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On the complexity of finishing a crossing on time: Elderly pedestrians, timing and cycling infrastructure

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A B S T R A C T

Aging population and reductions in car use by seniors have the potential to increase active transportation rates. While there are associated health benefits to this potential shift, there are also higher risks for elderly pedestrian injuries, especially at street crossings. This naturalistic study compares street crossing behaviors of different population age groups in large Québec cities through observational data, situational characteristics and environmental characteristics of location. We assess if observed crossings could be completed safely within the allocated time. Street crossing observations on 2073 pedestrians was gathered at 135 signalized crossings during a four-month period in the summer of 2013. Mixed effect logit models are used to assess the individual, contextual, behavioral and environmental correlates of street crossing ending. Differences in age groups and other correlates are assessed for their association with the type of street crossing ending (on red light, on red hand or on both). In multivariate models, older age did not have an impact on finishing crossing on time, but many factors associated with older age were: having a walking aid, hesitating, and slowing down mid-crossing. Longer "white man silhouette" timing was also associated with reduced odds ratio of failing to finish crossing on time. The presence of cycling infrastructure increased those odds. Without walking, many elders will experience decreasing level of access. In neighborhoods with high concentrations of elderly populations, providing shorten crossing distance or longer crossing timing, may increase the convenience of walking for elderly populations. Longer signal timing may also be warranted in locations where cycling infrastructures were added to account for the increased level of difficulty.

1. Aging pedestrians: a growing road safety issue

Many challenges come with population aging in North American cities. Road safety for senior pedestrians is one of them: as they lose the ability to drive, these residents still must fulfill basic needs. This precarious equilibrium between autonomy (to be able to do things by themselves) and fear of the street environment should be part of planners' concerns if increased active transportation is an objective.

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Unfortunately, aging pedestrians have been overrepresented in crashes; up to 50% of all injured pedestrians in OECD countries are seniors (International Transport Forum, 2012). They are also typically more severely injured in road crashes (Siram et al., 2011) and stay longer in hospitals (3–5 times more than injured pedestrians aged between 15 and 64 years old) (Abou-Raya and Elmeguid, 2009; Loo and Tsui, 2009). These preoccupying observations have led many researchers to study risk factors associated with this vulnerable population group. Results illustrate that the seniors' individual characteristics (cognitive and physical capacities), the road environment and the interactions between the two explain their greater road-related risk.

Through the process of aging, many changes in cognitive capabilities have been observed. These may alter senior's decision-making process when crossing the street, a major task in many walking journey. For example, loss of concentration or other cognitive assets may alter their ability to choose a safe gap in traffic (Oxley et al., 2005; Dommes and Cavallo, 2011), to overestimate incoming vehicle speed (Lobjois and Cavallo, 2009) or their own walking speed when they do choose to cross (Holland and Hill, 2010).

Other physical impairments such as loss of vision, hearing or muscle and articulation pain will also contribute to walking's arduousness (Huguenin-Richard et al., 2014). Such situations may make elderly pedestrians at best uncomfortable to travel by walking, and at worst, confined to their immediate environment without the ability to access neighborhood destinations. As a result of this unease, senior pedestrians may divert route and choose to cross more often at signalized intersections deemed safer. Nevertheless, there are more seniors injured at intersections than any other pedestrian age group. For example, an estimation based on crash data in Montreal, Canada for a seven-year period (2003–2009) showed that for seniors (65 years old and over), 85% of injuries, including fatalities, occurred at signalized intersections, while this share was of 60% for all pedestrians, regardless of age group (Cloutier et al., 2014; Auger et al., 2015).

