Gender Differences in Pedestrian Rule Compliance and Visual Search at Signalized and Unsignalized Crossroads

Ariane Tom, Marie-Axelle Granié

Accident Analysis and Prevention
Elsevier

Running head: Gender Differences in Pedestrian Rule Compliance and Visual Search

Gender Differences in Pedestrian Rule Compliance and Visual Search at Signalized and Unsignalized Crossroads

Ariane Tom PhD, corresponding author

French Institute of Science and Technology for Transport, Development and Networks

Laboratory of Exploitation, Perception, Simulators and Simulations

58, bd Lefebvre, F-75732 PARIS

Phone: +33(0)1.40.43.52.90

Fax: +33(0)1.40.43.54.99

arianectom@yahoo.fr

Marie-Axelle Granié PhD

French Institute of Science and Technology for Transport, Development and Networks

Research Unit on Accident Mechanism Analysis

Chemin de la Croix Blanche

F-13300 Salon de Provence, France

marie-axelle.granie@ifsttar.fr

Running head: Gender Differences in Pedestrian Rule Compliance and Visual Search

Gender Differences in Pedestrian Rule Compliance and Visual Search at Signalized and Unsignalized Crossroads

Abstract

Male pedestrians are over-represented in road crashes. Among pedestrians, males violate more rules than females do. For now, it is not known whether gender differences in pedestrian behaviors only concern rule compliance. The objective of this study was to explore gender differences in pedestrian rule compliance and in gaze targets before and during crossing. 400 adult pedestrians were observed at two signalized and two unsignalized crossroads, using a taxonomic observation grid which detailed 13 behavioral categories before, during and after crossing. The results show that the temporal crossing compliance rate is lower among male pedestrians but spatial crossing compliance does not differ between genders. Furthermore, different gaze patterns emerge between genders before and during crossing, notably as women particularly focus on other pedestrians during these two periods whereas men focus on vehicles. Moreover, females' gazes vary with the type of crossroads, but males' gazes do not. Spatial crossing compliance and gaze targets are furthermore modulated by the crossroad configuration. These results are discussed in terms of pedestrian visual strategy and compliance.

Keywords: gender, pedestrian, crossing, rule compliance, visual search, signalized crossroad, unsignalized crossroad.

Running head: Gender Differences in Pedestrian Rule Compliance and Visual Search

Gender Differences in Pedestrian Rule Compliance and Visual Search at Signalized and Unsignalized Crossroads

1. Introduction

Gender remains one of the main factors of road Accidentology. Injuries to males comprise seventy to eighty percent of fatal road injuries in 15-59 year-olds in France (Assailly, 2001). Studies in Canada have shown that male pedestrians are killed or injured more often in road accidents than female pedestrians (MTO, 2002; SAAQ, 2002). Joly *et al.* (1988) noted that men's mortality rate is one and a half times higher than women's and that non-severe injuries are greater in men than women. Leaf and Preusser (1999) noted that male pedestrians are over-represented in injuries: among 21,751 injury cases studied, 70.2 % involved males and only 29.8 % involved females. In particular, sex differences were observed in injury risk behaviors (Byrnes *et al.*, 1999) and female pedestrians have been shown to be more careful than males when crossing at intersections (Bergeron *et al.*, 1998; Thouez *et al.*, 2001). Dangerous behaviors and involvement in accidents among adult drivers were shown to be due to rule-breaking more often in males than in females (Harré *et al.*, 1996; Simon and Corbett, 1996; Yagil, 1998) and previous studies have shown that, among pedestrians, males violate rules more often than females do (Latrémouille *et al.*, 2004; Moyano Diaz, 2002; Rosenbloom, 2009; Rosenbloom *et al.*, 2004; Yagil, 2000). Observations in the City of Montréal have shown 66% of women and 56.6% of men complied with road signs and markings (Bergeron *et al.*, 1998). More broadly, research has shown that male pedestrians cross on red pedestrian lights more often than women (Moyano Diaz, 2002; Rosenbloom, 2009; Rosenbloom *et al.*, 2004; Yagil, 2000).

Studies based on declared behaviors (Holland and Hill, 2007; Moyano Diaz, 2002; Yagil, 2000; Zhou *et al.*, 2009) or as those based on observations of male and female pedestrians in daily situations (Latrémouille *et al.*, 2004; Rosenbloom, 2009; Rosenbloom *et al.*, 2004; Rosenbloom *et al.*, 2008) often focus on temporal crossing compliance, i.e. compliance with traffic light rules (Sisiopiku and Akin, 2003). For now, research has not finely explored gender differences in spatial crossing compliance, i.e. compliance with marked crosswalks (Sisiopiku and Akin, 2003). Some studies, however, have shown that spatial crossing compliance, often named “dangerous crossing” (Rosenbloom *et al.*, 2004), is higher among women (Latrémouille *et al.*, 2004; Rosenbloom *et al.*, 2004). More information on gender differences in spatial compliance is needed, because drivers’ attention to pedestrians is higher when pedestrians cross at designated locations, and therefore pedestrian-vehicle conflicts can be reduced when spatial compliance increases (Brenac *et al.*, 2003; Sisiopiku and Akin, 2003).

