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AN EXAMINATION OF CHILD PEDESTRIAN SAFETY: CROSSING BEHAVIORS, ROAD ENVIRONMENT, AND RULE COMPLIANCE NEAR PARKS IN MONTREAL, CANADA

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To my family, who have made me stronger and more fulfilled; love you to the moon and back.

ABSTRACT

In the past decades, physical activity of children has declined due to many reasons, such as unsafe roads, which can negatively influence parents' attitudes toward allowing their children to spend time outdoors. Urban parks, as natural and outdoor places, can promote children's physical activity and psychological health. However, child pedestrians' safety on roads next to parks has not been fully investigated. In order to fill this research gap, this study examines child pedestrians' safety considering four rule compliance measures: temporal, spatial and velocity compliance and visual search.

We employed a naturalistic approach to observe behaviors, road environment, and car interaction while children were crossing roads near parks. In this study, street crossings of 731 children were observed at 17 crosswalks around four parks in Montreal, Canada in the summer of 2017. Then, Chi-square tests were used to verify if the individual, situational, behavioral, and road environment characteristics are significantly associated with rules compliance. These characteristics were explored through mixed-effect logistic regression with the same set of independent variables.

Our results showed that parental close supervision, stopping at the curb before crossing, and the pedestrian countdown display had positive association with rule compliance. Moreover, about 50% of children started crossing at the same time as the adult companion. In the remaining group, more rule violations were observed when the adult initiated the crossing. As for effects of vehicles interacting with child pedestrians, a mixed impact on four rule compliance was observed: more spatial compliance and visual search, but less temporal and velocity compliance.

The current study outcomes can be used to provide safer road environment near urban parks. In this regard, longer crossing signal and pedestrian countdown display at traffic lights are quite advantageous.

Keywords: road traffic safety, crossing behavior, child pedestrian, rule compliance, intersection, urban parks

RÉSUMÉ

L'activité physique des enfants a diminué dans la dernière décennie pour de nombreuses raisons, notamment les routes dangereuses qui empêchent les parents de laisser leurs enfants jouer à l'extérieur. En parallèle, nous savons que les parcs urbains peuvent promouvoir l'activité physique et la santé mentale des enfants. Pourtant, peu de travaux de recherche se sont intéressés à la sécurité routière des enfants piétons à proximité des parcs. C'est pourquoi la présente étude examine leur sécurité en tenant compte de la conformité aux règles relatives aux piétons.

L'approche naturaliste a été adoptée afin d'observer les comportements des enfants, l'environnement routier et les interactions avec les voitures durant la traversée. Les tests Khi-deux ont été réalisés pour mettre en évidence les caractéristiques individuelles, situationnelles, comportementales et de l'environnement routier associées à la conformité aux règles. Ces caractéristiques ont été analysées à l'aide des modèles de régression logistique à effets mixtes.

Les résultats ont montré que la supervision des adultes, s'arrêter au bord du trottoir avant de traverser et la présence d'un compte à rebours sont positivement associées à la conformité aux règles. Environ 50% des enfants ont commencé à traverser en même temps que le compagnon adulte. Dans le groupe restant, plus de violations de règles ont été observées lorsque l'adulte a initié la traversée. L'interaction piéton-voiture a eu un impact mitigé sur la conformité aux quatre règles, ce qui a eu pour effet d'améliorer la conformité spatiale et la recherche visuelle, mais de réduire la conformité temporelle ainsi que la vélocité.

Nos résultats pourraient être utiles pour les municipalités désirant améliorer la sécurité des enfants autour des parcs urbains. À ce titre, allonger les temps de traversée et ajouter des décomptes numériques aux intersections avec feux semblent avoir un effet positif en ce sens.

Mots-clés : sécurité routière, comportement de traversée, conformité des enfants piétons, intersections, parcs urbains.

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LIST OF ABBREVIATIONS

AMT	Agence Métropolitaine de Transport
CCMTA	Canadian Council of Motor Transportation Administrators
CMVTC	Canadian Motor Vehicle Traffic Collision
CIHR	Canadian Institute of Health Research
ESSAIM	Environnement scolaire sécuritaire et analyse des interventions municipales
INRS	Institut National de la Recherche Scientifique
GP RED	GreenPlay Research, Education, and Development
MAPISE	la Marche À Pied pour les SEniors
MUTCD	Manual on Uniform Traffic Control Devices
NICE	National Institute for health and Care Excellence
NRPA	National Recreation and Park Association
QHSC	Quebec Highway Safety Code
RPP	Rosemont-La Petite-Patrie
SAS	Statistical Analysis System
SRTP	Safe Route to Park
SWOV	Institute for Road Safety Research
UI	Unintentional Injuries
VRU	Vulnerable Road Users
VSP	Villeray-Saint Michel-Parc extension
WHO	World Health Organization

INTRODUCTION

Regular physical activity is necessary for children's health because it decreases the incidence of chronic disease and influences children's energy level. Children with the adequate physical activity are more likely to have a healthy lifestyle in the future, and its benefits are seen over their lifespan. For children who live within a reasonable walking distance from a school, park, and playground, active transport can be a great opportunity for them to have physical activity on a regular basis. Since the benefits of children's physical activity affect their lifespan, a decrease in this type of activity is a major concern for children around the world. However, it was reported by Tremblay, Brownrigg and Deans (2008) that children and young Canadians spend less time to walk to and from their destination, such as school, parks, and extracurricular activity spots as significant sources of physical activity. This is partly attributed to the road safety concerns making the parents drive them to destinations.

Children are one of the major groups in society that face road risks. According to a Safe Kids Canada report (2007), one of the most important death causes for children under 14 years old was pedestrian injuries. More specifically, about 18% of the deaths were for children between five and nine years old as a result of a collision with motor vehicles. Previous research mainly focused on the safety of child pedestrians around their schools, as the school was their main destination. Although parks and playgrounds are also known as frequent destinations for children especially in urban settings, few studies examined children's safety on the road around parks.

The current study aims to fill this gap regarding child pedestrian safety via examination of individual, situational, behavioral and road environment characteristics determining whether children comply with various road safety rules during street crossings towards parks. Hence, the overall objective of this study is to examine child pedestrian's safety around parks by considering four rule compliance measures: temporal, spatial and velocity compliance, and visual search.

This thesis is organized into five chapters. The first chapter explores the basic safety concept, unintentional injuries (UI) of children, importance of urban parks, and safe routes to parks for children. This chapter presents various elements including the research question, objectives, and the conceptual framework. The second chapter explains in more details influential factors on child pedestrian injury and various pedestrian rules compliance.

The third chapter presents the methodological approach used to carry out the present study, including the study areas, the creation of data collection tools, and the methods of analysis. The fourth chapter is a manuscript submitted to the Journal of Environmental Psychology which presents the results of predictive models of rule compliance. Finally, the last chapter includes the discussion on the results using the factors that could explain child pedestrian compliance with various road safety measures. This chapter also provides the limitation of the current study and the conclusion.

CHAPTER 1: BACKGROUND: CHILDREN ACTIVE TRANSPORTATION, SAFETY, AND IMPORTANCE OF URBAN PARKS

1.1 Road insecurity and decline in children active transportation

In many developed countries, one hour of physical activity per day has been the suggested norm for children (Carver, Timperio and Crawford 2008; Tremblay et al. 2016). Since many children seem to fail to accomplish this daily prescription (Weiler et al. 2014), any opportunity to stay active should be explored. For instance, time spent outdoors leads to an increase in the regular physical activity of children, which can decrease the chances of chronic health problems such as obesity (Bouchard, Blair and Haskell 2007). Sallis et al. (2004) stated that active transportation is another way of getting those daily minutes of physical activity.

Routine travel in the form of commuting to school offers opportunities for walking at an early age for students and their parents (Bouchard, Blair and Haskell 2007). However, despite all the benefits of the physical activity, many parents today drive their children to schools, parks, and playgrounds (Tremblay, Brownrigg and Deans 2008). This is reflected in recent statistics in Canada where active transportation decreased from 25% to 19% between 1998 and 2005 (Turcotte 2008). In the Montreal region, a similar decrease in the active transportation from 45% to 34% between 1993 and 2003 can be seen among of children 6–12 years old (L'Agence Métropolitaine de Transport 1998,2003).

High traffic-risk perception is one of the reasons leading parents to using other types of transportation to school for their children (Cloutier, Bergeron and Apparicio 2011), which reduces children's opportunities to be physically active. Other examples illustrate this risk perception: in New Zealand, parents are worried about their children mostly due to the road safety, personal injuries, stranger danger, and bullying (Carver, Timperio and Crawford 2008). Another study by Gielen et al. (2004) in Maryland, USA, showed that about 70% of parents limited their children from playing outdoors because of danger associated with cars and trucks. Furthermore, for most English children between 9 and 11 years old, the important concern was safety on main roads (Matthews 1995). To some extent, road insecurity while crossing streets might be a good reason for parents and children to avoid walking to their destinations for safety reasons, either real or perceived.