Beyond individual variables, characteristics of streets and intersections where crossing takes place have also been studied for their influence on pedestrian crashes, but also on pedestrian behaviors, including those of seniors. Characteristics such as crossing width or crossing time have been related to higher risk of injury for senior pedestrians (Gates et al., 2006; Leden et al., 2006; Dumbaugh and Rae, 2009; Romero-Ortuno et al., 2010; Rastogi et al., 2012). Other results are not as conclusive. Parked vehicle at the curb had contradictory effects: while Tom and Granié (2011) show that pedestrians display more cautious crossing behavior when there are no parked vehicles nearby, Yannis et al. (2013) found that the presence of illegally parked vehicles at mid-block crossing makes the pedestrians more careful because of reduce line of sight. Similarly, the number of pedestrian crossing simultaneously has been hypothesized as an important factor in red light violation, but empirical results vary. Authors have found both positive relationships (i.e. more pedestrians crossing together was associated with more red light violation) (Rosenbloom, 2009; Brosseau et al., 2013) and negative ones (Ren et al., 2011).

Not all street features have been studied in details. Because many cities are currently developing cycling infrastructures, understanding how streets designed for use by multiple modes can influence street crossings for pedestrians will help identify how their safety and comfort can be improved. While there is considerable growth in the presence of on street cycling paths, literature on their impacts is lacking. A few reasonable hypotheses can nonetheless be made. Where cycling infrastructure is added, intersections become more complex because various incoming vehicles arrive at different speeds, with different trajectories. Oncoming traffic from multiple directions may be more of an issue for older pedestrians with slower reflexes. Cities need to know how to adapt intersections where a cycling infrastructure has been added.

As the existing literature shows, there are a number of issues for which data is inconclusive and others for which there is little to no research. A better understanding of the interaction between pedestrians and the crossing environment is needed for planners to identify "best practices" and create environments that can be used safely and pleasantly by pedestrians of all ages. The purpose of this paper is to fill this gap by assessing if crossing can be completed safely in the allocated time by adults and senior pedestrians. Our main objective is to determine the individual, situational, behavioral and environmental correlates of finishing a crossing when signals already indicate that pedestrians should no longer be on the street (i.e. red light, red hand or both). We use these three outcomes to cover the variety of assessed signalized pedestrian crossing intersections in multiple cities. While a pedestrian still on the street after a light has turned red is not automatically at high risk of being run over by cars, our logic is that such situation can be indicative of unfavorable environments for elderly pedestrians to walk in, creating insecurities, stress and discomfort, and ultimately reducing the likelihood of walking on a frequent basis.

2. Observations of unsafe street crossing: a naturalistic experiment

In order to assess unsafe street crossing behavior as an outcome, information on individual, behavioral, situational (at the time of crossing) and environmental correlates must be observed. The organization of these concepts in our research is presented in Fig. 1. As seen in the previous section, existing research have identified some of these correlates, but seldom studied them jointly using a naturalistic research design. We expect that four groups of factors will be associated with the likelihood of not completing a crossing on time. To be clear, this study does not assess if a pedestrian chose to cross, but rather if observed crossing were conducted safely while respecting the law.

