

762

763 **Table 2.** Characteristics of non-audible and audible pedestrian signals used by participants  
 764 (n=32)  
 765

Characteristics of use	Non-audible signal		Audible signal	
	n	%	n	%
<b>Training received</b>				
Yes	27	84.4	24	75.0
No	5	15.6	8	25.0
<b>Frequency of use</b>				
At least once a day	9	28.0	11	34.4
At least once a week	10	31.3	16	50.0
At least once a month	8	25.0	5	15.6
Less than once a month	3	9.4	0	0.0
Never	2	6.3	0	0.0

766

767 **Table 3.** Use of different pedestrian phasing with audible pedestrian signal configurations by  
 768 participants (n=32)  
 769

<b>Use of different pedestrian phasing with audible pedestrian signal configurations</b>	<b>n</b>	<b>%</b>
<b>Exclusive phasing/Non-directional audible pedestrian signals</b>		
Yes	31	96.9
No	1	3.1
<b>Exclusive phasing/Directional audible pedestrian signals</b>		
Yes	22	68.8
No	10	31.2
<b>Concurrent phasing/Directional audible pedestrian signals</b>		
Yes	19	59.4
No	13	40.6

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771 **Table 4.** Characteristics of participant sight profiles (n=11)  
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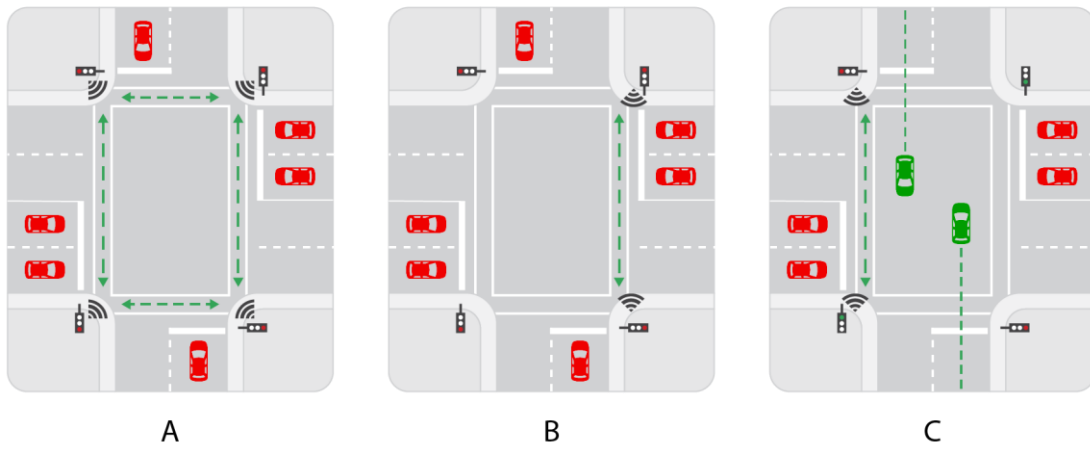
<b>Characteristics of sight profiles</b>	<b>n</b>	<b>%</b>
<b>Start of difficulties/impairment</b>		
Since birth	8	72.7
Acquired	3	27.3
<b>Use of residual sight</b>		
Yes, at all times	4	36.3
Yes, most of the time	2	18.2
Yes, but only under specific circumstances	2	18.2
No, I have no residual sight	2	18.2
No, never	1	9.1
<b>Assistive technology used during travel</b>		
Cane (always or occasionally)	9	81.8
Electronic assistance (e.g.: talking GPS, smart phone)	3	27.3
Guide dog	1	9.1
Nothing	1	9.1