1.2 Safety concept and unintentional injuries

1.2.1 Safety concept

According to the first international conference of World Health Organization (WHO) on injury prevention and control, safety is the control of those hazards leading to physical and psychological harm in order to preserve individual and community health; all people need safety to achieve their goals in life (World Health Organization 1989). Following this idea, safety should be seen as a fundamental human right and should be equal for all individuals and communities (World Health Organization 1989). In other words, safety as a basic need of humans is a necessity to raise the level of health and the social welfare of societies (Svanström 1999).

Another concept introduces safety as a dynamic process in terms of safety promotion (Maurice et al. 1997). The goal of safety promotion is to achieve optimum conditions of safety that are the ultimate requirement of human beings. Maurice et al. (1997) implied that accidents not only were not uncontrolled events, but also could be avoided once the risk factors of an activity were elucidated. This is in contrast to the concept of safety that states that accidents are uncontrolled occurrences leading to individual's harm and injury (World Health Organization 1989).

Maurice et al. (1997) stated that safety consists of two different dimensions (Figure 1.1): one is objective which is evaluated by behavior and environment parameters; the other is subjective, which is based on the feeling of safety or insecurity in the society. Forde (1993) believed that both dimensions affect each other, and all societies should adapt their safety promotion considering these components. To provide two-way and active relations between objective and subjective dimensions, one should recognize and evaluate the problems and plan for interventions (Maurice et al. 1997). In this figure and the other ones come afterwards, the arrows show causal relations.

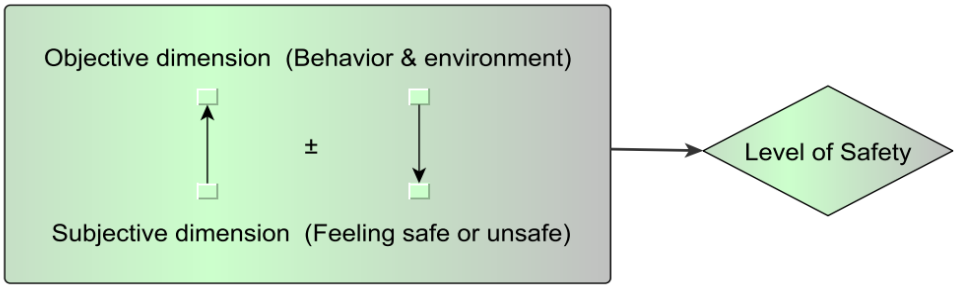

Figure 1.1 Two dimensions of safety
Source: Maurice et al. (1997)

Maslow (1968) introduced the concept of safety as a psychological need of humans to improve their health. He stated that behaviors and environmental conditions are another items affecting the safety and health of a society. According to Maslow's thoughts, health as an outcome of the level of safety would be determined by behavior and environment. As depicted in Figure 1.2, children's behaviors and the road environment resulted in the child pedestrian safety, and consequently the children's health.

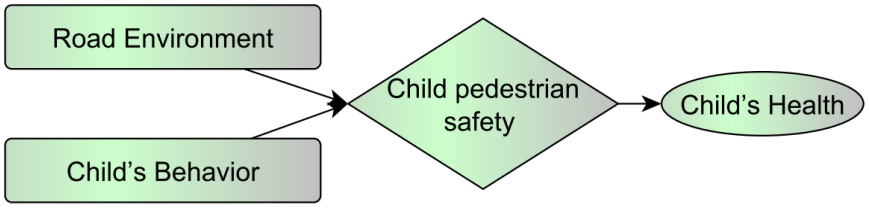

Figure 1.2 Two links between safety and health of children

Source: inspired by Maslow (1968)

Pedestrians are Vulnerable Road Users (VRU), this term applies to those who are at risk in traffic more than others. The Institute for Road Safety Research (SWOV) suggested three criteria to distinguish VRU from other road users: the absence of a protective "shell" in traffic to protect against kinetic energy (e.g. pedestrians, cyclists, and to some extent, motorcyclists); task capability (e.g. children and older adults); and resilience in case of injuries (e.g. older adults and people with disabilities) (Hakkert and Braimaister 2002). Because of these criteria, the injury and death risk associated with each transport mode is unequal. A small, light, slow pedestrian such as a child cannot rapidly absorb the kinetic energy of a heavy vehicle moving without sustaining severe injury, and this is why we should prevent those collisions through a systematic approach.

Historically, pedestrians are important road users who are not considered enough in the improvement of road user safety (Canadian Motor Vehicle Traffic Collision 2013). The safe system approach developed in Europe to tackle the road injury burden stresses the need to act on many levels at the same time for safe speeds, safe vehicles and safe roads and roadsides (Figure 1.3). In the system approach, humans are found to be vulnerable to injury, and it is believed that a safe road traffic system could significantly reduce the human vulnerability (World Health Organization 2009). Accordingly, evidence-based research supports built environment interventions of any type as long as they are locally appropriate, and suggests not to rely solely on educational interventions. The role of education is to generate public support and compliance with more effective built environment interventions, but not to stand alone as a solution(Wu et al. 2007).

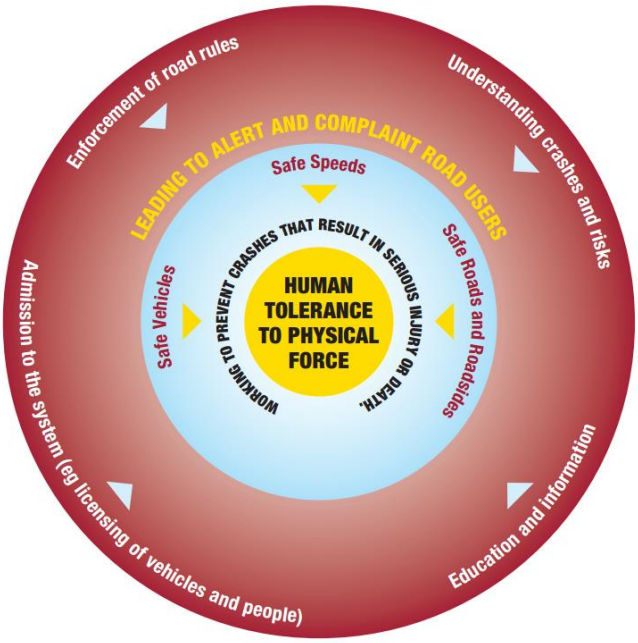

Figure 1.3 The system approach to road safety
Source: CCMTA (CCMTA 2013)

1.2.2 Unintentional Injuries (UI) in children

The National Institute for health and Care Excellence (NICE) (2016) studied injuries in children under 15 years old at home and used the term Unintentional Injury (UI) instead of accidents. UI was also used by Davis and Pless (2001) to emphasize that the injuries are usually predictable and preventable. NICE (2016) reported that the possibility of unintentional injuries occurrence depends on several factors: individual characteristics such as age, behavior characteristics such as risk taking, and the environment factors. These factors can be considered as effective parameters to predict the children's injuries.

Unintentional injuries are the main reason for the hospitalization and death of children, particularly for child pedestrians (Peden 2008; Turner et al. 2004). Injuries in child pedestrians younger than 14 years represent about 12% of all injuries leading to death (CCMTA 2013). Encountering child pedestrians and motor vehicles are the most common reasons for fatality and injuries in young ages in the most of industrialized countries (Meir, Oron-Gilad and Parmet 2015). In Canada, between 1994 and 2003, about 56 child pedestrians under the age of 14 years died every year, and about 780 in the same age category were hospitalized with serious injuries (Safe Kids Canada 2007). According to Safe Kids Canada (2007), about 70% of the mortality cases and 50% of those

suffering from serious injuries were reported where there was no form of traffic control. This report also stated that for child pedestrians between five and nine years old, those injuries leading to death are due to motor vehicle accidents, and injuries of pedestrians among 10 and 14 years old are possibly related to risk taking and inattention to vehicles (Safe Kids Canada 2007). Another study for the period between 2003 and 2012 for Canadian children under 14 years old stated that 12% of UI leading to death happened as a result of child pedestrians being struck by a vehicle (Parachute Canada 2016).

