Using a Virtual Environment to Study Pedestrian Behaviors: How Does Time Pressure Affect Children’s and Adults’ Street Crossing Behaviors?

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Abstract

Objective The aim of this study was to examine how crossing under time pressure influences the pedestrian behaviors of children and adults. Methods Using a highly immersive virtual reality system interfaced with a 3D movement measurement system, various indices of children’s and adults’ crossing behaviors were measured under time-pressure and no time-pressure conditions. Results Pedestrians engaged in riskier crossing behaviors on time-pressure trials as indicated by appraising traffic for a shorter period before initiating their crossing, selecting shorter more hazardous temporal gaps to cross into, and having the car come closer to them (less time to spare). There were no age or sex differences in how time pressure affected crossing behaviors. Conclusions The current findings indicate that, at all ages, pedestrians experience greater exposure to traffic dangers when they cross under time pressure.

Key words children; injury risk; pedestrians; time pressure.

Child pedestrian injuries are an issue worldwide, with more than 30,000 children killed annually (Toroyan & Peden, 2007). Moreover, unlike other causes of preventable injuries, this one has not been declining in recent years (World Health Organization, 2008). Children in the 5- to 10-year age range are at particular risk and account for a disproportionate number of pedestrian injuries (National Center for Injury Prevention and Control [NCIPC], 2013). Identifying factors that increase young children’s risk of pedestrian injury is essential for developing effective prevention strategies.

Research has shown that a variety of factors elevate risk of pedestrian injury for children. These include environmental factors, such as road design, traffic speed, and volume (Mueller, Rivara, Lii, & Weiss, 1990; Roberts, Norton, Jackson, Dunn, & Hassall, 1995); driver-related factors, such as speeding; and child behavior factors, including where and how children cross streets (Hoffrage, Hertwig, Weber, & Chase, 2003; Wazana, Krueger, Raina, & Chambers, 1997). Midblock crossings, for example, are particularly dangerous for young children to execute successfully (Warsh, Rothman, Slater, Steverango, & Howard, 2009).

Historically, one of the challenges limiting research on children’s crossing behaviors has been identifying ways to study this under realistic traffic conditions but without posing risk of actual injury. Recently, virtual reality (VR) environments have proven effective to address this challenge (Chihak et al., 2010; Schwebel, Gaines, & Severson, 2008; Thomson et al., 2005), with this assessment approach rated highly for scientific merit (Karazsia & Kirchman, 2013). VR offers a number of advantages, including that children engage in risky situations without actual risk of injury and that built-environment and traffic conditions can be studied systematically. In a VR environment, users are presented computer-generated but highly realistic visual images and audio sounds, effectively creating a simulated environment that models a real-life situation (Reid, 2002). Ideally the system is highly immersive, which evokes the feeling of being within the situation depicted and increases the person feeling like a participant rather than a viewer. Importantly, research has shown that the study of pedestrian behavior using VR technology has construct, convergent, and face validity (Schwebel et al., 2008). Thus, VR is emerging as an innovative and effective way to study children’s pedestrian behaviors. This approach was used in the current study.

Past VR systems are partially immersive and use an estimate of a participant’s walking speed. However, in the current research a highly immersive virtual environment was developed and interfaced...
with a 3D motion-tracking system so that actual crossing within traffic could be precisely measured from the time the pedestrian left the curb until she/he reached the opposite side of the street, or was hit by a virtual car. One notable benefit of the current system is that pedestrians can adjust their walking speed as they cross if they determine they are at risk of injury from approaching cars. In the current study, the aim was to determine whether adults and children differ in how time pressure impacts their crossing behaviors.