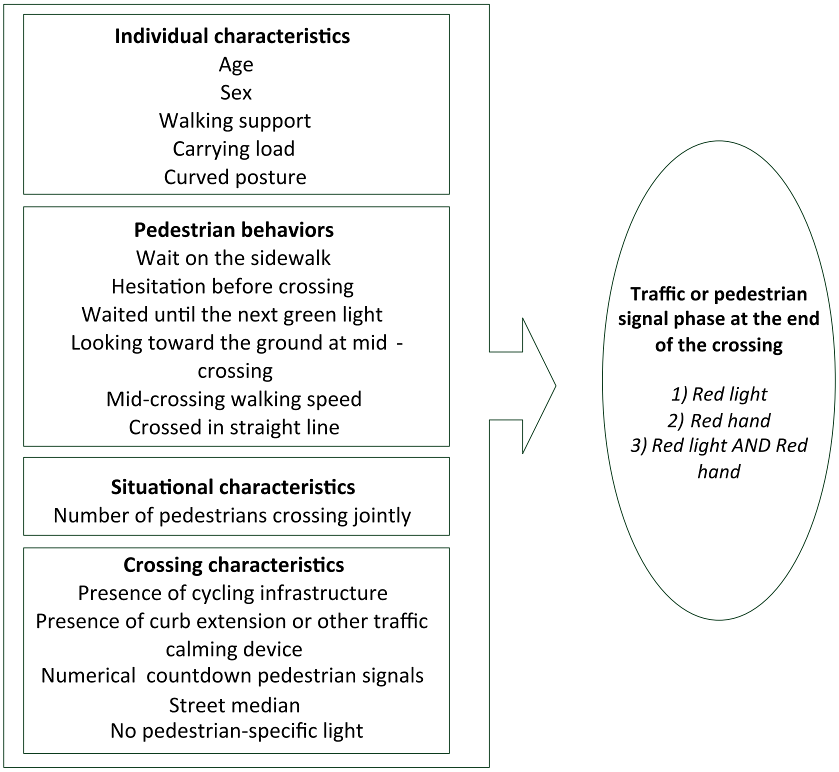

Fig. 1. Conceptual model.

3. Methods

3.1. Site selection

Because the field data collection was part of a research project on elderly road safety issues, observation sites were selected to represent a variety of street crossing situations in areas where (1) higher proportions of elderly population reside according to the 2006 Canadian census or where major elderly residential complexes are located; or (2) nearby "points of interest" for seniors: drugstores, banks, medical clinics, coffee shops, hair dressers, etc. (Lord et al., 2011). Nine trained observers were given a list of initial intersections but were allowed to move to other more relevant locations nearby if few pedestrians were crossing. Observations were recorded between June and October 2013. Observers worked in groups of three to ensure proper recording of crossing behaviors and other situational and environmental characteristics. Observers were posted on the sidewalk towards which pedestrians were heading. Street crossings were typically recorded between 8 and 10 AM and between 2 and 4 PM.

3.2. Observation grids for selected crossing sites

Before recording street crossing observations, each sampled street crossing was documented for road environment features. The *road environment grid* comprised six elements of which four are used in this analysis: presence of traffic calming device (mostly curb extensions), presence of cycling infrastructure, presence of street median, signal phasing for pedestrian when present (number of second for "white man silhouette" phase) and an indicator variable for the absence of pedestrian-specific light signals. Because traffic light phasing is based on a standard walking speed, we did not included road width in our database. The engineering manual produced by Transport Québec (the provincial government of the surveyed cities) suggests to calculate signal phasing for pedestrians by multiplying road width by walking speed with a range between 0.9 and 1.3 m per second, the usual speed interval applied in surveyed cities (MTQ, 2011 p.55). The document however provides no guidance on circumstances where slower walking speeds should be applied and officials sometimes increase phasing time based on residents' requests. Longer crossing times are thus found on wider streets. Variables on the presence and type of traffic lights (for vehicles and pedestrians) where used to exclude cases. Only street crossings with a light signal were retained for the analysis (n = 135, 44.4% of the original dataset). Of these, 117 were situated on the Island of Montreal, respectively 3 and 8 were situated in the suburban municipalities of Laval and Longueuil, and respectively 3 and 4 were situated in the cities of Gatineau and Québec. Table 1 presents road network characteristics for the studied intersections and crossings. More than 40% percent of observations were made on arterial roads. While fewer intersections had cycling infrastructure, a higher average number of observations were carried out in these sites.

3.3. Observation grids for crossing behaviors

Observation of crossings was conducted using an observation grid adapted from Tom & Granié (2011) that comprised 11 behavioral categories and four situational variables. Table 2 includes nine situational and behavioral categories retained for the present study. Situaltional categories include those related to the traffic light phase: which phase at the beginning of the crossing, and which one at the end, our outcomes of interest.

Observers also recorded two demographic (age and sex) and several situational variables. Age was approximated in five different categories: 0–12; 13–19; 20–64; 65–79; and 80+ years old and only the three last categories were retained for this analysis (another project using the same approach and data collection period was based on children's street crossing behavior). Three situational variables representing physical difficulties while walking were recorded for each observed pedestrian: if he/she was carrying a load (bag, suitcase, dog, stroller, carrier bag or other objects), used a walking aid (e.g. cane, white

Table 1
Street crossing characteristics and percentage of outcomes within crossings by characteristics.