1.3 Urban parks and children's safety

Urban parks play a key role in the urban landscape, environment, and ecological services. These parks are important to improve the social, physical, and psychological conditions of citizens, including children (Chiesura 2004; Bedimo-Rung, Mowen and Cohen 2005; Ho et al. 2003). One of the major consistent predictors of children's physical activity is the time spent outdoors, and parks provide the best settings for it (Ho et al. 2003). Children's outdoor play, after school gives them a balanced life, because of the connections they build with nature. Although children's skills, autonomy, and creativity increase by learning how to work with facilities in playgrounds (Alberta Recreation and Park Association 2010), Herrington and Brussoni (2015) stated that today's boring and over-controlled playgrounds are among the places that are least open to autonomy and creativity, particularly if kids are supervised.

Neighborhood characteristics surrounding parks, their accessibilities, safety perceptions (not only about the roads but also about attacks), and aesthetics influence the use of parks by nearby residents (Bedimo-Rung, Mowen and Cohen 2005). In contrast, the most common barriers to using parks for all ages are personal safety concerns, long distance between home and park, and poor quality of park facilities (Scott and Munson 1994; Cordell et al. 1999).

Reviewing the previous research concerning children and urban parks showed that they have been mainly carried out in two major streams: those looking at the health benefits of using parks and those looking at reasons to visit them (or not), which is the scope of the current study.

1.3.1 Safe route to parks for children

Parks and playgrounds are the most important destinations of children after school (Timperio et al. 2004). Despite this fact, few research studies target the safety of roads near parks compared to those on safety and quality of facilities in the parks (Allen et al. 2013), or on accessibility and equity in their spatial distribution (Reyes, Páez and Morency 2014). This study will focus on those research that address safe routes to parks. They provide useful tools and planning guidelines but some have research-based evidence.

National Recreation and Park Association (NRPA) (2016) employed a framework called "Safe Routes to Parks" to assess if policies and practices support safe and equitable access to parks for all users including children. They identified and prioritized parks based on demographic, traffic, health, and location information. Then, these data were used to suggest design safety factors on streets within and leading to parks, including signs and signals, traffic calming devices, marked crosswalks, and bike lanes.

The Safe Routes to Play (SRTP) created by GP RED (GreenPlay Research, Education, and Development) is another planning process to increase safe routes to play for children focusing on active transportation, such as walking and biking, implemented in Lebanon, New Hampshire. According to the parent survey results, within their neighborhood, children usually tended to either walk or bike to playgrounds, but when it came to playing outside their neighborhood, the majority of them preferred to use a vehicle. In this regard, parents stated some reasons for not using active transportation, in order of importance: lack of pathways, road traffic, distance, speed of traffic along route, safety at intersections and crossings, and violence or crime (Research Education and Development 2014).

Ferenchak and Marshall (2017) studied child pedestrians' safety on roads around parks and schools. They considered the urban locations where child pedestrians were facing fatal collisions with vehicles. Their results demonstrated that the risk around parks was higher than that around schools in all of their case studies. They suggested that, in addition to schools, parks are important locations to focuseon in the field of child pedestrian fatalities.

1.4 Research question and conceptual framework

The literature reviews have demonstrated that little attention has been paid to the road safety conditions around parks. Most of the studies referred to the safety of equipment and facilities in the park, proximity, and accessibility of the park to children. It is surprising that there are few studies on safety of children walking to parks and playgrounds. As child pedestrians' behaviors play a crucial role in their safety while crossing streets, this research concerns the factors with respect to child pedestrians affecting their safe crossing. Hence, the main question of this study is: *which characteristics are related to the safe crossing behavior of child pedestrian by considering rule compliance near parks?*

In the past two decades, ecological models have been widely used by researchers to guide behavior of populations in order to reduce potential health problems (Norman et al. 2006). Sallis et al. (1993) believed that the health and well-being of children resulted from interactions between behavioral, environmental, social, family, and public policy factors. In order to evaluate this belief, they employed an ecological model to assess children's physical activity behaviors, such as walking to school or using a park.

Inspired by above-mentioned studies, we would like to introduce our own view in order to answer our research question. Figure 1.4 highlights our operative framework presenting the individual, situational, behavioral, and road environmental characteristics. We expected that these four groups of factors would be associated with the likelihood of child pedestrian's rule compliance, which in turn influence crossing safety. It is worth mentioning that in our operative framework, compliance to pedestrian road rules and child's crossing safety are considered at the same level of pedestrian safety, as also pointed out by Şimşekoğlu and Akin and Sisiopiku (Şimşekoğlu 2015; Akin and Sisiopiku 2007). In this regard, Şimşekoğlu (2015) stated that low level of compliance with road rules and unsafe behaviors from either drivers or pedestrians are the main reasons for the low level of pedestrians' safety. In other words, appropriate usage of crosswalks (complying with rules) by pedestrians and motor vehicles users increases the safety of pedestrians (Akin and Sisiopiku 2007). The detailed description of our framework is provided in Chapter 3.

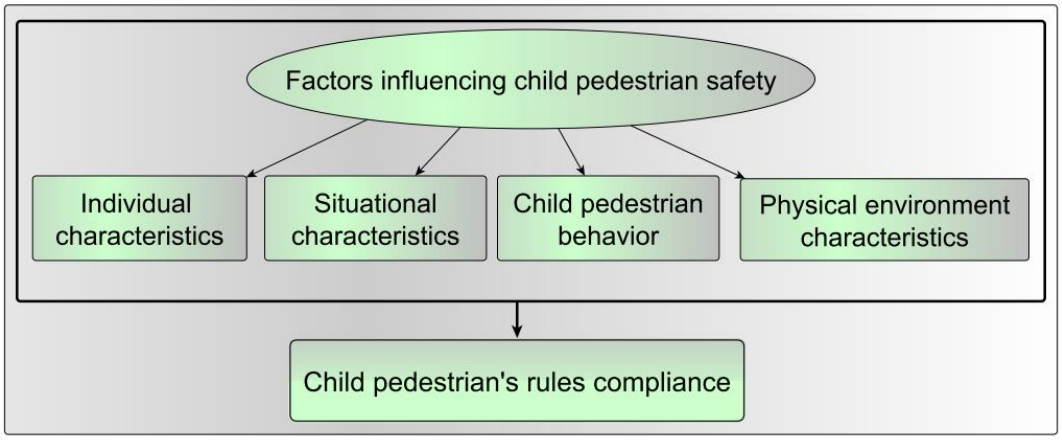

Figure 1.4 Operative framework employed in the current study
Source: Author (2018)

CHAPTER 2: LITERATURE REVIEW: CHILD PEDESTRIAN INJURIES AND RULE COMPLIANCE

Now that we have stated our research question, the second chapter will review the literature on two aspects: factors influencing child pedestrian injuries and rule of compliance, which are the two main elements of our question.

2.1 Factors influencing child pedestrian injury

Many studies in the last decades investigated the factors influencing the safety of children on roads. In fact, pedestrian injury risk has multiple complex explanatory factors, such as human and environmental ones (Cinnamon, Schuurman and Hameed 2011). With regards to the presence of a variety of risk factors influencing the safety of children, Fuselli et al. (2012) stated that a great number of children and young people's injuries are preventable. In addition, Desapriya et al. (2011) stated that child pedestrian fatalities could be highly preventable by control and modification of risk factors related to behavior, social, and environmental characteristics. Because injuries remain the leading cause of children's and youths' death and disability, prevention must be incorporated into strategies aimed at improving child's health (Yanchar et al. 2012).

Road traffic injuries involving children are known to be a consequence of the interaction of a variety of factors (Petch and Henson 2000). Four categories sum up most of the main influential factors on child pedestrian injury risk: individual demographics, situational, behavioral, and road environment characteristics (Schuurman et al. 2009; Rosenbloom, Ben-Eliyahu and Nemrodov 2008; Wazana et al. 1997). These factors are presented in more details in the following sections.

2.1.1 Individual demographics: children's age and gender

Demographic characteristics such as age, gender are known as predictors of child pedestrian injuries (Assailly 1997; Parachute Canada 2016; Schieber Richard and Vegega Maria 2002; Schuurman et al. 2009). According to a study by Connelly and Isler (1996) based on international road accident statistics, younger child pedestrians are more at risk than older ones. Children between five and seven years old are at a higher risk in Britain, while New Zealand, the United States, and Canada have the highest estimated rate of accidents for five to nine years old children.

Age matters for two reasons: Firstly, it is important to perceive what is significant in the surroundings (Bolstad and Hess 2000), and the awareness of what is happening around a person is related to experience (Bolstad 2001). Hence, younger children, with lack of adequate knowledge and experience, are less competent in traffic when compared with older ones (Dunbar, Hill and Lewis 2001; Whitebread and Neilson 2000). Secondly, crossing the street includes complex processes and behaviors, which are not developed in young children (CCMTA 2013). Younger children's ability to recognize safe behaviors in road crossing starts to develop from about six to ten years old, following their cognitive development (Oxley et al. 2005). In other words, older children can avoid the errors leading to injury because of a better understanding of road issues (Rosenbloom, Ben-Eliyahu and Nemrodov 2008).