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774 **Table 5.** Main themes discussed during interviews  
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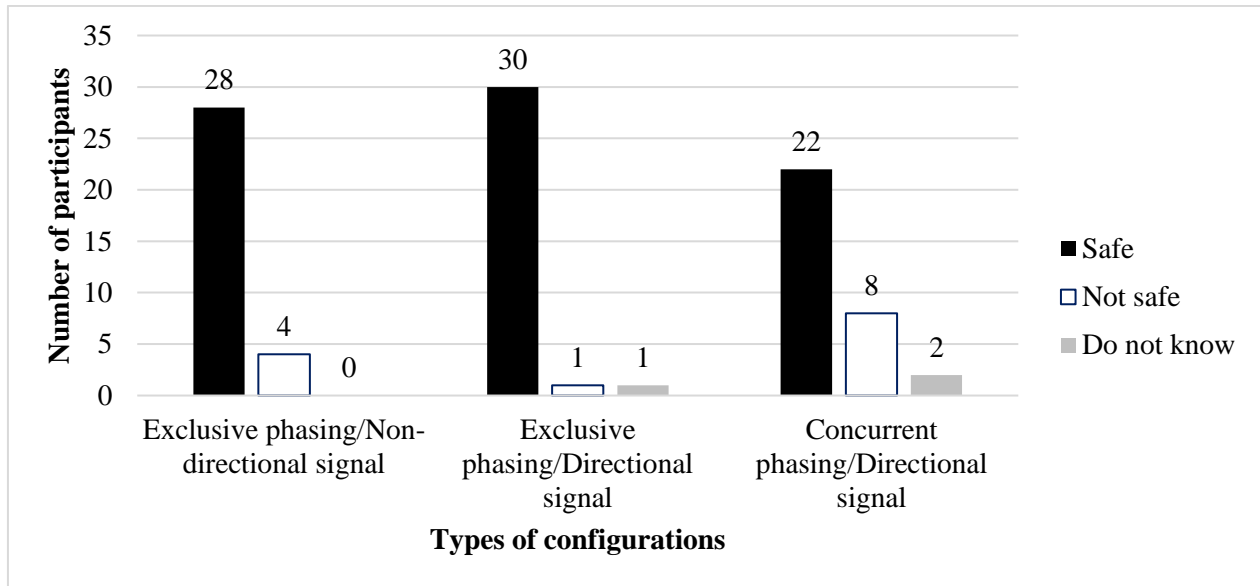
Themes and sub-themes	Number of participants (n=11)	Number of written transcriptions
<b>Expectations regarding pedestrian phasing with audible pedestrian signals</b>		
Uniformity	9	16
Number of intersections equipped with audible pedestrian signals	8	12
Type of configuration based on the characteristics of the intersection	2	3
Pushbutton for pedestrian signals and audible pedestrian signals	2	2
Audible pedestrian signal volume	1	2
Road user awareness	1	1
<b>Positive and negative aspects of each of the three configurations, exclusive phasing and directional audible pedestrian signals</b>		
Concurrent phasing with directional audible pedestrian signals	11	26
Exclusive phasing with non-directional audible pedestrian signals	10	22
Directional audible pedestrian signals	8	14
Exclusive phasing	5	10
Exclusive phasing with directional audible pedestrian signals	5	8
<b>Factors influencing one's sense of safety</b>		
Characteristics of intersections	11	38
Noise	11	37
External conditions	11	23
Traffic	10	17
Knowledge of intersections	10	14
Road sign adherence	6	12
Stress	6	7
Presence of unexpected elements	3	3