Characteristics	Number of street crossing sites[a]	(% of 135 crossing sites)[a]	Mean number of observation	Finished crossing on red light (%)[b]	Finished crossing on red hand (%)[b]	Finished crossing on red light or hand (%)[b]
Arterial road	51	41	11.1	12.2	17.3	21.5
Cycling infrastructure	15	11.1	19.3	38.1	36.1	48.5
Traffic calming device	15	11.1	9.7	31.1	13.3	30
Street median	14	10.4	8.6	14	24.8	29
No pedestrian-specific light	44	32.6	14.1	14.7	Not available[c]	16.6

[a] Values may not add up to total due to overlap.
[b] Share of observations with outcomes within the categories.
[c] Red hand signal only exists in crossings with a pedestrian light.

Table 2
Retained behavioral categories from the observation grid. Sources: Adapted from Tom and Granié (2011).

Categories	Possible answers
Pedestrian waiting zone until crossing	On the sidewalk
	On the pavement
	On the central island
Pedestrian wait until the next green light	Yes/No
Hesitation before crossing	Yes/No
Total number of pedestrian crossing jointly	None
	2 people
	3–5 people
	6 people or more
Pedestrian's walking speed at the beginning of the crossing	Stops
	Slows down
	Accelerate
	Regular walking speed
Pedestrian's walking speed at mid-crossing	Stops
	Slows down
	Accelerate
	Regular walking speed
Head movement while crossing (mid-crossing)	Towards the traffic light
NOTE: more than one answer possible	Towards the moving vehicle
	Towards other pedestrians
	Towards the ground
	Straight ahead
Type of crossing	Straight line
	Diagonal
State of the traffic light at the end of the pedestrian's crossing	Amber light
NOTE: more than one answer possible	Red light[a]
	Green Light
	White pedestrian silhouette
	Blinking red hand
	Constant red hand[a]

[a] Used as outcomes in the analyses.

cane, crutches, walker and scooter) or was curved forward while walking (Huguenin-Richard et al., 2014). Three or four-wheel scooters where rarely observed, but still included in the analysis as long as their behavior was one of a "pedestrian" (e.g. riding on the sidewalk). Other contextual factors included the number of pedestrians crossing at the same time as the observed person.

3.4. Statistical analyses

A total of 2073 observations at 135 different crossing sites are used in our analysis. Three outcomes are studied: ending the crossing (1) on a red light, (2) on a constant red hand signal (as opposed to a blinking red hand), (3) or either of them. All three outcomes are violations of road safety rules. This type of exclusive pedestrian phasing is put in place to ensure a better protection for pedestrians during crossing but is neither mandatory nor widespread in studied cities.

First, a descriptive analysis of observed street crossings is presented and provides an exploration of differences between age groups using Chi Square tests of statistical significance for binary and categorical variables, and one-way ANOVA for continuous variables. Second, a series of three multilevel mixed-effects logit models enable the assessment of the correlates of our outcome variables. Because multiple street crossing observations were conducted on each crossing site (observations were not independent from each other), a variable for observation sites was used as random intercept effect in the models. Multivariate analyses were conducted using STATA 14 melogit command. Mean-variance adaptive Gauss-Hermite quadrature was used as integration method. Observation sites contained a minimum of 1 observation, a mean of 15.4 observations and a maximum of 198 observations. After verifying for multicollinearity using Crammer's V (for binary and categorical variables) and Gamma (when age was correlated with others), and testing several combinations of variables in models based on hypothesized relationships, we provide parsimonious models that exclude 5 studied variables: crossing in a straight line (correlated with multiple variables), waiting until the next green light (category of interest was too small and correlated with tempo), carrying a load (no effect and no changes in model fit) as well as looking towards the ground while crossing and having a curved posture (correlated with age).