According to a study by Schieber and Vegega (2002), children's ability to be aware of traffic signs and simple traffic rules are determined by their cognitive development level. Perceptual development defines children's abilities to diagnose oncoming car speed, and to visually pay attention to the environmental elements. Due to the lack of cognitive ability and perception at a younger age, children are more at risk (Dunbar, Hill and Lewis 2001; Whitebread and Neilson 2000). In other words, there are some factors that jeopardize children in roads: they might be not able to correctly evaluate traffic situations; their decisions might be not followed by an appropriate behavior which is common in their age group; and they might inappropriately react to traffic situations (Rosenbloom, Ben-Eliyahu and Nemrodov 2008). Hence, children more than other pedestrians need to cross where roads are safer, where we give them sufficient time to cross before vehicles arrive, and where traffic situation is easy to respond to (Te Velde et al. 2005).

Boys (and men), no matter how old they are, tend to exhibit more risky behaviors, in part because they have more confidence in their ability to deal with accidents (Granié 2007).Two factors, higher risk exposure and behavioral differences, contribute to a higher number of pedestrian accidents involving boys (Assailly 1997). Some explanations from previous studies, illustrated by Barton and Schwebel (2007), explain the gender differences in injury rates by the boys' tendency to exhibit more uncontrolled behavior, and a higher chance of repeating risky behaviors compared to girls. In other words, since boy pedestrians have a tendency to be less attentive to the road rules than girls (Granié 2007), often the rate of injuries and fatalities among boys are higher than for girls (Connelly and Isler 1996).

2.1.2 Situational Characteristics while walking/crossing as a pedestrian

Situational factors while crossing, such as parental supervision, have an influence on safety and compliance of pedestrians (Cinnamon, Schuurman and Hameed 2011). Therefore, situational factors considered in the current study include presence of adults (supervision), adults' gender, presence of other pedestrians, occurrence of a child pedestrian-vehicle interaction, and presence of parked cars within crosswalks.

A. Adult Supervision

Road supervision by parents could prevent most injuries among young children, and the absence of or delinquency in supervision could lead to a variety of child pedestrian injuries (Morrongiello 2005). In other words, parental supervision performs the role of children protector from the pedestrian injury risks (Schwebel, Davis and O'Neal 2012), because accompanying adults can intervene when the child behaves dangerously in a pedestrian environment (Barton and Schwebel 2007). Figure 2.1 highlights a dynamic process including environment and child variables shaped by situational factors determining the safety of child pedestrians. "Caregiver" (supervisor) was also added to this model by Morrongiello al. (2005) as the most effective factor to reduce child injuries.

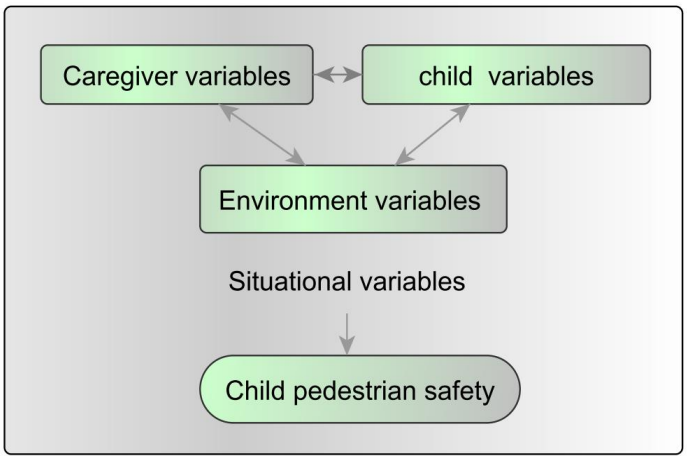

Figure 2.1 Conceptual model of child pedestrian safety with emphasis on the supervision
Source: inspired by Morrongiello et al. (2005)

Since children are normally under the supervision of parents (depending on their age and culture), parental factors have been known for a long time as important factors in examining childhood

pedestrian injuries (Lam 2001). However, as stated by Schwebel, Davis and O'Neal (2012), the positive influence of parental supervision on child pedestrians is not straightforward. For instance, some previous studies stated that children are less likely to run while holding hands with an adult companion (Fu and Zou 2016; Granié 2007; van der Molen 1982). Similarly, the study by Zeedyk and Kelly (2003) shows that the majority of adult-child pairs waited for the next green light before crossing. On the contrary, another study pointed out that the presence of adults did not have an influence on the decrease of some critical behaviors, including not stopping before crossing, and not looking before crossing (Rosenbloom, Ben-Eliyahu and Nemrodov 2008). Also, when children are crossing street with adults, both girls and boys exhibit the same behavior, except for holding hands: more adults took a girl's hand than a boy's (Zeedyk and Kelly 2003).

B. Gender of adult companion

Previous studies have stated that gender differences were related to the level of risk taking for adult pedestrians (Tom and Granié 2011; Rosenbloom 2009; Koh, Wong and Chandrasekar 2014). Also, much research with a focus on pedestrian's gender has shown that risky behavior and attitude are more common factors in males, and they have no relation to age (Rosenbloom and Wolf 2002; Harré, Brandt and Dawe 2000). Thus, male pedestrians have more tendency to violate rules than do females (Rosenbloom, Nemrodov and Barkan 2004). In this regard, Bergeron et al.'s (1998) study showed that, in the City of Montreal, the rate of women's compliance with road signs and markings is about 10% higher than that of men's.

C. Presence of other pedestrians

When pedestrians cross a street, their surrounding environment might include the presence of other pedestrians. Sucha, Dostal and Risser (2017) stated that one of the most common situations experienced by a pedestrian was the "presence of other pedestrians" while crossing on marked crosswalks. The question then is to know whether this makes a difference in a pedestrian's behavior and decision to cross, and the answer is not straightforward: there are contradictory results showing positive and negative influence of other pedestrians on road crossing behavior (Havard and Willis 2012; Yagil 2000). On one side, there is the "safety in numbers" hypothesis made by Jacobsen (2003) and (2015) stating that increase in the number of pedestrians leads to a decrease in the number of injuries (Geyer et al. 2006). Rosenbloom (2009) found that the

presence of other pedestrians increases the rule compliance when compared with that of a lone pedestrian. The same study also showed that illegal behavior of a pedestrian did not have an impact on the behavior of others. Moreover, Lachapelle and Cloutier (2017) depicted that being in larger groups increases the chance of finishing their crossing on time for adult and senior pedestrians.

On the other side, Faria, Krause and Krause (2010) found that, if nearby pedestrians started to cross, a pedestrian was 1.5–2.5 times more likely to cross as well (regardless of the rule compliance). Similarly, Zhou et al. (2011) stated that pedestrians in a group had less tendency to look at traffic signals than did single or paired pedestrians. In addition, when pedestrians were crossing in groups, their walking speed tended to be slower (Carey 2005; Zhang 2012). However, these results are coming from research on adult pedestrians, and it is not clear how the relation would be for child pedestrians.

D. Pedestrian-vehicle interaction

The term *interaction* usually refers to an event where, without any collision, the paths of both a vehicle and a pedestrian intersect while they are still on the roadway (Trozzi, Manley and Kasparias 2015). As conflicts lead to more collisions (Cloutier, Lachapelle and Howard 2018; Sacchi and Sayed 2016), the occurrence of such interaction may alter the trajectory and which may in turn lead to more collisions (Cloutier et al. 2017; Wazana et al. 1997).

Interaction for two road users can be broadly defined as the presence of two road users at an intersection in nearness in time and place so that one of them affects the other (De Ceunynck et al. 2012). Moreover, dangerous situation between two road users arises when one of them complies with informal rules; for example, when driver commits an illegal behavior to reduce driving time. (De Ceunynck et al. 2012).

Among some factors that might cause pedestrian-vehicle interactions, red light violation by pedestrian is one of the significant reasons (Langbroek et al. 2012; Pasanen and Salmivaara 1993). Crossing in designated crosswalks and in a straight line are other factors decreasing the chance of causing an interaction between vehicles and pedestrians (Akin and Sisiopiku 2000). Also, interactions could be minimized with proper visual search and pace of crossing (Langbroek et al. 2012; Wazana et al. 1997).

Regarding child pedestrians, it has been reported that presence of traffic signals at crosswalks near schools decreased by four times the interaction of child pedestrians with vehicles, while presence of stop sign could increase these interactions by about 4.7% (D'Amours Ouellet 2016).