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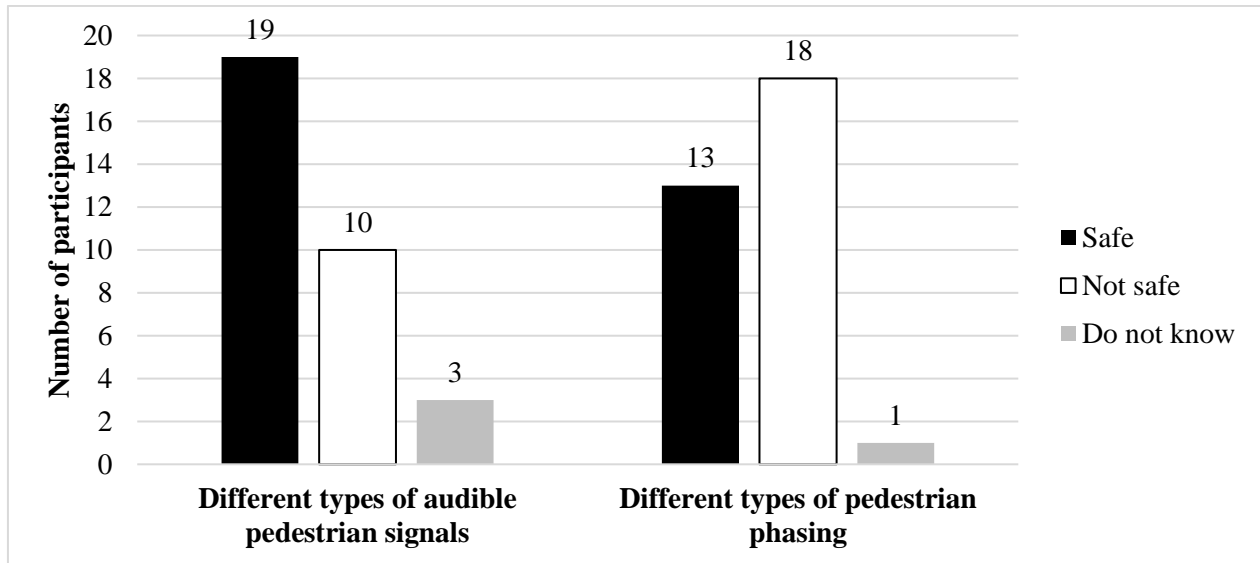
777  
 778 **Figure 1.** The three different types of pedestrian phasing with audible pedestrian signal  
 779 configurations found in Quebec City, Canada: A) exclusive phasing with non-directional audible  
 780 pedestrian signals; B) exclusive phasing with directional audible pedestrian signals; and C)  
 781 concurrent phasing with directional audible pedestrian signals.  
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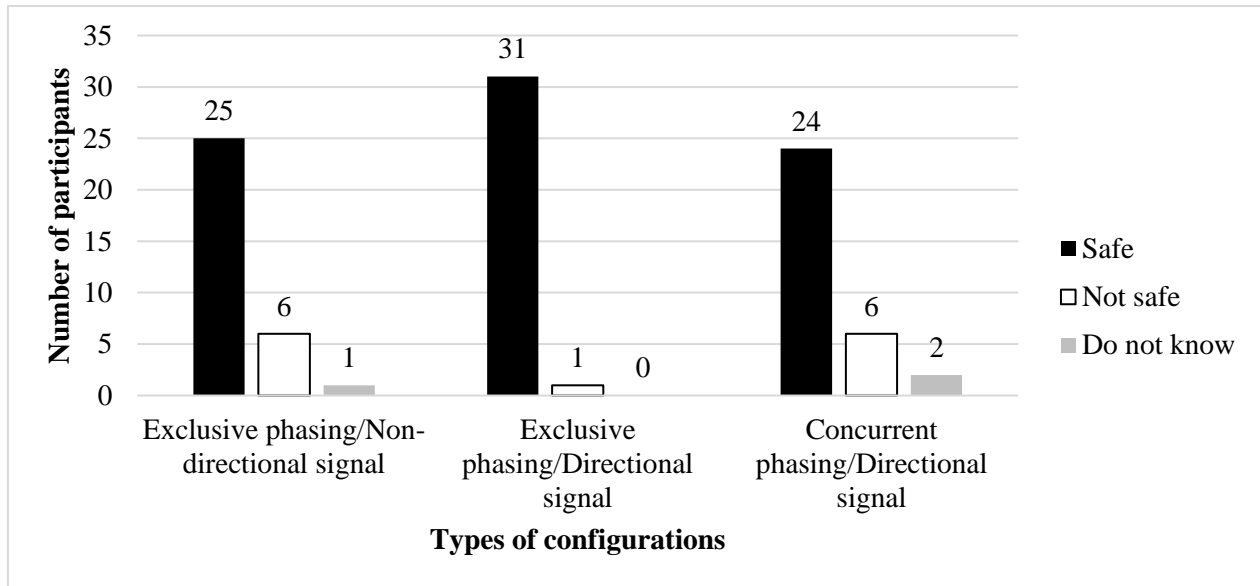
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**Figure 2.** The sense of safety expressed by participants regarding the different pedestrian phasing with audible pedestrian signal configurations (n=32)