4. Results

4.1. Sample description

Table 3 presents the observed pedestrians of different age for each individual, behavioral, situational and environmental characteristic. As age increases, the sample comprises significantly more women, suggesting that older women tend to walk more than men, at least in the observed sample. Older age groups, as expected, make increasing use of walking aids: users of canes and crutches increase from 8.5% for those aged 65 to 79, to 24.2% for those aged 80 and older. Amongst the 80 and older, 8% use walkers, and 2.2% use scooters. In addition, the older observed pedestrians are, the greater the share of pedestrians carrying loads and adopting a curved posture. A significantly higher percentage of the oldest observed pedestrians crossed in straight line, waited until the next green light to begin crossing and looked towards the ground while crossing. There was no statistical difference in hesitating before crossing, or in remaining on sidewalk before crossing. We also observed significant age differences in crossing tempo at mid-crossing. Younger individuals accelerate more often, while in general, few people stop or slowed down during the crossing. As for situational characteristics, there are generally fewer elderly pedestrians crossing alone, but younger pedestrians are seen more frequently crossing as part of large groups. In terms of road crossing environments, 9–14% of observed street crossings were carried out in locations with cycling infrastructures (those aged 65–79 were found significantly more frequently in areas with cycling infrastructures). Street median was not significant and nearly 30% of observed street crossings were carried out in locations with no pedestrian-specific lights, with significantly lower values for older pedestrians. No differences between groups were found for traffic calming. Finally, the only outcome that showed significant bivariate statistical difference between age group was ending crossing on a red light and a red hand at the same time.

4.2. Crossing environments timing

An ANOVA analysis of the only continuous environmental variable related to street crossings is presented in Table 4. While both older age groups crossed in location with a higher mean number of seconds for the numerical-countdown pedestrian signals, the younger age group is significantly associated with a shorter time span (ANOVA: $df = 2$; $F = 14.04$: $p < 0.001$).

4.3. Multivariate estimations of ending a crossing on red light, red hand or both

Table 5 presents the results of three multivariate mixed logit models for end of crossing situations. A positive odds ratio means the variable increased the odds ratio of NOT finishing the crossing on time. Compared with the reference category of adults aged from 20 to 64, those aged 65 to 79 were more likely to end crossing on a red hand or on a phase where either red light and red hand were on. The oldest pedestrian group was no more likely than the reference category to have this behavior but women were less likely than men to end up in the last explored situations. Strong positive relationships were found with

Table 3
Descriptive statistics.

Age categories	20–64 year-old	65–79 year-old	80+ year-old	Total	Chi Square test significance
Observations (%)	N = 424 (20.5)	N = 1335 (64.4)	N = 314 (15.1)	N = 2073 (100)	
Individual characteristics					
Women	51.7	59.9	63.7	58.8	0.002
Walking aid	98.1	88.5	65.6	87.0	0.000
None					
Cane/crutches/white cane	1.4	8.5	24.2	9.5	
Walker	0.5	2.0	8.0	2.6	
3 or 4 wheel scooter	0.0	1.1	2.2	1.0	
Carrying load	7.6	9.8	13.1	9.8	0.046
Curved posture	0.5	2.9	21.7	5.3	0.000
Situational characteristics					
Number of pedestrians crossing jointly					0.007
Alone	53.8	47.5	49.0	49.0	
2 people	12.5	16.1	20.7	16.1	
3–5 people	25.7	30.6	24.8	28.7	
6 people or more	8.0	5.8	5.4	6.2	
Behavior characteristics					
Crossed in straight line (Y/N)	78.3	79.8	86.6	80.5	0.010
On sidewalk until crossing (Y/N)	63.4	65.8	65.6	65.3	0.675
Hesitation before crossing (Y/N)	11.3	10.6	13.1	11.1	0.442
Waited until next green light (Y/N)	1.2	1.7	3.5	1.8	0.047
Looking towards the ground while crossing (Y/N)	23.1	33.3	47.1	33.3	0.000
Mid-crossing tempo					0.001
Stopped	2.1	1.4	1.9	1.6	
Slowed down	1.4	2.0	2.9	2.0	
Accelerates	12.7	6.2	6.4	7.6	
Constant speed	83.7	90.5	88.9	88.9	
Crossing environment characteristics					
Cycling infrastructure (Y/N)	9.0	14.2	12.4	12.8	0.020
Traffic calming (Y/N)	5.9	7.3	6.4	6.9	0.583
Street median (Y/N)	7.6	5.3	5.2	5.8	0.203
No pedestrian-specific light (1 = no)	40.09	26.50	27.04	29.39	0.000
Outcomes: Crossing ended on					
Red light	18.4	17.53	18.15	17.8	0.906
Red hand	20.75	17.3	21.66	18.67	0.095
Red light and red hand	28.3	22.62	26.11	24.31	0.043

Table 4
Numerical countdown pedestrian signals (seconds) means and ANOVA test.