Furthermore, gender differences in visual search strategies have not been explored for now, whereas visual search is an important skill involved in the crossing task (Thomson *et al.*, 1996). For instance, what pedestrians look at before and during crossing is not specified (Latrémouille *et al.*, 2004) or only compliant gaze behavior (left-right-left head movements) is taken into account (Zeedyk and Kelly, 2003; Zeedyk *et al.*, 2002). Road crossing behaviors are also based on the ability to make the correct decision at the right time. This activity relies on the comprehension of the situation, hence on situation awareness, as defined by Endsley (1988; 1995; 2000). In Endsley’s theory, situation awareness is composed of three interdependent levels: perception of the surrounding elements in the environment, comprehension of their meaning, and anticipation, i.e. projection of their status into the near future. The core facet of situation awareness is to precede decision-making in dynamic situations, themselves defined as having two aspects: decisions are made within a short time

period and they depend on a continuously updated analysis of the situation. It must be highlighted that, in order to facilitate situation awareness, strategies are often used that focus attention on features in the environment that are relevant to a specific situation. These processes are triggered both in working and long-term memory (general knowledge of such situations). As gender differences have been observed in compliance, we could still expect that gender may influence what males and females look at before and during crossing. Yagil (2000) showed that situational factors had an influence on self-reported crossing behaviors of male and female pedestrians. On one hand, women were more concerned by the presence and behaviors of other pedestrians, which stimulated their compliance with the rules. On the other hand, men were more influenced by traffic volume and physical conditions. Thus, it seems that women are more influenced by their social environment, whereas men seem to be more concerned with the physical aspects of the setting. If, as Yagil (2000) found, men and women use different strategies to gain awareness of the crossing situation, we could expect that these have an effect on men's and women's visual search before and during crossing. Women may be more focused on other pedestrian's behaviors, whereas men may be more focused on moving vehicles.

Based on the literature, we thus hypothesize that, during street crossing, 1/ temporal and spatial crossing compliance will be higher among female pedestrians than among male pedestrians; 2/ women pedestrians will look at other pedestrians more than men pedestrians; 3/ men pedestrians will look at moving vehicles more than women pedestrians. Moreover, we explore the effect of the presence of traffic lights on males' and females' gazes and compliance. The goal here is to verify whether gender differences in temporal and spatial crossing compliance and in target gazes remain whatever the crossing configuration may be.

2. Method

2.1 Experimental sites and participants

Four different urban four-way intersections (named A, B, C and D), all located in the North of France, were chosen as experimental sites. Sites A, B and C are located in the city of Paris and site D is located in the city of Rouen. All the sites were equipped with zebra crossings on each side of the crossroad. Crosswalks on sites A and B were signalized with traffic and pedestrian lights (noted as crossroads S), whereas crosswalks on sites C and D were unsignalized (noted as crossroads US). The automobile speed limit for all crossroads was 50 km/h.

Four hundred ($N = 400$) pedestrians, aged 18 to 55 years (mean age=40 years-old), were observed on the 4 selected sites, with an equal number of males and females observed on each site. Density of traffic, presence of traffic lights and the number of male and female pedestrians observed on each site are presented in Table 1.

2.2 Material

An observation grid was developed to observe all pedestrian behaviors during all phases of the crossing task. This grid is intended to follow each participant from the sidewalk approach to the very end of the crossing. Figure 1 shows the 3 experimental zones analyzed below, corresponding respectively to before, during and ending crossing activities. Such a division into three areas stems from Geruschat *et al.* (2003), who found that crossing the street relied on three phases: walking to the curb, standing at the curb, and the crossing itself.

The observation grid was based on grids used by Latrémouille *et al.* (2004) and previous research (Granié, 2007; Rivara *et al.*, 1991; Routledge *et al.*, 1974; Zeedyk and Kelly, 2003). However, the grid was adapted to observe pedestrian behaviors on French crossroads. Items from van der Molen's observation grid (1983) were furthermore added to the grid used here in

order to better understand the behavior of pedestrians who crossed the street. For example, the "sidewalk approach" was defined as the zone of the sidewalk between 5 and 0.5 meters from the curb.

Items concerning head movement were subdivided in two items ("head movement(s) before crossing", vs. "head movement(s) during crossing"), each referring to four targets which indicated the direction of head movements: a/ toward the traffic lights, b/ toward the moving vehicles, c/ toward the other pedestrians, d/ toward the ground. Lastly, the items were presented in chronological order to facilitate the experimenter's task on site. In the final version presented below, it is made up of 51 items distributed into 13 behavioral categories. The observation grid is shown in Table 2.

2.4 Procedure

These observations were part of a broader study with the goal of modeling pedestrian behaviors. Thus, the observers did not focus on behavioral gender differences, but aimed at describing, as finely as possible, all observable pedestrian behaviors. Data was collected at different times of the day covering peak periods either in the morning (8:00-10:00 a.m.) or in the afternoon (4:00-7:00 p.m.) over a 2-week period during June 2010. Only one of the four marked crosswalks on each site was observed and, on each crosswalk observed, all the pedestrians were observed in the same crossing direction. The experimenter stood on the opposite sidewalk, just in front of the zebra crossing, near the very beginning of the crosswalk. There, she could easily check where the pedestrian was looking. The looking target was also sometimes deduced from pedestrian's head movements. Behaviors such as turning the head toward a landmark while looking somewhere else were not observed in our sample. The experimenter was equipped with an Olympus® DS 2000 digital voice recorder, with a 64MB SmartMedia card, and orally noted the behaviors of the pedestrians according to

the observation grid. This grid was entirely memorized before the beginning of the experiment in order to record behaviors faster. Two pre-experiments were conducted which showed that ticking the behaviors on the grid while observing behaviors was too slow (relative to the walking speed of pedestrians and to the length of the zebra crossing) and induced omissions (as the experimenter missed some of the behaviors while writing). These pre-experiments also enabled the experimenter to establish that pedestrians usually moved their heads before or during crossing toward more than one item. Consequently, the order in which these targets were looked at was also recorded.

Accompanied pedestrians and pedestrians under the age of 18 or over 55 were excluded from the sample, with the constraint that an equal number of males and females should be observed on each site. If several pedestrians came to the observed crossing site, only the first of the group approaching the site was included in the sample. Nonetheless, it should be pointed out that the first of a group approaching the curb might be influenced by pedestrians who were already crossing or might not be the first one to start crossing. Therefore, in any case, influence by others may emerge.