The experience of time pressure often pits safety against convenience and results in riskier behavior. A midblock crossing, for example, saves the time of walking to the corner to cross but elevates risk of pedestrian injury, particularly for younger children (DiMaggio & Durkin, 2002; Mayr et al., 2003). Similarly, at intersections with pedestrian signage, pedestrians often ignore a sign changing from Walk to Don’t Walk and dart across the street because they are in a hurry. Hence, in the course of their day-to-day lives, individuals often must choose between safety and convenience or saving time, and decide which of two competing goals (e.g., safety vs. social needs) to prioritize (Morrongiello & Dayler, 1996). Moreover, choices are not always rational or necessarily even consciously debated and decided. Rather, risk decisions can be emotionally driven, especially if the stakes are highly valued (Morrongiello & Matheis, 2004). Past research examining factors that affect the risky play decisions of children has shown that not only will children shift from less to more risky behaviors when under time pressure but they systematically change their injury appraisals and anticipated emotional reactions to support this behavior change. Hence, a decision to take a riskier and more hazardous path when biking, to meet a friend who is about to leave, is accompanied by a lowering of ratings of danger and injury severity and an increase in ratings of fun and excitement (Morrongiello & Matheis, 2004).

Building on previous research showing that time pressure arising from social-situational factors leads to greater risk-taking by children in play situations (Christenson & Morrongiello, 1997; Morrongiello & Matheis, 2004), the current study considered how social-situational-based time pressure (i.e., the threat of a peer leaving if one does not quickly meet him/her) influences how children and adults cross streets.

Participants in the current study were presented various intervehicle gap sizes and selected one to cross into on each trial, with some trials presenting a time-pressure context and others not; this allowed crossing patterns on time-pressure and no time-pressure trials to be compared within participants. Crossing indices that were measured included start delay (i.e., index of cognitive processing time based on the length of time observing traffic before crossing), missed opportunities (i.e., temporal gaps missed that the child could have safely crossed in based on the individual’s walking speed), average gap choice (i.e., average of all temporal gap sizes the child selected to cross into), actual hits, walking speed, and time left to spare (i.e., an index of risk or how closely the car passed to the pedestrian in seconds). It was hypothesized that pedestrians would show more risky crossings under time pressure trials; no additional a priori hypotheses were made owing to the exploratory nature of this study.

Method

Participants
The sample comprised 28 adults (51% male) who were university students (17–19 years) and 143 children who were in one of two age-groups: younger or 7–9 years (N = 77, 49% male, M = 8.46, SD = 0.89 years) and older or 10–12 years (N = 66, 56% male, M = 11.68, SD = 0.89 years). Children were recruited throughout the community and the adults through university courses. All children were developing normally (as reported by parent) and had ever been injured by a car as a pedestrian. The child sample comprised predominantly middle-upper income families (78% earned >$80,000), with 70% of parents having some/completed college/university. Nearly all of the participants were caucasian (97%). All measures and procedures were reviewed and approved by the university research ethics board, and all participants gave independent written consent before testing began.

Materials

Screening Questionnaire
The Simulator Sickness Questionnaire was completed before booking an appointment to ensure the participant was not at an increased risk for sickness while wearing the VR headset. The questionnaire, which was designed originally to be given after a simulator session, was modified to assess the person’s history of migraine headaches, claustrophobia, motion sickness, and dizziness/nausea (Kennedy, Lane, Berbaum, & Lilienthal, 1993) and anyone reporting these symptoms was excluded from the sample (N = 2).

VR and Movement Tracking System

The system was constructed in an 8 × 5 m² room using an eight-camera optical-motion tracking system (PPTH by Worldviz) to feed position data to specialized software (Vizard), using a high-level scripting language (Python) to accomplish many low-level graphics and hardware interfacing actions. Participants viewed the virtual environment through a Virtual Research Systems 1,280 × 1,024 resolution stereoscopic head-mounted display (HMD). Mounted on the HMD is an Inertia Cube 3, which is a 3 degrees of freedom (i.e., X,Y, and Z coordinates) orientation-tracking system that uses accelerometers, gyroscopic, and magnetic sensors to track the orientation data of a participant’s head such that changes in head orientation change the participant’s view of the virtual environment virtually instantaneously. All movement and orientation data are captured at a rate of 60 times per second. The virtual environment is a two-lane street with sidewalks. The virtual environment’s realism is enhanced visually by trees, shadows, and textures, and aurally by realistic sounds of traffic movement (e.g., engine sound becoming louder as cars get closer). Participants control the direction they walk, their speed of movement, and if they make a poor crossing decision they have the ability to step back to the curb or speed up to evade the approaching vehicle.