Age categories	Mean (s)	Standard error	95% Confidence interval lower	95% Confidence interval upper	ANOVA test significance
20–64 year-old	11.1	0.57	10.0	12.2	$p < 0.001$
65–79 year-old	15.2	0.41	14.4	16.0	
80+ year-old	15.2	0.83	13.6	16.9	

respect to the use of walking supports. Using a cane, white cane or crutches made users nearly twice as likely to end a crossing late. The use of a walker increased the odds by between 2.8 and 4.5 times, depending on the outcome used. As scooters provide people with the ability to travel faster, using these devices reduced the odds of finishing late, but this variable was only significant in the last model. As observations of persons using scooters perfectly predicted the outcome of finishing on a red hand signal, they were excluded from the analysis. This explains the loss of 21 observations in the second model.

With respect to situational aspects, a greater number of pedestrian crossing simultaneously had a negative association with all three outcomes: pedestrians who crossed as part of larger groups were more likely to finish their crossing on time. This result confirms a protective effect in the number of pedestrians, elsewhere referred to as the "safety in number" hypothesis as applied to cyclists (Jacobsen, 2003; Jacobsen et al., 2015) albeit through different mechanisms.

As for behavioral characteristics, waiting on sidewalk until crossing revealed a negative relationship with the outcomes and hesitating before crossing was positively associated. While the latter is plausible and supportive of the idea that limited crossing time cannot be wasted on hesitation, it shows how even slower individual reaction to street lights can limit the ability to cross during the allocated time. Accelerating at mid-crossing was significantly and strongly associated with increased

Table 5
Mixed logit models of street crossing ending.[1]

	Finished crossing on red light	Finished crossing on red hand	Finished crossing on red light or hand
Individual characteristics			
Age (years)			
20–64 [Ref.]			
65–79	0.792	0.625*	0.689*
80+	0.787	0.91	0.867
Women	0.765	0.833	0.718**
Walking support			
None [Ref.]			
Cane/crutches/white cane	1.738*	1.876**	1.684*
Walker	4.452***	2.883**	2.796**
3 or 4 wheel scooter	0.175	1	0.099*
Situational characteristics			
Number of pedestrians crossing jointly			
Alone [Ref.]			
2 people	0.545**	0.606*	0.501***
3–5 people	0.410***	0.354***	0.320***
6 people or more	0.641	0.184***	0.231***
Behavior characteristics			
On sidewalk until crossing	0.466***	0.394***	0.366***
Hesitation before crossing	1.827**	1.851**	2.086***
Mid-crossing tempo			
Stopped	2.491*	1.097	2.629*
Slowed down	3.339**	1.157	2.218*
Constant speed [Ref.]			
Accelerates	4.758***	3.888***	5.375***
Crossing environment characteristics			
Cycling infrastructure	6.441***	13.742***	4.010***
Curb extensions or street calming	1.87	0.282*	0.731
Street median	0.376*	0.985	0.537
No pedestrian-specific light (1 = no)	0.607		0.244***
Numerical-countdown pedestrian signals (seconds)	0.969**	1.014	0.962***
Constant	0.397**	0.195***	1.824
Site constant	0.521	2.51	0.697
Intraclass correlation	0.14	0.43	0.18
Observations	2073	2052	2073
Crossing environments	135	135	135
Chi square	199.6	161.2	246.5
Significance	0.000	0.000	0.000
AIC	1528.7	1578.3	1849

[1] Values are odds ratio; stars denote significance level.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

odds of finishing a crossing late in all models, suggesting capable individual's awareness that required crossing time is longer than allocated time. As compared with the reference category of maintaining a constant speed during the crossing, slowing down or stopping did increase the odds of finishing late, but not as importantly as those accelerating to finish the crossing. However, the observed effect might occur because the acceleration of pace is related to a light phase change during crossing. Such information was not available in our dataset. Finally, three behavioral variables were not significant in any of the tested models and were therefore not included in the final models: crossing in a straight line (as opposed to diagonally), waiting until the next green light and looking towards the ground while crossing.