Once the 400 observations were been made, the experimenter transferred all 400 files onto a PC via the appropriate card reader. She then listened to each of the 400 files with the DSS Player software and transcribed them on an Excel sheet using a binary code for each item of the observation grid (0: absence; 1: presence). Data were then recoded according to the behavioral categories and analyzed via the Statistica and IBM SPSS Statistics 19 software.

3. Results

Contingency tables were constructed and data were processed by computing χ^2 values for each of the 13 behavioral categories. Data were compared by gender for the whole sample and for signalized (S) and unsignalized (US) crossroads separately. Data were also compared by

crossroad configuration (crossroads S versus crossroads US) for males and females separately. For clarity, only significant results are reported for each behavioral category.

3.1 Pedestrians' behaviors before crossing

Tempo of the participant while approaching the curb (5-0.5m)

Most of the 400 participants (94.5%) walked regularly while approaching the curb, instead of stopping (1.3%), slowing down (2.8%), or running (1.3%). Only one pedestrian (man) made a false start (0.3%). There was no gender difference in tempo while approaching the curb for the whole sample (χ^2 (4, N = 400) = 2.22, *ns*, Cramér's V = 0.07), nor for crossroads S (χ^2 (4, N = 200) = 3.22, *ns*, Cramér's V = 0.13), or crossroads US (χ^2 (2, N = 200) = 1.16, *ns*, Cramér's V = 0.08).

Crossing site

The great majority of pedestrians (86.5%) chose the zebra crossing, and the remaining 11.3% chose to cross less than 5 meters away from the zebra crossing. The three other items were rarely observed (2.4%). These data did not differ according to the participant's gender (χ^2 (4, N = 400) = 5.70, *ns*, Cramér's V = 0.12). On the other hand, a significant difference between configurations emerged, as men (χ^2 (4, N = 200) = 12.58, $p < .01$, Cramér's V = .25) and women (χ^2 (4, N = 200) = 9.31, $p < .01$, Cramér's V = .22) started their crossing in zebra crossings less often on crossroads US (75% and 83% for men and women, respectively) than on crossroads S (92% and 96% for men and women respectively).

Total number of pedestrians waiting to cross

The most frequent situation observed is a pedestrian crossing alone (61.3%) or a pedestrian encountering a group of 2 pedestrians waiting to cross (20.0%) (remember that in this case, only the first person arriving at the crossing site was observed). 16% of all cases were a group of 3-5 pedestrians approaching to cross. Finally, the least frequent case was that of more than

6 pedestrians waiting to cross (2.8%). There was a significant difference between genders (χ^2 (3, N = 400) = 9.51, $p < .05$, Cramér's V = 0.15), as men (67%) were alone when waiting to cross more often than women (55%). This difference between men and women is particularly marked in crossroad US, where 85% of men and 67% of women were alone when waiting to cross (χ^2 (3, N = 200) = 10.94, $p < .05$, Cramér's V = 0.23). Furthermore, a significant difference between configurations emerged, with men (χ^2 (3, N = 200) = 32.99, $p < .001$, Cramér's V = 0.41) and women χ^2 (3, N = 200) = 21.74, $p < .001$, Cramér's V = 0.33) crossing alone on crossroads US (85% and 67% for men and women, respectively) more often than on crossroads S (49% and 44% for men and women, respectively).

Tempo of the participant next to the curb (0.5-0m)

At the sidewalk, 18.2% of the observed sample slowed down or stopped. 80.1% of the sample continued to walk and 1.8% ran. There was no difference between the sexes (χ^2 (3, N = 400) = 4.15, *ns*, Cramér's V = 0.10) in the tempo of pedestrians next to the curb. Nevertheless, a significant difference between configurations emerged, with men (χ^2 (3, N = 200) = 36.74, $p <$ .001, Cramér's V = 0.43) and women (χ^2 (3, N = 200) = 27.04, $p < .001$, Cramér's V = 0.37) stopping next to the curb more often on crossroads S (29.3% and 31.6% for men and women, respectively) than on crossroads US (2.0% and 5.0% for men and women, respectively).

Starting position of the pedestrian

Again here, the observed sample showed safe behaviors, as 91.7% of the pedestrians stayed on the sidewalk and 8.3% on the pavement before crossing. No difference between the sexes emerged for whole sample (χ^2 (1, N = 400) = 0.28, *ns*, Cramér's V = 0.03), nor for crossroads S (χ^2 (1, N = 197) = 0.62, *ns*, Cramér's V = 0.06), or crossroads US (χ^2 (1, N = 200) = 0.00, *ns*, Cramér's V = 0.00).

Head movement(s) before crossing

Most of the participants (94.4% of the sample) looked at their physical environment before crossing: 82.3% of the sample turned their heads toward the moving vehicles and 2.3% toward the ground. The remaining 5.8% of the sample looked at the other pedestrians before crossing. For the sample observed in crossroads S, 69.5% of the sample looked at vehicles, 19.5% of the sample turned their heads toward the traffic lights and 9% toward other pedestrians before crossing. For the sample observed on crossroads US, 86% looked at moving vehicles and 9.5% looked at other pedestrians before crossing.

The results revealed significant differences between genders. Whereas men focused on moving vehicles more than women (88.5% and 76%, respectively), women turned their heads toward traffic lights (13%) and other pedestrians (8%) more than men (6.5% and 3.5% for traffic lights and pedestrians, respectively) (χ^2 (3, N = 400) = 10.75, p <.01, Cramér's V = 0.16). This significant difference was observable on crossroads S, where 81% of men and 58% of women turned their heads toward vehicles (χ^2 (3, N = 200) = 14.14, p < .001, Cramér's V = 0.27), but not on crossroads US, where women (94%) and men (96%) looked at vehicles first (χ^2 (2, N = 200) = 2.02, *ns*, Cramér's V = 0.10).