Procedure

Participants were tested at a lab on campus. Two trained research assistants were involved, with one overseeing the operation of the computer that controlled the VR equipment and instructing the participant on the VR street crossing trials, and the other remaining in the test room and available to assist if needed during completion of the trials. Each participant completed two phases. In Phase 1 (VR Familiarization), they were introduced to the virtual environment. First, a researcher demonstrated how to cross the street while wearing the headset as the participant watched a computer monitor, this included demonstrating the traffic they would see and what would happen if one were to be hit by a car (i.e., all vehicles disappear and a siren plays). Then the participant was fitted with the VR headset. To ensure the headset was fitted properly and the participant could
see clearly, a test screen appeared with letters and she/he had to correctly identify the letters before she/he was shown the street environment; knob adjustments allowed the viewer to adjust the headset to improve fit and make the letters clearly visible. Subsequently, the person was presented the street scene and she/he was positioned to stand on the curb facing a two-way street (i.e., one lane each way); to prevent possible tripping hazards, all curbs were visually presented but the child did not have to step down/up on these. The participants were instructed to walk across the closest lane (2.75 m) and stop once they reached a green dot that was positioned beyond the solid yellow line in the center of the two-lane road. They then turned and crossed back (no traffic) to reach the curb they had started from and proceeded to repeat this process 10 times with no cars appearing. This gave the person time to adjust to the VR environment, experience walking with the headset on, and ask any questions and make any adjustments before traffic was presented. Note that previous research has shown that by the end of this phase, individuals are fully accustomed to the VR equipment (Kennedy, Stanney, & Dunlap, 2000), and our own pilot data confirmed that walking speed stabilized (i.e., the data reached asymptote) by 10 trials (i.e., length of this phase). Subsequently, participants were presented with six randomized trials, with vehicles travelling in the near lane coming from the left, two trials at each of 30, 50, and 70 km/hr. Intervehicle gaps for these trials were randomly presented and ranged from 2 to 6 s.

In Phase 2 (Test Trials), the participant was again introduced to traffic and told to monitor the traffic flow and walk across the near lane when she/he deemed it safe to do so; traffic came from one direction in the near lane. Two types of trials were presented in a random order: (1) no time-pressure trials and (2) time-pressure trials on which the participant was told “On trials when you hear a ticking clock, imagine that your close friend is already on the other side of the street and she/he is about to leave. You need to speak to him/her right away about something important and you are worried that if you don’t get across really soon she/he will leave without you. So you want to get across the street as quickly as you can, but remember to go only when you feel it is safe.” To remind the participant of trial condition as she/he viewed traffic, a ticking clock could be heard on time-pressure trials. Ten traffic trials were presented across the two conditions and in randomized order, with all vehicles travelling at 50 km/hr; note that 50 km/hr is a moderate speed and is associated with increased risk of pedestrian injury among children (Mueller et al., 1990; Roberts et al., 1995). Intervehicle gaps in seconds (2, 2.5, 3, 3.5, 4.5, 5, and 6) were randomized for the trials in which there was no time pressure and identical trials were presented for the time-pressure trials with the addition of a ticking clock sound. Gap choice was measured as temporal gap between vehicles that the participant chose to cross into.

Crossing Measures

The crossing measures that were taken are labeled and described in Table I.