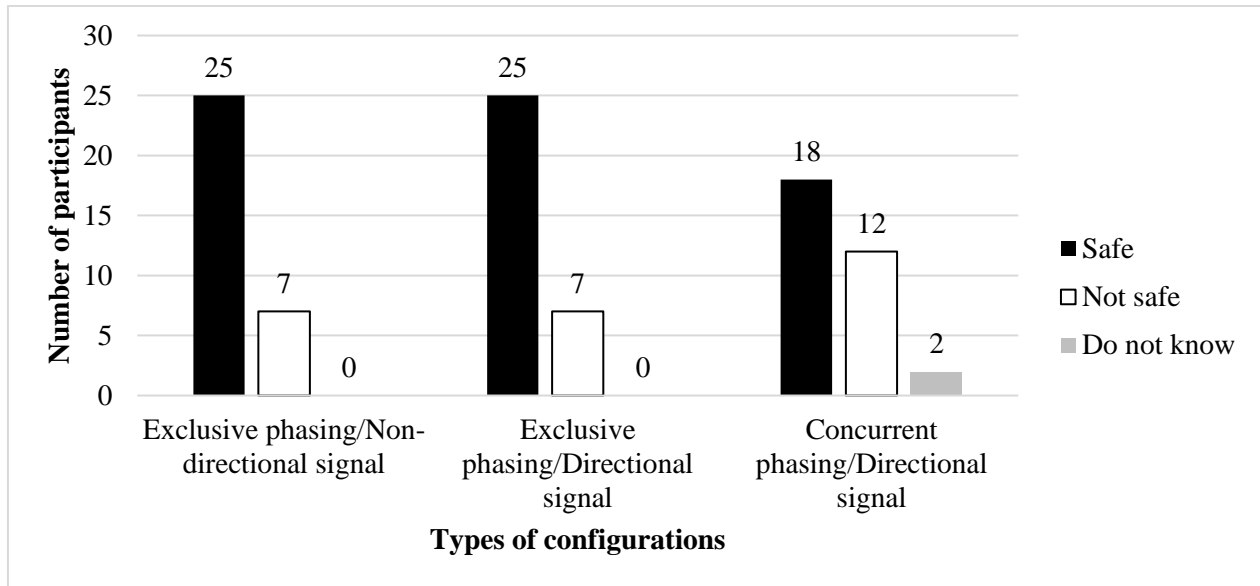
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**Figure 3.** Participants' sense of safety when faced with different types of audible pedestrian signals and pedestrian phasing (n=32)