E. Visibility: Presence of a parked car near a crosswalk

As seen before, children's physical features (including their shorter height) can put them at risk since they are not as visible as an adult from long distances (Schieber Richard and Vegega Maria 2002). Accordingly, parked cars create specific risks for child pedestrians, since they restrict the view of both drivers and children. (Petch and Henson 2000). Yannis, Papadimitriou and Theofilatos (2013) reported that the presence of prohibited parking areas near mid-block crosswalks led to more careful behavior by pedestrians. Road injuries can be prevented by making sure that child pedestrians are visible near crosswalks even with the presence of parked vehicles.

2.1.3 Behavior characteristics

The behavior of children is recognized as an influential factor on road injuries (Rosenbloom, Ben-Eliyahu and Nemrodov 2008; Schwebel, Davis and O'Neal 2012). Similarly, Papaioannou (2007) stated that road users' behavior was the most important factor in pedestrian injuries. Despite the importance of the interrelationship between humans and environment, the behavior of pedestrians in different environments is yet an understudied factor in road injuries (Cinnamon, Schuurman and Hameed 2011).

In order to study pedestrian behavior, three levels were modeled by Hoogendoorn, Bovy and Daamen (2002) and used by other scholars (Daamen 2004; Ishaque and Noland 2008; Schadschneider et al. 2009). The first level of pedestrian behavior is expanded at a *strategic level* showing that pedestrians are making decisions on their activities. Then, at the *tactical level* pedestrians are making short-term decisions, such as route choice, according to the density of other pedestrians and obstacles. The last level of pedestrian behavior in this model is the *operational level* describing instantaneous decisions based on actual walking behavior such as walking fast, slowing down, stopping, and waiting before crossing, as well as performing an activity and interaction with other road users (Daamen 2004; Ishaque and Noland 2008; Schadschneider et al. 2009) (Figure 2.2). Actions performed at the operational level are the results of decisions

made at the strategy and tactical levels. For instance, pedestrians on crosswalks with no signals (tactical level) walk faster to save time (operational level) to reach their destination (strategic level) (Schadschneider et al. 2009). The current study occurs at the operational level to examine the behavior (i.e. the rule compliance) of child pedestrians before and while crossing, and see what characteristics are influencing this behavior. The number of common and specific factors involving pedestrian's behavior explained in previous studies will be described here to highlight the behavior characteristics of pedestrians in general. As we are studying children, the information about them in the literature is highlighted in the following sections; otherwise, the results for general pedestrians are provided.

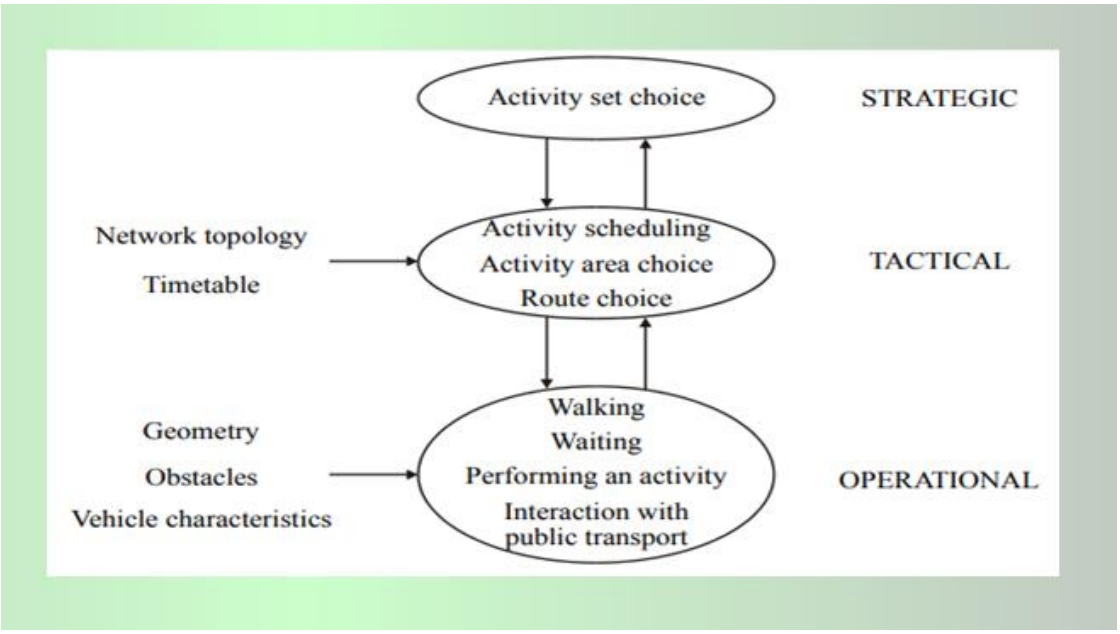

Figure 2.2 Levels in pedestrian behavior
Source: Based on Hoogendoorn et al. (2001)

A. Pedestrian behavior: tempo and activity before and while crossing

The tempo (rhythm of walking) shown before and while crossing is proven to influence the risk of fatalities: the fatal-accident reports involving child pedestrians under 15 years in France showed that nearly seven out of ten cases were pedestrians running or playing (Fontaine and Gourlet 1997). Children in a study by Zeedyk, Wallace and Spry (2002) showed similar behavior, as 75% of them completed the crossing while running or skipping. As well, Fu and Zou (2016) stated that for higher percentage of children, running behavior occurred during the last second of the red man

in the traffic phase light. In a study by D'Amours Ouellet (2016) which is conducted for child pedestrians-vehicle interaction at crosswalks near schools, it was reported that 37.9% of children approached the curb with constant speed or acceleration, while others slowed down or stopped before crossing. Tom and Granié (2011) evaluated the tempo of adult pedestrians while approaching the curb and during crossing by considering regular walking, stopping, slowing down, and running. Their results showed that most of the participants walked regularly to reach the curb, and the majority of them regularly crossed the crosswalk. A few of them ran, stopped, or slowed down in the middle of the crosswalk.

Koh, Wong and Chandrasekar (2014) demonstrated that most adult pedestrians waiting for the next green light at the curb could finish crossing before the red light, and 45% of those starting at flashing hand/clearance phase faced red light at the end. Lachapelle and Cloutier (2017) studied waiting until the next green light at the curb for adults and senior pedestrians. Their results showed that higher percentage of senior pedestrians stopped for the next green light compared to the other age groups.

B. Pedestrian behavior: head and eye movements

Head and eye movements before and during crossing are defined as factors affecting the safety of pedestrians (Rosenbloom, Ben-Eliyahu and Nemrodov 2008; Tom and Granié 2011). These movements go toward the traffic lights, moving vehicles, other pedestrians, and the ground. Tom and Granié (2011) showed that the majority of adult pedestrians at signalized crosswalks looked at the moving vehicles before crossing, while only 19.5% of them looked at the traffic light and 9% at the other pedestrians. At unsignalized crosswalks, more than 82% of pedestrians looked at incoming vehicles before and during crossing, while only 9.5% of the sample looked at other pedestrians before crossing (Tom and Granié 2011).

With regards to child pedestrians, it was found that most of them do not look at both ways before crossing (Zeedyk et al. 2001; Rosenbloom, Ben-Eliyahu and Nemrodov 2008). In a study by Zhuang et Wu (2011), only 3.3% of pedestrians in all age groups did not look left and right before crossing in the waiting zone. D'Amours Ouellet (2016) studied child pedestrian-vehicle interactions at crosswalks near schools. According to their results, 17.1% of child pedestrians looked straight ahead or at the ground without paying attention to vehicles, while 22.1% looked at the vehicles before and during the crossing.

2.1.4 Road environment characteristics

Accidents leading to pedestrian injuries often occur in complex road environments (LaScala, Gerber and Gruenewald 2000). Certain road and physical environment risk factors have been evaluated in previous studies in order to examine safety of pedestrians. In this regard, number of researchers assessed traffic control devices such as presence of traffic light, pedestrian countdown display, traffic sign (e.g. speed limit), and marked crosswalks (Sisiopiku and Akin 2003; Paschalidis et al. 2016; Mitman, Ragland and Zegeer 2008; Wazana et al. 1997). In addition, some other studies have investigated required crossing time, crosswalk width, and required crossing speed (Lobjois and Cavallo 2007; Chandra and Bharti 2013; Rastogi et al. 2011; Akin 2000). The above-mentioned road environment risk factors are elaborated in detail in the following sections.

A. Intersection and crosswalk environment

As explained above, lack of appropriate roads and crosswalks put child pedestrians' safety at risk. Many crosswalk characteristics can then be taken into consideration when trying to improve the safety of crossing. Based on the Manual on Uniform Traffic Control Devices (MUTCD) (2009), it is expected that signalized and controlled intersections have a positive impact on the safety of road users (Wang and Abdel-Aty 2014).