Analytic Approach

Descriptive and parametric statistics (analysis of variance, ANOVA) were applied to characterize the data and compare the pattern of results across traffic conditions. Several preliminary data-checking procedures were applied before analyses were conducted (Howell, 2007). Specifically, variables were examined for violations in normality and transformed, if needed. Similarly, we assessed for multivariate outliers based on Cook’s distance, and removed occasional data as appropriate (max = 3 for a given analysis). Before reporting within-participant ANOVAs, we assessed for violations of sphericity to determine whether adjustment to the degrees of freedom was warranted, in which case Greenhouse-Geiser results are reported. In conducting paired contrasts using t tests, a Bonferroni adjustment for family-wise error rate was applied; the results reported are based on this adjustment.

Results

Does Time Pressure Affect Start Delay and Missed Opportunities?

An ANOVA with age (3: younger, older, adults) and participant sex (2: male, female) as between-participant factors and trial type (2: time pressure, not) as a within-participant factor was conducted on the start delay scores; lower start delays indicate less time viewing traffic before initiating a crossing. Table II gives the descriptive statistics. A main effect of type of trial was obtained, $F(1, 164) = 21.92$, $p < .001$, $\eta^2_p = .12$. As can be seen in Table II, time pressure resulted in approximately a 10% (0.09 s) decrease, indicating significantly less time appraising traffic before starting to cross. There were no significant interactions between trial type, age, and participant sex. Thus, when crossing under time pressure, there was a consistent decrease in start delay for both males and females and pedestrians at all ages.

Similarly, an ANOVA with age (3: younger, older, adults) and participant sex (2: male, female) as between-participant factors and trial type (2: time pressure, not) as a within-participant factor was applied to the average number of missed opportunities per trial; lower scores indicate that pedestrians let fewer acceptable gaps pass before initiating a crossing. Log transformed data were analyzed to correct for positive skew but raw means are reported in Table II for ease of interpretation. A main effect of type of trial was obtained, $F(1, 165) = 54.12$, $p < .001$, $\eta^2_p = .25$. Participant age and sex did not interact significantly with trial type. As can be seen in Table II, for both sexes and across all ages the magnitude of impact was comparable and time pressure resulted in approximately 2.3 times fewer missed opportunities than for non-time-pressure trials, indicating they start crossing sooner on time pressure trials.

Does Time Pressure Affect Gap Size Selected to Cross Into, Hits, Walking Speed, or Time Left to Spare?

An ANOVA with age (3: younger, older, adults) and participant sex (2: male, female) as between-participant factors and trial type (2: time pressure, not) as a within-participant factor was applied to the gap choice scores; lower scores indicate crossing into riskier traffic conditions because the temporal gap between cars is smaller. A main effect of type of trial was obtained, $F(1, 165) = 42.14$, $p < .001$, $\eta^2_p = .21$. Participant age and sex did not interact significantly with trial type. As can be seen in Table III, participants chose approximately a 7% smaller gap on average when crossing under time pressure. Thus, under time pressure, participants of both sexes at all ages responded by making riskier crossings and selecting smaller gaps between cars to cross into.

Similarly, an ANOVA with age (3: younger, older, adults) and participant sex (2: male, female) as between-participant factors and trial type (2: time pressure, not) as a within-participant factor was conducted on the average number of hits per trial. No significant results were obtained. Regardless of age, sex, and trial type, participants experienced hits on fewer than 2% of trials ($M = 1.92$, $SD = 0.03$), presumably because they were able to wait for gaps they
deemed safe and then adjust their walking speed when they detected the car on a hit course. Consistent with this interpretation, an ANOVA comparing walking speed while in the path of an approaching vehicle as a function of type of trial revealed a main effect of trial type, $F(1, 165) = 49.37$, $p < .001$, $\eta^2_p = .32$, with greater walking speed under time pressure than when not, $M = 1.38$ and $1.28 \text{ m/s}$, $SD = 0.31$ and 0.26, respectively. Trial type also interacted with participant sex, $F(1, 165) = 6.61$, $p < .05$, $\eta^2_p = .14$. Simple effects using paired samples $t$ tests revealed that the effect of time pressure on walking speed was slightly stronger for males ($t(94) = 7.34$, $p < .001$) than females ($t(75) = 5.13$, $p < .001$), indicating greater increase in crossing speed for males than females in reaction to experiencing time pressure. These data are given in Table III.