Of all the variables in the models, the presence of cycling infrastructure has the strongest odds of being associated with finishing a crossing late. We can imagine that this type of street configuration requires additional cognitive effort as bicycles arrive in a different lane and at different speeds and sometimes from two directions. Furthermore, cycling infrastructures tend to be a more recent feature of street design at most intersections in the studied cities. All road users must adapt to this influx of cyclists on roads and planners may need to revise allocated crossing times where these infrastructures are implemented. While one of the outcomes (finishing on a red hand) was negatively and strongly associated with street calming features, the lauded qualities of these design to improve safety does not emerge as a systematic correlate of finishing a crossing on time for all outcomes. As expected, the presence of street median reduced the odds of finishing a crossing late. As the timing of the numerical countdown signals increased, the odds of finishing a crossing on the red light (and either red light or red hand) decreased, a clear sign of the importance of allocating more time to cross.

5. Discussion

Discussion of our main results is threefold. First, while we expected that elderly pedestrians would be more likely to fail crossing on time, we did not find this to be strongly supported by observations. This result is however consistent with research that found younger pedestrians to take more risks than do older pedestrians (Rosenbloom, 2003). However, we did find that many of the features that increased the odds of failing to cross during the allocated time were more frequently present in pedestrians of older age groups (hesitating, slowing down at mid-crossing or using a walking support). The study also found that aging populations wait more frequently for the next green light, do not accelerate as frequently at mid-crossing and cross in straight line more often than younger pedestrians do. They also tend to carry loads and adopt a curved posture more frequently than younger pedestrians do. These results recall what Holland and Hill (2010) found in her simulation experiment: "Older people are less influenced by external factors and are more determined to cross safely than younger people (p. 233)". However, all these "safe" behaviors might contribute to greater odds of finishing a street crossing on a red light or hand, depending on the road environment. Their safety depends more on stopping or stopped drivers' attention.

Second, results point to the idea that younger pedestrians accelerate more often to finish crossing (starting at mid-crossing). We can hypothesize here that people beginning crossing when the signal has been turned on for a while might want to accelerate while the light changed to a yellow or blinking red hand. Moreover, 67% of studied crossing environments had a numerical countdown display, a device that shows the number of seconds before the light will change, thereby helping pedestrians make their choice. This hypothesis is in line with results from Brosseau et al. (2013) and Wanty and Wilkie (2010), who suggested that people tend to underestimate their crossing time when a numerical countdown display is present and therefore probably either made sure to complete their crossing before the end of the countdown (by running) or finished too late, on the red light.

Despite the fact that a countdown display seems to reduce the total number of pedestrian finishing on the red light in some cases (Cambon de Lavalette et al., 2009; Brosseau et al., 2013; Lipovac et al., 2013), there is a need to examine the effects of these device more closely. As Lipovac et al. (2013) reported, published results so far do not present a consistent view concerning the impact of countdown displays. For example, a study in San Francisco shows that after the countdown display was installed, the percentage of pedestrians who started crossing the road during the blinking red pedestrian light (i.e. the "Do not Walk"), was slightly higher, even though not statistically significant (Markowitz et al., 2006). Similarly, a research by Schmitz, cited in Lipovac et al. (2013) observed that a countdown display increased the walking speed of pedestrians when crossing the road. To the opposite, Lipovac et al. (2013), in their before-and-after study, found that older pedestrians, especially those over 60 years old, made fewer mistakes after countdown displays had been installed.

The result about cycling path and the high odds of ending the crossing late is preoccupying given that many cities are striving to develop their cycling network. Particular attention needs to be given to the increasing presence of cycling infrastructures, as they make crossing more time consuming and cognitively complex for pedestrians. This is even more important since collisions between cyclists and pedestrians often result in severe injuries. Although the burden of injuries and fatalities from cyclists-vehicles collisions still needs to be addressed, Chong et al. (2010) remind readers that "in the absence of appropriate controls, increasing the opportunity for conflict between cyclists and pedestrians (through an increase in shared spaces for these users) may shift the burden of injury from cyclists to pedestrians, in particular, older pedestrians (p. 290)".When installing a cycling path on a street, planners should consider increasing visibility and allocated crossing time to account for added complexity.