In fact, uncontrolled crossings (often mid-block) are particularly problematic for both pedestrians and drivers (Beckwith and Hunter-Zaworski 1998): pedestrians have the right of way on the street at those marked crossings but drivers do not respect it all the time. Therefore, uncontrolled crosswalks have the potential to create a conflict between pedestrians and vehicles in urban areas (Hakkert, Gitelman and Ben-Shabat 2002). For instance, signalized intersections reduce the probability of pedestrian accidents by half (Gårder 1989). In addition, a study by Cambon de Lavalette et al. (2009) demonstrated that the absence of signals at an intersection increases the rate of rule violation by road users. Accordingly, Brosseau et al. (2013) stated that the presence of pedestrian signals has a positive impact on pedestrians' decision making and encourages them to respect the rules.

In crosswalks with a countdown timer, results are contradictory. On one side, a study demonstrates improvement in behavior: a higher number of pedestrians older than 12 years old complied with pedestrian signals compared to those in a crosswalk without a countdown display

(Lipovac et al. 2013), and dangerous crossings were significantly reduced compared to the rate at intersections without a timer (Brosseau et al. 2013). On the other side, many other studies stated that the presence of countdown timers created chances of non-complying behavior (Huang and Zegeer 2000; Vujanić et al. 2014), and led to an increase in the number of late-starter and late-finisher pedestrians (Wanty and Wilkie 2010).

The results of Fu and Zou's (2016) study have shown that presence of a countdown display helped child pedestrian during the clearance phase not to be caught in the crosswalk before the red man signal's onset, and to finish their crossing on time (by speeding up or running, for example).

B. Crossing time, crosswalk width, and required speed to cross on time

The essential need for pedestrians is to recognize the available and necessary time to cross the road, which depends on road width, walking speed, and ability to speed up (Lobjois and Cavallo 2007). Crosswalk width influences risk of having an accident since it affects the time a pedestrian is exposed to traffic (H. Li, Graham and Majumdar 2015; Rastogi et al. 2011; Tarawneh 2001).

Collision risk increases with the width of the road (Abrashev et al. 1999; Cloutier et al. 2017; Noland and Quddus 2004). In other words, pedestrians in a wider street have a wider exposure to risk (Montella and Mauriello 2010), so with reductions in road width at crosswalks, pedestrians would have a shorter distance to cross, leading to less exposure to road risks (Hakkert, Gitelman and Ben-Shabat 2002; Martin 2006; Neumann and Wagner 2008).

The crossing time, is the time required by pedestrians to cross a road with traffic signals (Virkler and Guell 1984; Cambon de Lavalette et al. 2009), which is affected by crosswalk width (Hakkert, Gitelman and Ben-Shabat 2002). As such, the pedestrians' behaviors are associated with the speed required to cross the street: in crosswalks with higher required speed (because of a greater width, for example), pedestrians move more quickly (Zhuang, Wu and Ma 2018; X. Zhang et al. 2013; Tarawneh 2001; Rastogi et al. 2011).

According to Chandra and Bharti (2013), crossing speed is analyzed with respect to road width, and it is calculated as the crossing distance (length of the crosswalk) divided by the estimated time needed by a pedestrian to cross (Wanty and Wilkie 2010; Li et al. 2013; Marisamynathan and Perumal 2014). However, walking speed is related to age, gender, group size, disability, traffic control condition, and departure signal (Gates et al. 2006; Marisamynathan and Perumal 2014).

Most of the guidelines and the manuals (e.g. Highway Design Manual – the Road (3rd Edition) (Hong et al. 2006) did not consider the different situations and characteristics of pedestrians to specify the speed while crossing (Almodfer et al. 2017).

A crossing speed of 1.2 meter/second is recommended in North America (Avineri, Shinar and Susilo 2012; National Advisory Committee on Uniform Traffic Control Devices 1988; Milazzo II et al. 1999; Manual on Uniform Traffic Control Devices 2006). Based on the study by Tarawneh (2001), many scholars believed that a crossing speed of 1.2 m/s was too fast for most pedestrians. Furthermore, Dewar (1992) suggested a 0.91 to 0.99 m/s value for traffic signal timing in general. Similarly, Rastogi et al. (2011) stated that 15th-percentile speeds were between 0.83–1.02 m/s for adult pedestrians, which vary with road width, traffic volume, and size of the urban area. Again, average crossing speed showed by Alhajyaseen (2012) ranged between 0.9 and 1.1 m/s. On average, an older pedestrian crossing speed of 0.95 m/s is slower than a child pedestrian speed, while for adults, crossing speed is 1.12 m/s (Marisamynathan and Perumal 2014). It is worth mentioning that the results of Knoflacher (1987) and Weidmann (1993) showed that children under 12 years of age had a slower walking speed in comparison with adults. The speed of adults and elderly pedestrians have received a lot of attention during the past decades, with lack of attention paid to children (Li et al. 2013). Therefore, there is great diversity in the research and recommendations and that little has examined children.

C. Crosswalk marking

A painted crosswalk encourages pedestrians to cross within the marked zone, where drivers expect more the presence of pedestrians (Montella and Mauriello 2010). Hence, several studies have shown that there was a considerable reduction in pedestrian injuries at marked crosswalks (Gorell and Tootill 2001; Morgan, Ogden and Barnes 2004; Zein 2004). Also, crosswalk marking seems to influence the behavior of pedestrians: they tend to cross faster in the absence of markings, which might mean that they tend to reduce the time they are exposed to traffic (Ekman 1996; Meir, Parmet and Oron-Gilad 2013).

D. Speed limits

It is well established that the main cause of road injuries is high speed of motor vehicles: the rate of pedestrian injuries leading to death is eight times higher in a street with a speed limit more than

40 km/h (Parachute Canada 2016; Peden et al. 2004). For areas where the speed limit was 50 km/h and 30 km/h, the probability of fatalities was found to be 40% and 5%, respectively (Montella and Mauriello 2010). In the case of parks, Ferenchak and Marshall (2017) illustrated that lowering vehicles speed makes drivers more aware of the environment which leads to safer roads for pedestrians. These speeds depend on the density of the neighborhood in each location.

According to these authors, solutions can be found through initiatives and regulations that reduce speed of vehicles and increase driver awareness of the presence of children through some changes in road near parks such as installation of traffic calming devices, which are proven to be efficient to reduce the rate of child pedestrian injuries (Jones et al. 2005). Traffic calming device has two main purposes including reduction of the frequency and severity of accidents, and improving the environment of local areas (e.g., decreasing speed of vehicles and traffic flow) (García et al. 2011).

Accordingly, providing a high quality and proper crossing location raises the level of pedestrian safety and reduces the likelihood of pedestrian accidents (Akin and Sisiopiku 2007), especially for children, who, as we said before, are unequally exposed to accidents in the environment (Pucher and Renne 2003).

2.2 Pedestrian rule compliance

Generally speaking, compliance refers to obeying a rule, standard, or policy (Lin 2016). Rule compliance, as discussed by Granié Granié (2007), needs internalization of social rules which eventually leads to obtaining personal values and attributes. This process is essential in the process of child development (Kopp 1982; Lytton 1980).

In terms of road rules, it is necessary for all road users to obey the road rules in order to establish a safe traffic system. Rule compliance can be seen as a crucial component of any safety strategy (Hopkins 2011) since not complying with road rules from both ends can lead to pedestrian injury (Cinnamon, Schuurman and Hameed 2011).

Many factors influence pedestrian rule compliance: the street location; individual; and environmental characteristics. These factors might also affect pedestrian's habits and preferences. Pedestrian's behavior and attitude are known as decisive factors in rule compliance (Akin and Sisiopiku 2007). Compliance with pedestrian rules could also be affected by children’s gender (Granié 2007) and by their age (Rosenbloom, Ben-Eliyahu and Nemrodov 2008). Although

compliance is an important factor for both children and adults (Toepfer, Reuter and Maurer 1972), most of the previous research did not study children compliance, so many results presented here are for adult pedestrians.

2.2.1 Temporal crossing compliance (compliance with signal timing at signalized intersections)

According to the Quebec Highway Safety Code (QHSC)(Quebec Highway Safety Code 2017), in an intersection with a pedestrian light, pedestrians should comply with their light, and if there is no pedestrian light they should comply with the traffic light. In addition, pedestrians facing a flashing signal with a countdown display may only start to cross if they can reach the other side before the start of the orange signal. The results of some previous studies in temporal crossing compliance showed that compliance with walk signals was about 50% (Akin and Sisiopiku 2007), and it was lower among male pedestrians in the study of Tom and Granié (2011). Also, non-compliance with signs and signals had positive association with pedestrian collision injuries, while installing pedestrian countdown display could reduce these injures (Markowitz et al. 2006).