Moreover, a significant correlation was revealed between walking speed and gap choice on time-pressure trials, as well as non-time-pressure trials, $r(169) = -.47$ and $-.27$, $p < .001$, respectively. Thus choosing smaller gaps was associated with greater walking speed to compensate for increased risk.

Finally, an ANOVA with age (3: younger, older, adults) and participant sex (2: male, female) as between-participant factors and trial type (2: time pressure, not) as a within-participant factor was applied to the time left to spare scores; lower scores indicate greater proximity of the car to the pedestrian when they are exiting the vehicle’s path and, therefore, riskier crossings. Results revealed only a main effect of type of trial, $F(1, 165) = 9.49$, $p < .005$, $\eta^2_p = .06$. As shown in Table III, when participants crossed under time pressure, there was less time to spare than when they crossed without time pressure, which indicates the car came closer to the pedestrian, reflecting a riskier crossing under time pressure.

Discussion

Pedestrian-related injuries are a leading cause of death and disability in children 5 to 10 years of age. A variety of factors have been shown to increase injury risk, including pedestrian behavior. In the current study, use of an innovative highly immersive VR system that allowed pedestrians to cross in traffic while various measures of their crossing behaviors were taken provided several insights into how time pressure elevates risk of injury for pedestrians.

First, based on when and how they crossed, time pressure was associated with changes in crossing behavior that can increase risk of injury. Specifically, time pressure resulted in less time appraising traffic before starting across and, hence, pedestrians initiated their crossing sooner compared with when they crossed on non-time-pressure trials. They also made riskier crossings by virtue of selecting shorter temporal gaps to cross into on time-pressure trials. These behaviors resulted in pedestrians having less time to spare, which is another indicator of elevated risk of injury because it signifies the car coming closer to the pedestrian. The fact that the

**Table I. Crossing Behavior Definitions and Computations**

<table>
<thead>
<tr>
<th>Crossing behaviors</th>
<th>Definition</th>
<th>Computation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start delay</td>
<td>An index of cognitive processing time when watching traffic before crossing. The time (in seconds) between the rear bumper of the first car in the chosen gap and the beginning of the child’s crossing.</td>
<td>For each trial, the time starts when the first car’s rear bumper passes the participant and stops when the participant starts to cross.</td>
</tr>
<tr>
<td>Missed opportunities</td>
<td>The number of times the participant did not cross the road when she/he could have been able to get across safely, based on their crossing speed on that trial and the intervehicle gap size.</td>
<td>The number of intervehicle gaps that were rejected that were 1.5 times the length of the child’s actual crossing time on that trial.</td>
</tr>
<tr>
<td>Gap size choice</td>
<td>The average size of the intervehicle gap for which the participant chose to cross into.</td>
<td>The time, in seconds, between when car one reaches the participant and when car two reaches the participant, for the gap the participant chose to cross into.</td>
</tr>
<tr>
<td>Hit</td>
<td>Whether the participant was hit by a car or not.</td>
<td>Determined based on whether the coordinates of the vehicle’s front bumper crosses the position coordinates of the participant.</td>
</tr>
<tr>
<td>Time left to spare</td>
<td>The time remaining for the approaching car to intersect with the child’s path.</td>
<td>Calculated as the time left between the child and the approaching car when the child just cleared the car path of the approaching car.</td>
</tr>
</tbody>
</table>

**Table II. Descriptive Statistics Giving the Mean (SD) for Start Delay Scores (s) and Missed Opportunities as a Function of Trial Type, Age-Group, and Gender**