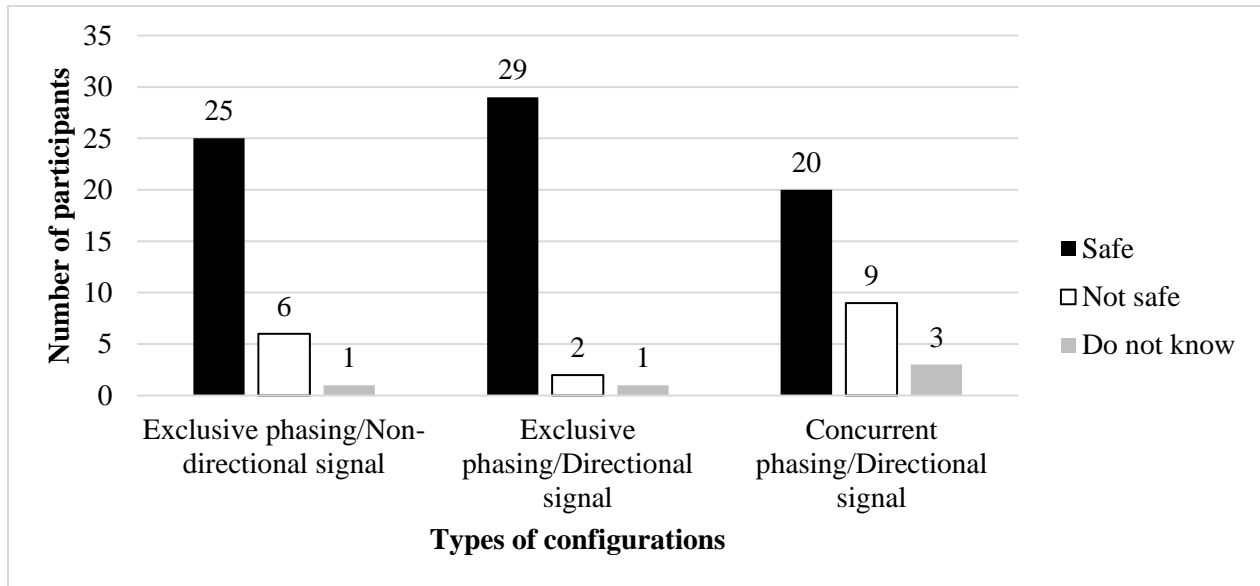
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**Figure 4.** Participants' sense of safety when crossing intersections with one lane in each direction during light traffic (n=32)



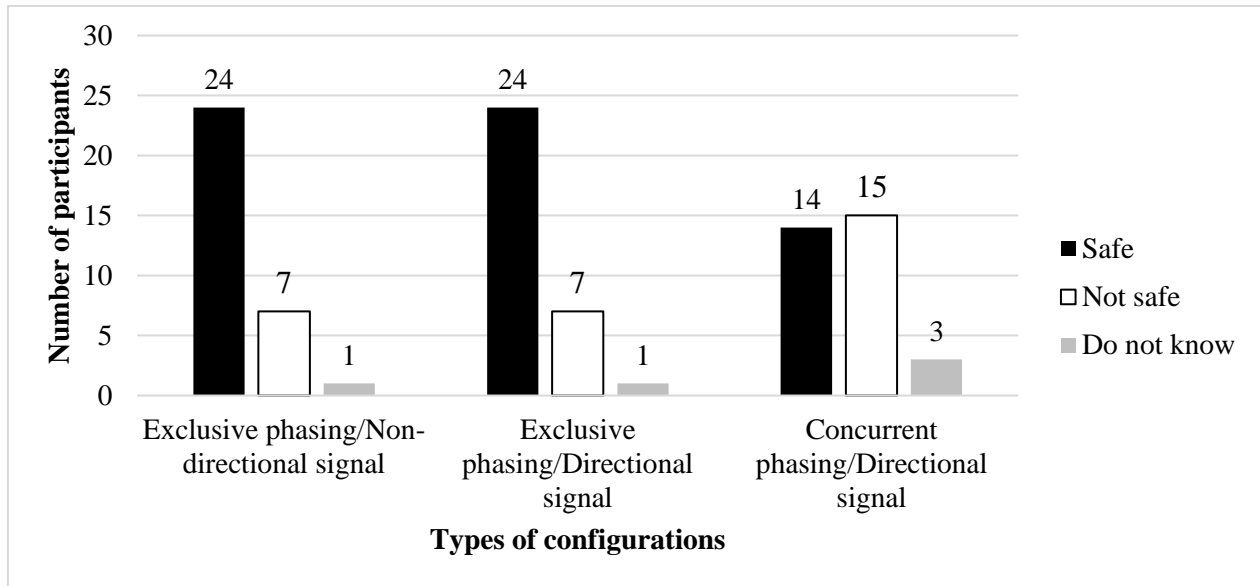
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**Figure 5.** Participants' sense of safety when crossing intersections with one lane in each direction during heavy traffic (n=32)



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**Figure 6.** Participants' sense of safety when crossing an intersection with two lanes in each direction during light traffic (n=32)



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**Figure 7.** Participants' sense of safety when crossing an intersection with two lanes in each direction during heavy traffic (n=32)