Where there is a countdown signal, pedestrians tend to cross according to the remaining time of the countdown display, though they might underestimate their crossing time duration and finish on the red light (Wanty and Wilkie 2010). In addition, the waiting time before the next green light has a significant impact on compliance with the temporal rules, and the likelihood of crossing against the red light on a long-time cycle are higher (28%) than on a shorter-time cycle (20%) (Keegan and O'Mahony 2003).

2.2.2 Spatial compliance (crossing in/at the crosswalk)

Pedestrians should cross the street in a straight line, within the crosswalk if marked; only in the presence of a peace officer, school crossing guard, sign, or signal, can they cross the street diagonally (Quebec Highway Safety Code 2017). In other words, crossing compliance refers to respecting the crossing location (i.e., crosswalks) (Akin and Sisiopiku 2007).

As studies revealed, drivers' attention to pedestrians is higher when pedestrians cross at designated locations, such as a crosswalk, and pedestrian-vehicle conflicts can be reduced by this behavior (Morel et al. 2003; Sisiopiku and Akin 2003). It has been reported in the literature

that the majority of adult pedestrian (59%) crossed compliantly in the crosswalk (Sisiopiku and Akin 2003), and there was no difference in compliance between genders for spatial compliance (Tom and Granié 2011).

2.2.3 Velocity (crossing speed)

One of the most critical and important issues in road safety planning is pedestrian speed. Crossing speed includes both walking and running (Chandra and Bharti 2013; Zhou et al. 2011) as two different types of movement for pedestrians. Walking is known as a common behavior, while running is considered by some as a risky and unsafe behavior since it decreases the pedestrian safety margin (Almodfer et al. 2017).

The rate of pedestrian exposure to vehicles is related to speed (Tarawneh 2001) since road users can make more reasonable decisions at lower speeds. However, among pedestrians, a higher percentage of running was seen for children (Li et al. 2013), especially when they were unaccompanied or in a group (Ishaque and Noland 2008). In France, pre-school children learn some safe road behaviors consistent with pedestrian rules, such as stopping at the curb, and walking (not running) during crossing (crossing speed) (Granié 2007). In addition, most pedestrians have the ability to adjust their speed if they encounter a potential or certain risk (Murray 2006; Tarawneh 2001), which might not be the case for children.

2.2.4 Visual search (before crossing)

Visual search is another important skill involved in the crossing task (Thomson et al. 1996). The visual system has an important role when crossing the street, because it can acquire information quickly and reliably (Geruschat, Hassan and Turano 2003). For the reasons mentioned above, children have often inadequate visual search behavior (Tapiro et al. 2014). About 41% of child pedestrians aged 5-6 years in a study by Zeedyk, Wallace and Spry (2002) did not look for oncoming vehicles, and if they were looking, they often did so in the wrong direction or with restricted view.

Assessing the previous studies concerning child pedestrian's safety revealed that there is no comprehensive investigation on children's safety crossing streets near urban parks. Hence, a study evaluating the characteristics pertaining to child pedestrians' safety with regards to rule

compliance at crosswalks adjacent to parks is much needed. The following chapters aim to achieve this goal by providing the methodology and discussing the results.

CHAPTER 3: METHODOLOGY

This chapter will present the study areas and main research tools used in this study. We collected data on children's level of compliance to pedestrian rules at crosswalks. The current study is based on a quantitative approach built on direct observation.

3.1 Operative framework

As presented before, an ecological model was chosen to evaluate interactions between people and the environment. Among different levels involved in any ecological model, four levels: individual, situational, road environmental, and behavioral characteristics are considered for their close associations with child pedestrian rule compliancy. The variables measured for each level are presented in Figure 3.1. The objective of this framework is to help us to generate our observation form in order to examine child pedestrian's safety by assessing relations between those variables and child pedestrian compliance rules.

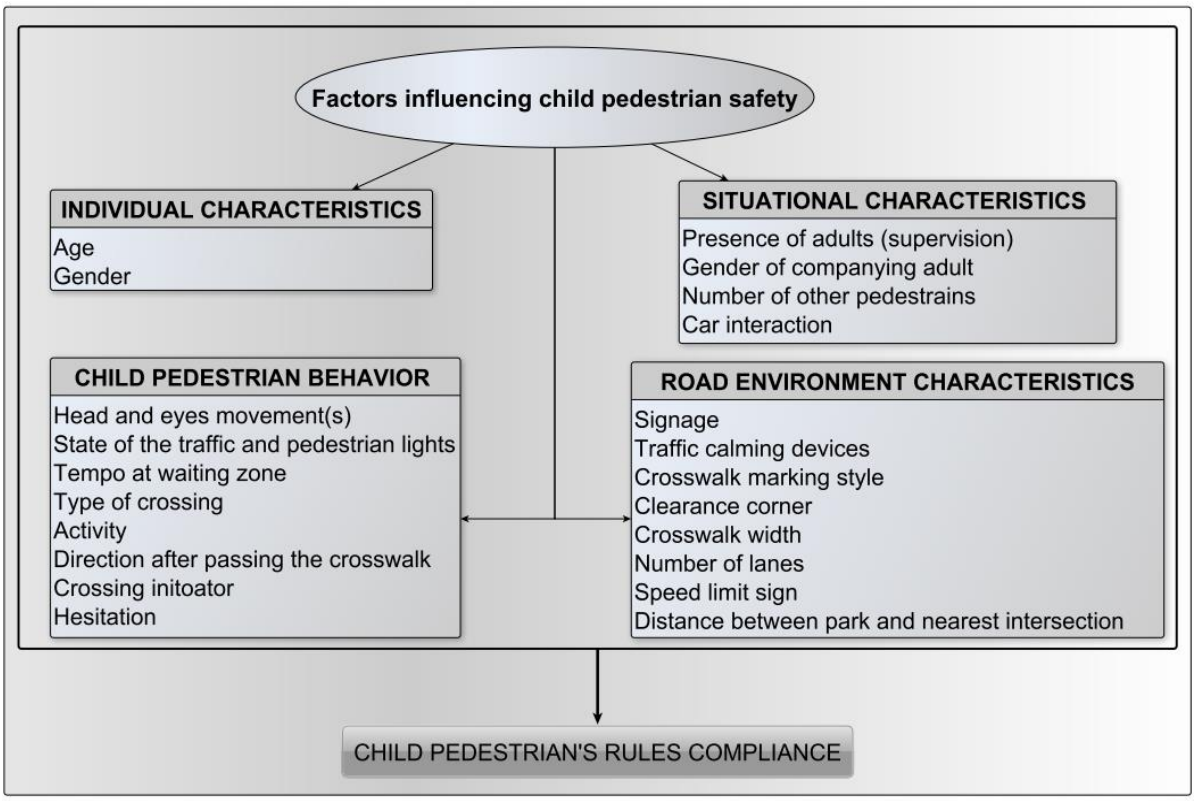

Figure 3.1 Operative framework used in the current study
Source: Author (2018)

3.2 Selection of study areas

Montreal is the second most populated city in Canada, located in the southwest of the province of Quebec. The city of Montreal with its 1.7 million inhabitants is the core part of metropolitan Montreal. Children under 14 years of age consist 15.6% of the city's population (Ville de Montréal 2016). Neighborhoods located in the city's central core are commonly known as "inner-cities" (Statistics Canada 2006). We selected inner-cities boroughs since they tend to have larger and denser populations, heavier traffic, and less room for children's play than the suburbs. The studied boroughs include Villeray-Saint Michel-Parc extension (VSP) and Rosemont-la Petite-Patrie (RPP) (see Figure 3.2).