<table>
<thead>
<tr>
<th>Trial</th>
<th>Group</th>
<th>Gender</th>
<th>Start delay</th>
<th>Missed opportunities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time pressure</td>
<td>Younger</td>
<td>Male</td>
<td>0.79 (0.30)</td>
<td>0.18 (0.33)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>0.93 (0.30)</td>
<td>0.27 (0.42)</td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>0.86 (0.30)</td>
<td>0.23 (0.38)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Older</td>
<td>Male</td>
<td>0.72 (0.24)</td>
<td>0.10 (0.19)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>0.79 (0.17)</td>
<td>0.17 (0.28)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>0.76 (0.21)</td>
<td>0.13 (0.23)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td>Male</td>
<td>0.66 (0.25)</td>
<td>0.08 (0.14)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>0.86 (0.26)</td>
<td>0.08 (0.11)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>0.72 (0.26)</td>
<td>0.08 (0.13)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female overall</td>
<td>0.87 (0.26)</td>
<td>0.21 (0.35)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>0.80 (0.27)</td>
<td>0.17 (0.30)</td>
<td></td>
</tr>
<tr>
<td>No time pressure</td>
<td>Younger</td>
<td>Male</td>
<td>0.88 (0.26)</td>
<td>0.42 (0.69)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>1.01 (0.25)</td>
<td>0.65 (0.72)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>0.95 (0.26)</td>
<td>0.54 (0.71)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Older</td>
<td>Male</td>
<td>0.82 (0.24)</td>
<td>0.27 (0.45)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>0.93 (0.18)</td>
<td>0.36 (0.44)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>0.87 (0.22)</td>
<td>0.31 (0.44)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td>Male</td>
<td>0.74 (0.24)</td>
<td>0.18 (0.20)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>0.83 (0.29)</td>
<td>0.10 (0.21)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>0.76 (0.25)</td>
<td>0.16 (0.20)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Male overall</td>
<td>0.82 (0.25)</td>
<td>0.31 (0.53)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female overall</td>
<td>0.96 (0.24)</td>
<td>0.48 (0.61)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>0.89 (0.25)</td>
<td>0.39 (0.57)</td>
<td></td>
</tr>
</tbody>
</table>

**Note.** *Significant main effect of trial type for both start delay and missed opportunities, $p < .001$.*
frequency of hits was not affected by time pressure is not surprising given pedestrians were instructed to avoid being hit on all types of trials and they could, and did, adjust their walking speed to prevent hits when crossing. Nonetheless, all the remaining indices are consistent in supporting the conclusion that pedestrians experience greater exposure to traffic dangers when crossing under time pressure.

Second, the impact of time pressure on crossing behaviors was comparable for younger and older children and adult pedestrians (i.e., trial type did not interact with age), as well as for males and females (i.e., trial type did not interact with sex of the participant except for males walking faster than females on time-pressure trials). Generally, pedestrians showed the same types of risk reactions to time-pressure trials and the changes in their behaviors were of comparable magnitude. Thus, under the current testing conditions, there were no age differences and all pedestrians responded to time pressure by engaging in riskier crossings. Moreover, they mitigated some of this risk by entering the gap sooner and by increasing walking speed when crossing into smaller gaps on time pressure trials.

With respect to clinical implications, the current findings highlight the importance of making pedestrians aware that time pressure leads to risky crossing behaviors, and this issue applies across a broad age range. Consistent with this, recent research examining the impact of countdown Walk signs indicating when the light is to change and traffic will start reveals these signs actually predict increased pedestrian injury from being hit by vehicles (Camden, Boliung, Rothman, Macarthur, & Howard, 2014). The current findings suggest that differential elevated injury rates among older child pedestrians, compared with older children and/or adults, may be linked to more complex traffic conditions than tested herein or relate to nontraffic factors (e.g., distractions, triggering stimulus such as a ball going into the street) that exist in real-life crossing situations but that were not modeled in the virtual environment. Dunbar, Hill, and Lewis (2001), for example, examined attention switching and concentration skills and found that children who were better at switching and concentration showed less reckless crossing behavior regardless of age. Similarly, Demettre et al. (1992) found that children and adults did not differ in indices of risky crossing decisions in roadside simulation tests and subsidiary analyses led them to conclude that attentional factors are likely coming into play to create age differences. Exploring if comparable effects across age are obtained when crossing under time pressure in more complex traffic conditions (e.g., multiple lanes of traffic with vehicles varying in speed) and/or in the presence of distractions in the immediate environment (e.g., children running by, buses with ads in view) is an important next step in this research and will help to elucidate the factors that differentially negatively impact young children’s pedestrian behaviors. Suffice it to say, under the current testing conditions, there were no age differences and all pedestrians responded to time pressure by engaging in riskier crossings. Moreover, they mitigated some of this risk by entering the gap sooner and by increasing walking speed when crossing into smaller gaps on time pressure trials.