As stated before, participants usually turned their heads toward two different indexes before crossing. Consequently, we analyzed the second target of head movement for each pedestrian observed. Detailed results are shown in Figure 2a. Only 70 (17.5%) of the 400 pedestrians observed turned their heads toward a second target before crossing. The second targets were traffic lights (44.3%) or moving vehicles (27.1%). For the whole sample, women (40.5%) more than men (12.1%) secondly looked at moving vehicles (χ^2 (3, N = 70) = 9.31, p < .05, Cramér's V = 0.36).

For the sample observed on crossroads S, 55 pedestrians (27.5%) moved their heads toward a second target: 56.4% of the sample turned their heads toward the traffic lights, 30.9% of the sample looked at moving vehicles and 12.7% toward other pedestrians before crossing. Men

(72%) were more likely than women (43.3%) to secondly turn their heads toward the traffic lights; whereas women (46.7%) were more likely than men (12%) to secondly turn their heads toward moving vehicles ($\chi^2(2, N = 55) = 7.68, p < .05$, Cramér's $V = 0.37$). For the sample observed on crossroads US, only 15 pedestrians (7.5%) moved their heads toward a second target: 13.3% looked at moving vehicles, 33.3% looked at other pedestrians and 53.3% looked at the ground before crossing. There was no gender difference in head movement toward a second target on crossroads US (χ^2 (2, $N = 15$) = 3.75, *ns*, Cramér's $V = 0.50$).

3.2 Pedestrians' behaviors during crossing

State of the traffic lights at the beginning of the crossing

Out of the 200 pedestrians observed on crossroads S, 88.3% of the pedestrians complied with the pedestrian street light rules (crossing with pedestrian green light and traffic red light) and only 11.2% of the sample did not comply with the rules (crossing with pedestrian red light). There was a significant gender difference in compliance with the traffic light rules (χ^2 (2, $N = 200$) = 10.44, $p < .01$, Cramér's $V = 0.23$): men (18%) crossed at pedestrian red lights more than women (4.1%).

Starting position for crossing

91.8% of the 400 pedestrians observed started to cross the street at the zebra crossing. This figure did not differ according to sex for the whole sample (χ^2 (1, $N = 400$) = 0.03, *ns*, Cramér's $V = 0.01$), nor for crossroads S (χ^2 (1, $N = 200$) = 0.00, *ns*, Cramér's $V = 0.00$), or crossroads US (χ^2 (1, $N = 200$) = 0.05, *ns*, Cramér's $V = 0.02$).

Tempo of the participant at the middle of the zebra crossing

93.5% of the participants steadily walked on the zebra crossing. Some pedestrians ran (5.8%), stopped (0.5%) or slowed down (0.3%) in the middle of the crosswalk. There was no difference between sexes for the whole sample (χ^2 (3, $N = 400$) = 1.41, *ns*, Cramér's $V =$

0.06). Nevertheless, a significant difference between configurations emerged among men, with men running more often on crossroads S (11.1%) than on crossroads US (2%), where they more often walked (87.9% and 98% on crossroads S and US, respectively) (χ^2 (2, N = 200) = 2.08, $p < .05$, Cramér's V = 0.20).

Head movement(s) during crossing

Once the participants started to cross, they mainly looked at the physical environment (93.9%): moving vehicles (82.9%), traffic lights (7.0% of the sample) or the ground (4.0%). Moreover, more participants looked at the others pedestrians during crossing than before crossing (13.1% instead of 5.8%). There is a gender difference for the whole sample for the target of the head movement during crossing, with women (18.6%) looking at other pedestrians more than men (7.5%) (χ^2 (3, N = 400) = 12.07, $p < .01$, Cramér's V = 0.17).

On crossroads S, 64.5% of the sample looked at vehicles. There was no significant difference between the sexes (χ^2 (3, N = 200) = 5.42, *ns*, Cramér's V = 0.16).

On crossroads US, 86.5% of the pedestrians looked at vehicles while crossing. A significant gender difference emerged, as women (15.2%) looked at other pedestrians more than men (4%) (χ^2 (3, N = 200) = 7.50, $p < .05$, Cramér's V = 0.19).

As for before crossing, we also took into account the second target of head movement during crossing. Only 68 pedestrians (17%) secondly turned their heads toward pedestrians (35.3%), traffic lights (25.0%) or vehicles (19.1%). There was no significant gender difference for the whole sample in the second target of head movement (χ^2 (3, N = 68) = 1.50, *ns*, Cramér's V = 0.15). For the sample observed on crossroads S, only 48 pedestrians (24%) moved their heads toward a second target: traffic lights (35.4%) or other pedestrians (31.3%). There was no significant difference between the sexes (χ^2 (3, N = 48) = 3.82, *ns*, Cramér's V = 0.28). On crossroads US, only 20 pedestrians (10%) moved their heads toward a second target: the

ground (55.0%) or other pedestrians (45.0%). There was no significant difference between the sexes (χ^2 (1, N = 20) = 0.90, *ns*, Cramér's V = 0.21). Detailed results are shown in Figure 2b.

If there is an interaction with a driver when crossing

Data showed that there was almost no interaction between drivers and pedestrians. Out of 400 participants in our sample, only 29 pedestrians (7.25%) (14 men and 15 women) made a visual contact with a driver. There was no significant difference between genders for the whole sample (χ^2 (1, N = 29) = 0.17, *ns*, Cramér's V = 0.08), nor for crossroads S (χ^2 (1, N = 9) = 1.41, *ns*, Cramér's V = 0.40), or crossroads US (χ^2 (1, N = 20) = 0.05, *ns*, Cramér's V = 0.05).