Finally, while Jacobsen's studies (2003) demonstrates that motorists seem to adjust their behavior to a safer one in the presence of a larger group of pedestrians and cyclists, we found a similar effect for pedestrian behaviors with respect to ending crossings late (significant in all three models). Similar results can be found in papers looking at red-light violation: the larger the group of pedestrian crossing simultaneously, the less likely a pedestrian is to violate the traffic light (Keegan and O'Mahony, 2003; Rosenbloom, 2009; Zhuang and Wu, 2011). Further studies are needed to understand the mechanism underlying this significant relationship. Examples of questions of interest could include: Do pedestrian walking speeds tend to increase in larger group? Is the presence of other pedestrians nearby increase the odds of starting to cross earlier and therefore having more time to finish? Or is the group crossing effect simply an artifact of groups gathered at the street corner and waiting for a crossing signal?

As with any field survey, limitations from the data gathered through observations exist. For example, there is a possibility that observers misreported age and crossing pace even though few categories were used. Observers were clearly indicated to determined age through facial traits, posture and general common sense but individuals' signs of aging differ depending on their lifestyles and genes. There is a possibility that observers interpreted mobility-challenged pedestrian as being older than they were, or active-looking individuals to be younger. Even so, the studied mobility challenges (and especially the evident ones like walking aids) do clearly point to added difficulty in completing crossings within allocated times. Again, we cannot rule out that older age pedestrians chose crossing locations where they feel they have more time to cross or can cross without worries. We did find evidence that pedestrian countdowns were on average shorter for younger age groups, possibly suggesting a selection effect amongst older pedestrians for intersections that allocate more time. Our analysis focuses on observed crossings and provides an original database to do so. Crossings might have been avoided in streets with heavy traffic, but this goes beyond the purpose of this study. The amount of car traffic on the street, the precise types of streets and intersections should be considered in future studies. We identified the correlates of failures to cross on time but did not attempt to calculate population estimates and further research and a more systematically representative sample is needed to confirm this trend.

6. Conclusion

This study explores adult and senior pedestrians' street crossing behaviors through an observational survey. We assessed the factors associated with ending a crossing on a red light, red hand signal or either. These correlates range from individual and behavioral characteristics to situational and environmental ones. Our unique data set of observations in different urban road environments in Quebec, Canada is one of the strength of this study. Instead of assessing unsafe or illegal behaviors, we focused on identifying evidence of street crossing features that may be detrimental to slower moving population. Accordingly, two topics need further attention: the complexity of intersections where there are cycle paths and the time allocated to pedestrian to cross a street at signalized intersections.

Previous studies have shown that older pedestrians generally cross the road more slowly (Avineri et al., 2012; Bollard and Fleming, 2013; Dommes et al., 2015, just to name a few). Our results did not include exact walking speed (see above for a qualitative tempo variable), but other behavioral characteristics possibly influencing speed were significant: older age pedestrians are often carrying loads or using some walking aids and are more frequently hunched back and look towards the ground when crossing, all of which slows them down and reduces situational awareness. As many authors have argued for several years now, "slower" pedestrians are excluded of the design value of 1.2 m/s, recommended in several manuals of traffic control devices (Federal Highway Administration, 2012; Transport Association of Canada, 2014). Montufar et al. (2007) estimated that two-third of older pedestrians would not reach this speed while Romero-Ortuno et al. (2010) estimated the average speed at 0.91 m/s at the age of 80 years-old and Rastogi et al. (2012) suggested 0.95 m/s as a new standard. Our results lead us to agree with the latter viewpoint. As the share of aging population is growing in Canada, these research results should be considered in future traffic control design manuals. Standards that consider the presence of cycling paths in street crossing allocated time should also be considered. Designing and building road infrastructures suitable for the most vulnerable population will ultimately benefit to all.

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