Table III. Descriptive Statistics Giving the Mean (SD) for Gap Choice (s), Walking Speed (m/s), and Time Left to Spare (s) as a Function of Type of Trial, Age-Group, and Gender

<table>
<thead>
<tr>
<th>Type of trial</th>
<th>Age-group</th>
<th>Gender</th>
<th>Gap choice</th>
<th>Speed (m/s)</th>
<th>Time left to spare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time pressure</td>
<td>Younger</td>
<td>Male</td>
<td>3.97 (0.57)</td>
<td>1.48 (0.35)</td>
<td>1.76 (0.44)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>4.05 (0.58)</td>
<td>1.42 (0.26)</td>
<td>1.73 (0.47)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overall</td>
<td>4.01 (0.57)</td>
<td>1.45 (0.31)</td>
<td>1.75 (0.45)</td>
</tr>
<tr>
<td></td>
<td>Older</td>
<td>Male</td>
<td>3.98 (0.50)</td>
<td>1.31 (0.37)</td>
<td>1.71 (0.40)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>4.12 (0.42)</td>
<td>1.28 (0.22)</td>
<td>1.76 (0.42)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overall</td>
<td>4.04 (0.47)</td>
<td>1.30 (0.31)</td>
<td>1.73 (0.41)</td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td>Male</td>
<td>3.82 (0.52)</td>
<td>1.38 (0.36)</td>
<td>1.64 (0.46)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>3.98 (0.34)</td>
<td>1.30 (0.14)</td>
<td>1.55 (0.40)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overall</td>
<td>3.87 (0.47)</td>
<td>1.35 (0.32)</td>
<td>1.61 (0.44)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male overall</td>
<td>3.94 (0.53)</td>
<td>1.39 (0.36)</td>
<td>1.71 (0.43)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female overall</td>
<td>4.07 (0.50)</td>
<td>1.35 (0.24)</td>
<td>1.72 (0.44)</td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>Male</td>
<td>4.00 (0.52)</td>
<td>1.38 (0.31)</td>
<td>1.72 (0.43)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>4.03 (0.65)</td>
<td>1.35 (0.26)</td>
<td>1.95 (0.45)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overall</td>
<td>4.13 (0.67)</td>
<td>1.34 (0.24)</td>
<td>1.89 (0.55)</td>
</tr>
<tr>
<td>No time pressure</td>
<td>Younger</td>
<td>Male</td>
<td>4.32 (0.65)</td>
<td>1.35 (0.26)</td>
<td>1.95 (0.45)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>4.33 (0.70)</td>
<td>1.33 (0.23)</td>
<td>1.82 (0.63)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overall</td>
<td>4.33 (0.67)</td>
<td>1.34 (0.24)</td>
<td>1.89 (0.55)</td>
</tr>
<tr>
<td></td>
<td>Older</td>
<td>Male</td>
<td>4.25 (0.64)</td>
<td>1.21 (0.31)</td>
<td>1.71 (0.54)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>4.35 (0.47)</td>
<td>1.22 (0.21)</td>
<td>1.76 (0.48)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overall</td>
<td>4.29 (0.57)</td>
<td>1.22 (0.27)</td>
<td>1.74 (0.51)</td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td>Male</td>
<td>4.24 (0.58)</td>
<td>1.24 (0.29)</td>
<td>1.82 (0.55)</td>
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<tr>
<td></td>
<td></td>
<td>Female</td>
<td>4.30 (0.50)</td>
<td>1.27 (0.18)</td>
<td>1.86 (0.46)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overall</td>
<td>4.26 (0.55)</td>
<td>1.25 (0.26)</td>
<td>1.83 (0.52)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male overall</td>
<td>4.28 (0.62)</td>
<td>1.27 (0.29)</td>
<td>1.83 (0.51)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female overall</td>
<td>4.34 (0.60)</td>
<td>1.28 (0.55)</td>
<td>1.80 (0.55)</td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>Male</td>
<td>4.30 (0.61)</td>
<td>1.28 (0.26)</td>
<td>1.81 (0.53)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Female</td>
<td>4.30 (0.47)</td>
<td>1.22 (0.18)</td>
<td>1.86 (0.46)</td>
</tr>
</tbody>
</table>