3.3 End of crossing

Ending the crossing in the pedestrian crossing

73.8% of the participants ended their crossing in the zebra crossing. There was no significant gender difference for the whole sample (χ^2 (1, N = 400) = 0.13, *ns*, Cramér's V = 0.01). Men ended their crossing more frequently outside the zebra crossing on crossroads US (32%) than on crossroads S (20%) (χ^2 (1, N = 200) = 3.74, $p < .05$, Cramér's V = 0.14).

Crossing path

The kind of crossing could be divided into two categories: straight line (72.0%) and diagonal (26.8%). Crossings between vehicles stopped on the pavement were seldom observed (1.3%). For the whole sample, this result did not differ according to the pedestrian's sex (χ^2 (2, N = 400) = 2.01, *ns*, Cramér's V = 0.07). Nevertheless, a significant difference between configurations emerged, with men (χ^2 (2, N = 200) = 16.45, $p < .001$, Cramér's V = 0.29) and women (χ^2 (2, N = 200) = 7.89, $p < .05$, Cramér's V = 0.20) crossing diagonally more often on crossroad US (38% and 34% for men and women, respectively) than on crossroads S (17% and 18% for men and women, respectively).

4. Discussion

The objective of this study was to explore gender differences in pedestrian crossing behaviors, and specifically gender differences in compliance and in pedestrian gaze behaviors before and during crossing.

The results show that women are more compliant with traffic light rules than men. Nevertheless, compliance with other pedestrian rules is equivalent for male and female pedestrians: both men and women comply with the use of zebra crossings, the starting position for crossing and crossing paths. Thus, our results show gender differences in temporal crossing compliance, i.e. compliance with traffic light indications (Sisiopiku and Akin, 2003), but not in spatial crossing compliance, i.e. the use of zebra crossings and crossing paths (Sisiopiku and Akin, 2003). Our first hypothesis predicting that women pedestrians would have higher temporal and spatial crossing compliance than men pedestrian is thus partially validated, for temporal crossing compliance only. Research on self-reported or observed crossing behaviors generally has already shown that men cross on red traffic lights more frequently than women (Moyano Diaz, 2002; Rosenbloom, 2009; Rosenbloom *et al.*, 2004; Yagil, 2000). As our results also show that men more often run during crossing on signalized crossroad than on unsignalized crossroad, this lack of male compliance with traffic lights could be due to a need to hurry or a desire to keep moving, which have been proven to be the main reasons for lack of compliance with pedestrian signals (Forsythe and Berger, 1973). Furthermore, temporal crossing compliance seems to be influenced by pedestrian gender and males, unlike females, seem to comply differently with temporal and spatial rules. This difference between genders in temporal crossing compliance may be due to the perception of traffic lights as more external rules than rules concerning the crossing path and the use of zebra crossings, which could reflect on individual traits such as self-perceived

caution. Granié (2009) has found that, among adolescents, rule internalization, the process by which individuals acquire social values and rules from external sources and transform these into personal attributes, values and self-regulated behaviors (Grolnick *et al.*, 1997), is a predictor of declared pedestrian compliance. In our results, it seems that, for males more than for females, formal temporal crossing rules may be perceived as external conventional rules – i.e. rules varying with the context and subject to the presence of an authority (Turiel, 1983) – , and males more or less comply with this kind of rule depending on the situation. On the contrary, females may perceive temporal crossing rules as internal prudential rules that are rules relative to one's own physical and psychological well-being (Tisak and Turiel, 1984), and comply with this kind of rule whatever the situation may be.

Nevertheless, excluding the most formal traffic light rules, males seem to be as careful as females in their pedestrian behaviors and the results indicate that crossroad configurations seem to have more of an influence than gender on spatial crossing compliance. Compared to unsignalized crossroad, pedestrian crossing, especially among males, seems to be more cautious on signalized crossroads: men as women more often started the crossing within the zebra crossing, stopped along the side of the sidewalk more often, crossed diagonally less often, and men ended their crossing outside the zebra crossing less frequently. The frequency of jaywalkers and partial jaywalkers (Akin and Sisiopiku, 2000) is higher and spatial crossing compliance is lower on unsignalized crossroads. These results confirm those of Sisiopiku and Akin (2003), who showed that the observed pedestrian rate of spatial crossing compliance is higher at signalized crossroads than at unsignalized crossroads. The presence of traffic lights seems to have slightly more effect on men's spatial compliance than on women's. Therefore, this could signify that men's spatial crossing compliance is slightly more dependent on road signs such as traffic lights than women's spatial crossing compliance. Situation awareness can explain this last result, as it is known that general knowledge (here, hazard knowledge relative

to a precise road configuration) can influence subsequent decision making (Serfaty *et al.*, 1997). Thus, as Rouphail (1984) found a link between pedestrians' perception of crosswalk safety and crossing compliance, greater caution on signalized crossroad could be explained by pedestrian perception of this kind of crossroad. Pedestrians may understand the presence of traffic lights as a sign of higher danger, complexity and/or traffic density on signalized crossroads than on an unsignalized crossroads, where traffic density is lower and where no regulation is needed. Thus, the presence of traffic lights might be understood by French pedestrians as a cue for danger and this could influence their decision-making, especially in terms of spatial crossing compliance. This explanation will be tested in future research. Furthermore, the results indicate that men and women particularly differ in visual search, before and during crossing. Before crossing, men look at vehicles more than women and women look at traffic lights and other pedestrians more than men. During crossing, women focus on other pedestrians more than men do, particularly on signalized crossroads. Our second and third hypotheses, which stipulated that women pedestrians would gaze at other pedestrians more, and that men pedestrians would gaze at moving vehicles more, are thus validated. These findings confirm the results from Yagil (2000). It seems that the situational factors of self-reported pedestrian behavior found by Yagil (2000) could also explain observed pedestrian behaviors. In keeping with Yagil, the focused gaze on moving vehicles and traffic lights by males in our sample could be explained by their focus on traffic density and physical conditions as factors behind their crossing decisions. Likewise, results showing females' focused gaze on other pedestrians in this study could be explained by their concern with the presence and behaviors of other pedestrians as factors behind their crossing decisions (Yagil, 2000). Underwood *et al.* (2007) found that, in childhood, boys already differ from girls in reading road scenes. When assessing the safety of a road scene, boys focus on factors in the physical environment, in particular visibility and line of sight, whereas girls focus on