Note. aSignificant main effect of trial type for gap choice, walking speed, and time left to spare, p < .001.
bSignificant interaction with trial type, p < .05 for walking speed.
issues of convenience are important determinants of behavior. To ef-
fect improvements in safety practices, whether targeting pedestrian
behaviors or otherwise, interventions must be effective in convincing
individuals to place greater value on securing their safety than saving
time and maximizing convenience.

Limitations and Future Research Directions

There are several limitations in this research that merit mentioning
and consideration when planning future research. First, the sample
comprises predominantly upper income, well-educated Caucasian
families and this might limit generalizability of the findings. Extending
this research to examine these pedestrian issues in a more
ethnically and economically diverse sample is important. In addi-
tion, if the nature of one’s traffic experience affects crossing com-
petency, then even comparing urban versus suburban samples would
be important. Second, the current study examined gap choices but
did not determine gap threshold per se (i.e., the smallest gap a pedes-
trian can safely navigate) and these are quite different indicators.
Although gap choices when crossing under time pressure did not dif-
fer with age-group or gender, it might be that gap thresholds would.
For example, younger pedestrians might select gaps to cross into
that are at their threshold limits, whereas older pedestrians might
have lower thresholds than reflected in the gaps they selected to
cross into under time pressure. Hence, comparing gap thresholds
across groups would be important to do in future research. Third,
because past research indicates that the desire to not miss meeting
up with friends is sufficiently important to children that it motivates
behavior change (Morrongiello & Matheis, 2007), a social-situational
reason was used as the basis for the experience of time pres-
sure in this study. Nonetheless, in future research it would be useful
to explore how the nature of the reason impacts children’s crossing
behaviors. It could be, for example, that some types of reasons have
greater impact than others to evoke riskier crossings, and this infor-
mation could inform intervention planning. Related to this, a ticking
clock was presented for constant reminding throughout time pres-
sure trials, however, no direct measures of children’s experience
of this manipulation were taken. Finally, programming naturalistic dis-
tractions into the virtual environment (e.g., children calling; horns
honking) is an important next step in this research. Although the
current study suggests comparable capacities across age when cross-
ing under time pressure, it could be that risk of pedestrian injury for
younger children is closely tied to attentional skills and, therefore,
such differences are not likely to be realized unless one manipulates
attentional load, such as by distraction or varying the complexity of
the traffic environment. Systematically exploring how features of the
social and built environments impact pedestrian injury risk for
young children represents an important future direction for research
in this field, and virtual systems provide the means to do so while at
the same time ensuring children’s safety. Suffice it to say, based on
the current findings, it appears that time pressure alone is not suffi-
cient to account for differential pedestrian injury rates between chil-
dren and adults. Thus, intervention approaches need to be
multifaceted in scope and not limited to addressing time pressure
concerns when crossing streets.

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bmorrong@uoguelph.ca.

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