the presence and activity of other road users. In the same way, Granié (2007) has found that, as early as 5 years-old, boys explore the physical environment before crossing more than girls. On the other hand, girls initiate hand-holding with adults more than boys. Thus, it seems that, in reading road scenes as well as in crossing behaviors, boys are more sensitive to physical cues and control, whereas girls are more sensitive to social cues and support. Accordingly, it appears that a gender difference exists in reading road scenes depending on safety and crossing decisions and that this difference is a cross-age phenomenon. Also, the more frequent gazes at other pedestrians among women could be interpreted as the result of stronger social influence on women's decision-making than on men's. Indeed, the prevalence of peer compliance is also known to be higher among women. This phenomenon has been observed in different domains such as task resolution (Coleman *et al.*, 1957), technological innovation (Mazman *et al.*, 2009), or even physical attractiveness (Graziano *et al.*, 1993). Hence, this finding both replicates these results and extends them to the road crossing task. Furthermore, women look at other pedestrians almost twice more often during crossing than before crossing. This may reflect a need to be reassured and/or a lack of self-confidence in their decision to cross.

Results also show an effect of crossroad configuration on rule compliance and on gaze targets. On signalized crossroads, men are less compliant with traffic lights and more focused on vehicles than women, whereas women are more compliant and more focused on traffic lights and pedestrians. Furthermore, the gaze target order differs according to pedestrian gender: men first looked at vehicles and then at traffic lights; women first looked at traffic lights and pedestrians, and then at moving vehicles. According to situation awareness theory (Endsley, 1995), gender differences in gaze targets and order could be linked to gender differences in pedestrian compliance. As males cross on pedestrian red lights more often, they need to focus on moving vehicles more than females.

More broadly, whereas the configuration of the crossroads influences men's spatial crossing compliance, it does not influence their visual search: in both types of crossroads, men are more focused on moving vehicles before and during crossing. Among men, visual search is therefore focused on dynamic features of the traffic environment, such as moving vehicles, but they do not seem to be influenced by cues linked to static features, such as traffic lights, which can be used to understand a specific road scene and make crossing decisions (Tolmie *et al.*, 2003). On the contrary, visual search varies among women depending on the crossing phase and crossroad configuration. On signalized crossroad, women are more focused on the traffic light before crossing, and during crossing they are more focused on other pedestrians, especially on unsignalized crossroads. Women's visual search seems to be influenced by static features in the traffic environment (traffic light) more than men's visual search, and focuses on cues such as traffic lights or others pedestrians, the latter all the more so when static features are lacking and do not facilitating compliance and decision-making, such as on unsignalized crossroads. Traffic light and other pedestrians could be perceived here as guiding pedestrian behavior and could be seen as stimulating behavioral compliance (Yagil, 2000) and facilitating decision-making through anticipation (Endsley, 1995). Indeed, anticipation is a key ability in dynamic tasks such as driving, road crossing, and human transportation in general where decisive actions often have to be executed at a fast pace. Anticipation is called projection in Level 3 of Endsley's model, and has been shown to vary, notably according to age (Bolstad, 2001) or gender (Gugerty *et al.*, 2004). Here again, further studies would be necessary to confirm this finding.

Additionally, results also show a huge decrease for both sexes in the proportion of indexes observed during crossing, compared to indexes observed before crossing. This last result appeared central as it clearly showed that the information-gathering process mainly takes place before crossing. As the same targets are observed before and during crossing, it could

therefore be hypothesized that head movements and visual search during crossing are mainly done to check that the previously collected information has remained unchanged. Indeed, according to Endsley's model (1988; 1995; 2000), situation awareness is not about elaborating a static mental representation. Rather, it appears to be a dynamic representation, continuously fed by the current selected stimuli, and hence permanently updated. The updating process is not global but only applies to the dynamic elements of the situation. This could explain why, in our results, men continue to focus on moving vehicles before and during crossing, whereas traffic lights are only looked at before crossing. Though Endsley's model was first built to account for situation awareness in aeronautics, it has been applied to different domains such as driving (Gugerty, 1997), internet shopping (Lee *et al.*, 2003) and emergency medical dispatch (Blandford and Wong, 2004). Thus, we believe this concept can also be transferred to road crossing tasks, especially in complex situations such as those studied here for crossroad crossing, where pedestrians cope with multiple sources of information coming from the different sides of the crossroads.

5. Conclusion

The grid used in this study for *in situ/in vivo* observations appears to be an effective tool to finely assess the behavior of pedestrians seeking to cross a street. Overall, the results obtained in this study provide validation for our three hypotheses on gender differences in a crossing task at urban crossroads. Gender differences are found in temporal crossing compliance and in visual search strategies. Such a dichotomy between men and women is refined according to the moment when the action takes place (before or during crossing). Furthermore, differences are found according to the crossroad configuration for spatial crossing conformity in both genders and for visual search strategy among women. Different relationships to rules and social control among males and females seem to be on display in visual search strategies and

decision-making. Further studies are needed to confirm these assertions on gender differences in visual search and compliance during pedestrian crossing.

In summary, behaviors among males tend to be more independent of the rules than those of females. These gender differences seem to be due to difference in motivation to comply with temporal crossing rules and the importance of social factors in women's displays through their visual search strategy. Previous research has suggested that gender differences in compliance and risk-taking can be explained by social pressures on gender role-playing (Granié, 2009; Yagil, 2000). These results highlight the need for researchers to gain a better understanding of how gender role pressures lead women to internalize traffic rules more than men do and how the internalization of temporal crossing rules might be increased among men in order to reduce pedestrians' accident rates.

Our findings also suggest that pedestrians cannot be assumed to be consistently safe in their behavior and that they are more or less compliant depending on the crossroad configuration. The onus thus has to be placed not only on adjusting pedestrian behavior toward traffic but also on adjusting driver behavior toward pedestrians by creating more alert drivers and traffic calming zones.

Acknowledgements

The authors wish to thank the French Road Safety Foundation for funding this research.

References

Akin, D., Sisiopiku, V.P., 2000. Estimating spatial crossing compliance at pedestrian crosswalks. In: Proceedings of the 70th ITE Annual Meeting, Nashville, TN.

Assailly, J.-P., 2001. La mortalité chez les jeunes [Mortality among teenagers] Que sais-je? P.U.F., Paris.

Bergeron, J., Bélanger Bonneau, H., Bourbeau, R., Thouez, J.P., Rannou, A., 1998. Influence des caractéristiques des individus et de l'environnement sur le taux de respect de la signalisation chez les piétons et les cyclistes [Influence of individual and environmental characteristics on compliance with road signs and markings among pedestrians and cyclists]. Université de Montréal, Montréal, Qc.

Blandford, A., Wong, B.L., 2004. Situation awareness in emergency medical dispatch. Internation Journal of Human-Computer Studies 61 (4), 421-452.

Bolstad, C.A., 2001. Situation awareness: does it change with age? 45th Meeting of the Human Factors and Ergonomics Society. St.Paul, Minneapolis.

Brenac, T., Nachtergaële, C., Reigner, H., 2003. Scénarios types d'accidents impliquant des piétons et éléments pour leur prévention [Accident prototypical scenarios involving pedestrians and elements for their prevention]. Rapport n°256 Les collections de l'INRETS, Arcueil.

Byrnes, J.P., Miller, D.C., Schafer, W.D., 1999. Gender differences in risk taking: a meta-analysis. Psychological Bulletin 125 (3), 367-383.

Coleman, J.F., Blake, R.R., Mouton, J.S., 1957. Task difficulty and conformity pressures. Journal of Abnormal and Social Psychology 57, 120-122.

Endsley, M.R., 1988. Design and evaluation for situation awareness enhancement. In: Proceedings of the Human Factors Society 32nd Annual Meeting, Santa Monica, CA.

Endsley, M.R., 1995. Toward a theory of situation awareness in dynamic systems. Human Factors 37, 32-64.

Endsley, M.R., 2000. Theoretical underpinnings of situation awareness: A critical review. In: Endsley, M.R., Garland, D.J. eds. Situation Awareness Analysis and Measurement. Lawrence Erlbaum Associates, Mahwah, N.J., pp. 1-24.

Forsythe, M.J., Berger, W.G., 1973. Urban pedestrian accident countermeasures experimental evaluation. Vol 1, Appendix C: Behavioral evaluation Summary Data, Biotechnology, Inc. Falls Church, VA. US Department of Transportation, Washington DC.

Geruschat, D.R., Hassan, S.E., Turano, K.A., 2003. Gaze behavior while crossing complex intersections. Optometry Vision Science 80 (7), 515-528.

Granié, M.-A., 2007. Gender differences in preschool children's declared and behavioral compliance with pedestrian rules Transportation Research Part F: Traffic Psychology and Behaviour 10 (5), 371-382.

Granié, M.-A., 2009. Sex differences, effects of sex-stereotype conformity, age and internalization on risk-taking among pedestrian adolescents. Safety Science 47, 1277-1283.

Graziano, W.G., Jensen-Campbell, L.A., Lundgren, S.R., 1993. Social influence, sex differences, and judgments of beauty: putting the interpersonal back in interpersonal attraction. Journal of personality and social psychology 65 (3), 522-531.

Grolnick, W.S., Deci, E.L., Ryan, R.M., 1997. Internalization within the family: the self-determination theory perspective. In: Grusec, J.E., Kuczynski, L. eds. Parenting and children's internalization of values. John Wiley, New York, pp. 135-161.

Gugerty, L., Brooks, J., Treadaway, C., 2004. Individual differences in situation awareness for transportation tasks. In: Banbury, S., Tremblay, S. eds. A Cognitive Approach to Situation Awareness: Theory, Measures and Application. Ashgate Publishers, London, pp. 193-212.

Gugerty, L.J., 1997. Situation awareness during driving: explicit and implicit knowledge in dynamic spatial memory. Journal of Experimental Psychology: Applied 3 (1), 42-66.

Harré, N., Field, J., Kirkwood, B., 1996. Gender differences and areas of common concern in the driving behaviors and attitudes of adolescents. Journal of Safety Research 27 (3), 163-173.

Holland, C.A., Hill, R., 2007. The effects of age, gender and driver status on pedestrians' intentions to cross the road in risky situations. Accident Analysis & Prevention 39, 224-237.

Joly, M.-F., Thouez, J.P., Bourbeau, R., Bussière, Y., Rannou, A., 1988. Geographical variation in traffic-related mortality and morbidity among pedestrians in Québec, 1983-1988. Journal of Advanced Transportation 26 (1), 61-77.

Latrémouille, M.-E., Thouez, J.-P., Ranou, A., Bergeron, J., Bourbeau, R., Bussière, Y., 2004. Le sexe est-il une variable pertinente pour l'étude du comportement des piétons en intersection urbaine? [Is gender a relevant variable when studying the behaviors of pedestrians at urban intersections?]. Recherche - Transports - Sécurité 84, 171-188.

Leaf, W.A., Preusser, D.F., 1999. Literature review on vehicle travel speeds and pedestrian injuries in US Department of Transportation. National Highway Traffic Safety Administration, Washington, DC.

Lee, M.B., Suh, K.S., Whang, J., 2003. The impact of situation awareness information on consumer attitudes in the Internet shopping mall. Electronic Commerce Research and Applications 2, 254-265.

Mazman, S.G., Usluel, Y.K., Çevik, V., 2009. Social influence in the adoption process and usage of innovation: gender differences. Engineering and Technology 49, 409-412.

Moyano Diaz, E., 2002. Theory of planned behavior and pedestrians' intentions to violate traffic regulations. Transportation Research Part F: Traffic Psychology and Behaviour 5 (3), 169-175.

MTO, 2002. Rapport annuel sur la sécurité routière de l'Ontario [Annual report on road safety in Ontario]. Ministère des Transports de l'Ontario, Ottawa.

Rivara, F.P., Booth, C.L., Bergman, A.B., Rogers, L.W., Weiss, J., 1991. Prevention of pedestrian injuries to children: effectiveness of a school training program. Pediatrics 88 (4), 770-775.

Rosenbloom, T., 2009. Crossing at a red light: Behaviour of individuals and groups. Transportation Research Part F: Traffic Psychology and Behaviour 12, 389-394.

Rosenbloom, T., Nemrodov, D., Barkan, H., 2004. For heaven's sake follow the rules: pedestrians' behavior in an ultra-orthodox and a non-orthodox city. Transportation Research Part F: Traffic Psychology and Behaviour 7 (6), 395-404.

Rosenbloom, T., Shahar, A., Perlman, A., 2008. Compliance of Ultra-Orthodox and secular pedestrians with traffic lights in Ultra-Orthodox and secular locations. Accident Analysis & Prevention 40, 1919-1924.

Rouphail, N.M., 1984. Midblock crosswalks: a user compliance and preference study. Transportation Research Record 959, 41-47.

Routledge, D.A., Repetto-Wright, R., Howarth, C.I., 1974. A comparison of interviews and observation to obtain measures of children's exposure to risk as pedestrians. Ergonomics 17 (5), 623-638.

SAAQ, 2002. Bilan routier de la Société d'Assurance Automobile du Québec [Road record of Quebec Car Insurance Society]. SAAQ, Montréal.

Serfaty, D., MacMillan, J., Entin, E.E., Entin, E.B., 1997. The decision-making expertise of battle commanders. In: Zsambok, C.E., Klein, G. eds. Naturalistic decision making. LEA, Mahwah, NJ, pp. 233–246.

Simon, F., Corbett, C., 1996. Road traffic offending, stress, age, and accident history among male and female drivers. Ergonomics 39, 757-780.

Sisiopiku, V.P., Akin, D., 2003. Pedestrian behaviors at and perceptions toward various pedestrian facilities: an examination based on observation and survey data. Transportation Research Part F: Traffic Psychology and Behaviour 6, 249-274.

Thomson, J.A., Tolmie, A.K., Foot, H.C., Mc Laren, B., 1996. Child Development and the Aims of Road Safety Education: A Review and Analysis. Road Safety Research Report No1. H.M.S.O., London.

Thouez, J.P., Bergeron, J., Bélanger Bonneau, H., Bourbeau, R., Bussière, Y., 2001. Analyse comparative des comportements des piétons et des automobilistes à l'égard des piétons au Québec et en Ontario [Comparative analysis of pedestrians' and drivers' behaviors toward pedestrians in Quebec and Ontario]. Université de Montréal, Montréal, Canada.

Tisak, M.S., Turiel, E., 1984. Children's conceptions of moral and prudential rules. Child Development 55, 1030-1039.

Tolmie, A., Thomson, J., Foot, H., Whelan, K., Sarvary, P., Morrison, S., 2003. Training children in safe use of designated crossings. Department of Transport, London, pp. 79.

Turiel, E., 1983. The development of social knowledge: morality and convention Cambridge University Press, Cambridge.

Underwood, J., Dillon, G., Farnsworth, B., Twiner, A., 2007. Reading the road: the influence of age and sex on child pedestrians' perceptions of road risk. British Journal of Psychology 98, 93-110.

Van der Molen, H.H., 1983. Pedestrian ethology University of Groningen, Groningen.

Yagil, D., 1998. Gender and age-related differences in attitudes toward traffic laws and traffic violations. Transportation Research Part F: Traffic Psychology and Behaviour 1, 123-135.

Yagil, D., 2000. Beliefs, motives and situational factors related to pedestrians' self-reported behavior at signal-controlled crossings. Transportation Research Part F: Traffic Psychology and Behaviour 3 (1), 1-13.

Zeedyk, M.S., Kelly, L., 2003. Behavioural observations of adult-child pairs at pedestrian crossings. Accident Analysis & Prevention 35 (5), 771-776.

Zeedyk, M.S., Wallace, L., Spry, L., 2002. Stop, look, listen, and think?; What young children really do when crossing the road. Accident Analysis & Prevention 34 (1), 43-50.

Zhou, R., Horrey, W.J., Yu, R., 2009. The effect of conformity tendency on pedestrians' road-crossing intentions in China: An application of the theory of planned behavior. Accident Analysis and Prevention 41, 491-497.