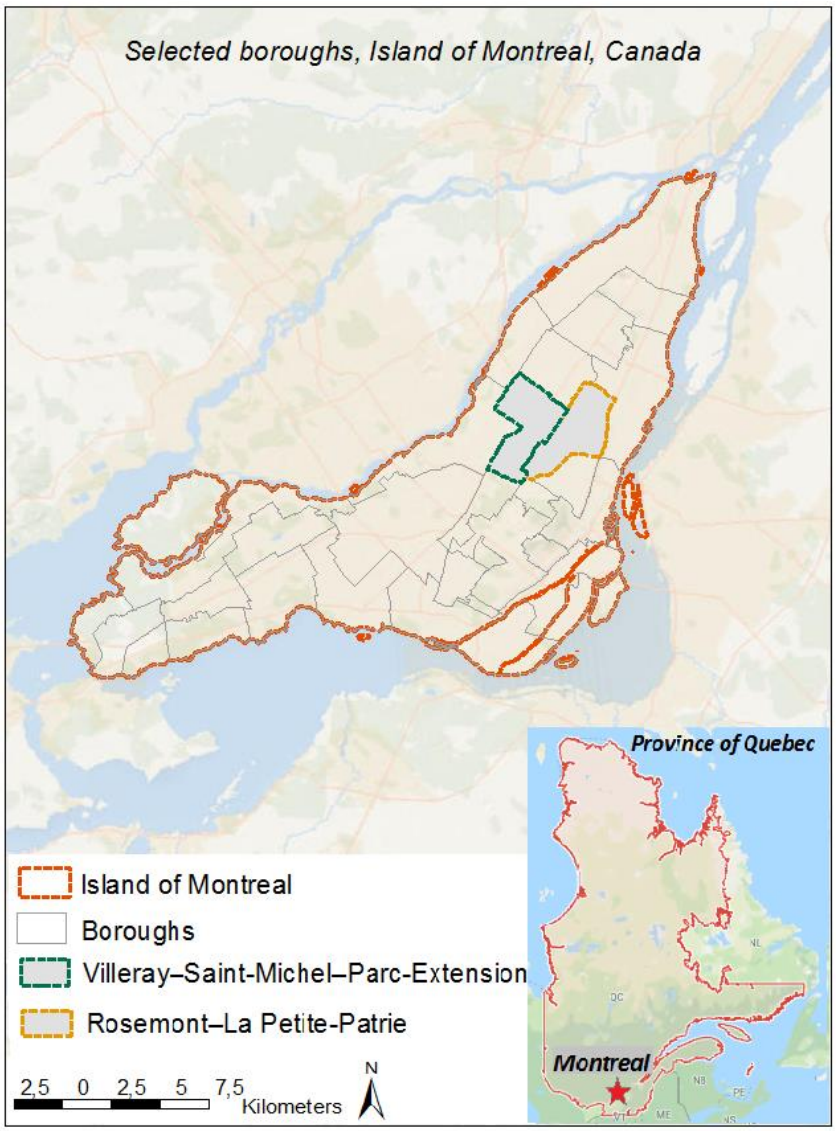

Figure 3.2 Selected boroughs
Source: Author (2018)

3.2.1 Park selection

We selected parks according to previous work by Apparicio et al. (2010). This paper classified parks into six different classes according to the presence or absence of facilities and the parks size (Table 3.1). Parks of type (A) are very small and include one playground. As per Apparicio et al. (2010), this kind of park is especially intended for children aged four and under. The next type (B) consists of small parks with two facilities including a playground and a sports field. Type (C) parks are also small but offer more equipment. Type (D) parks are also smaller but offer more than seven facilities on average including a skating rink and a swimming pool. The (E) type consists of larger parks and contains many types of equipment (5 on average). Finally, type (F) are metropolitan parks providing winter equipment and hiking trails.

Table 3.1 Typology of urban parks on the island of Montreal

Type of parks	A	B	C	D	E	F	Total
Number of parks	296	144	104	46	88	15	693
Size of parks	very small park (less than 1 ha)	small park (1 to 5 ha)	small park (1 to 5 ha)	small park (1 to 5 ha)	large park (5 to 20 ha)	metropolitan park (more than 20 ha)	
Percentage of parks with playground for children 0-4 years old	96.6	80.6	85.6	80.4	79.5	20.0	86.7
Average number of equipment[1]	1,4	2,2	3,5	7,2	5	3,7	2,8

Source : Apparicio et al. (2010)

Parks in the first four categories (A, B, C, D) were selected because they are local and provide a greater chance of child pedestrians to walk and being present in them. Eighteen parks in different boroughs of the City of Montreal were selected within these four categories, between 4 to 5 Parks in each category. An exploratory visit to these parks was undertaken before making the final choice. We aimed to choosing different local parks having different size, traffic density, and different features in crosswalks next to the parks. The final parks were carefully chosen to have playground facilities in order to increase the chance of children presence. Finally, we ended up with four parks in the inner city of Montreal which had the above criteria. The analyses provided

[1] This variable presents the average number of different types of equipment in the parks like playgrounds, sports fields (baseball, football, soccer, etc.), winter sports (skate ring, arena, snow shoeing lanes, etc.), specialized equipment (skate parks), and swimming pools.

in Chapter 3 shows that number of observations in these four parks provides reliable statistical results. Figure 3.3 summarizes our method to select the final four parks.

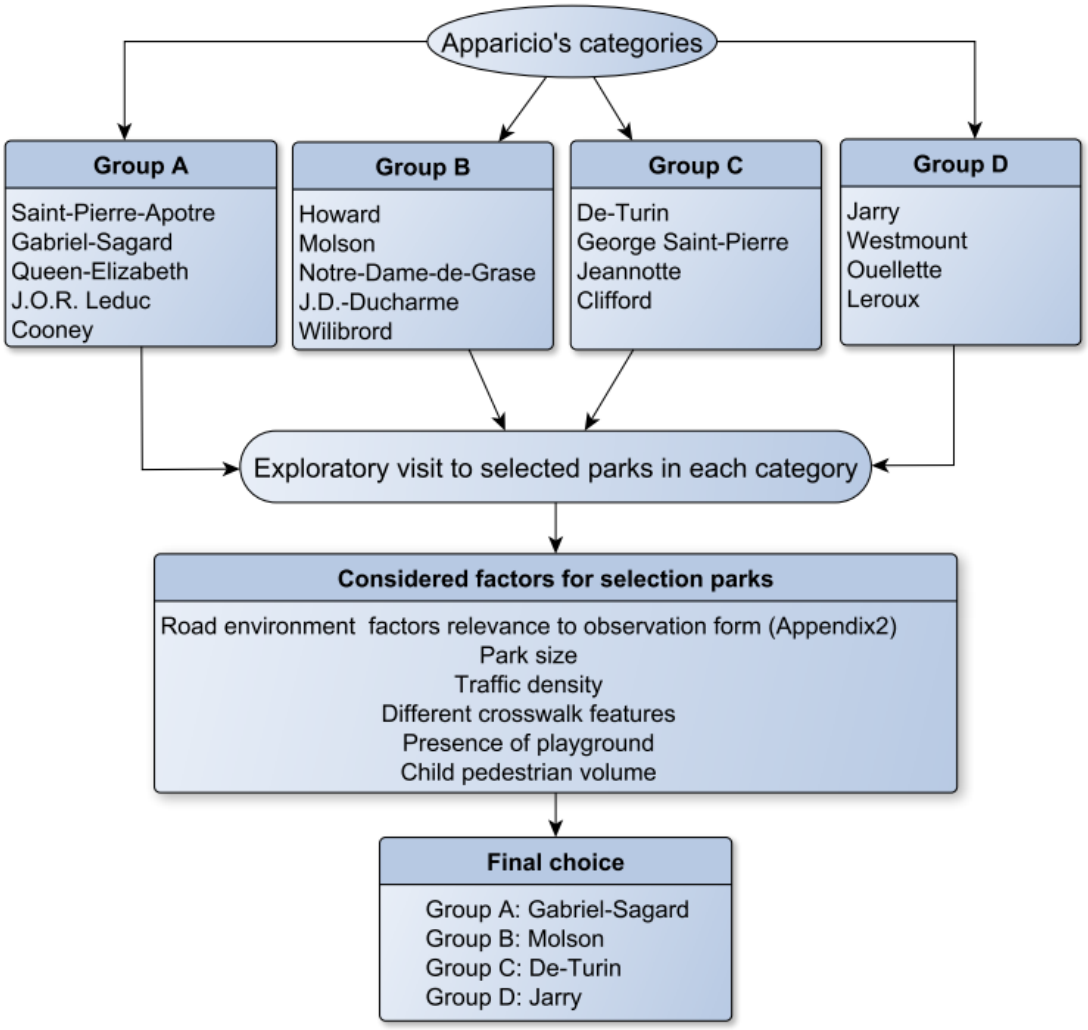

Figure 3.3 Different steps in choosing the parks
Source: Author (2018)

Jarry, De Turin and Gabriel-Sagard Parks are located in the Villeray-Saint Michel- Parc Extension (VSP) borough. The borough area is 16.5 km^2 with a population of more than 140000 (the second largest in the city), with children under 14 years of age representing 17% of it (Ville de Montréal 2016). The fourth park is in the Rosemont La Petite-Patrie borough (RPP), adjacent to the Villeray-Saint Michel-Parc Extension one. Rosemont La Petite-Patrie is the third most populated borough in the City of Montreal with 15.9 km^2 of territory and fewer than 140000 residents, with 14% children under 14 years old (Ville de Montréal 2016) (Figure 3.4).

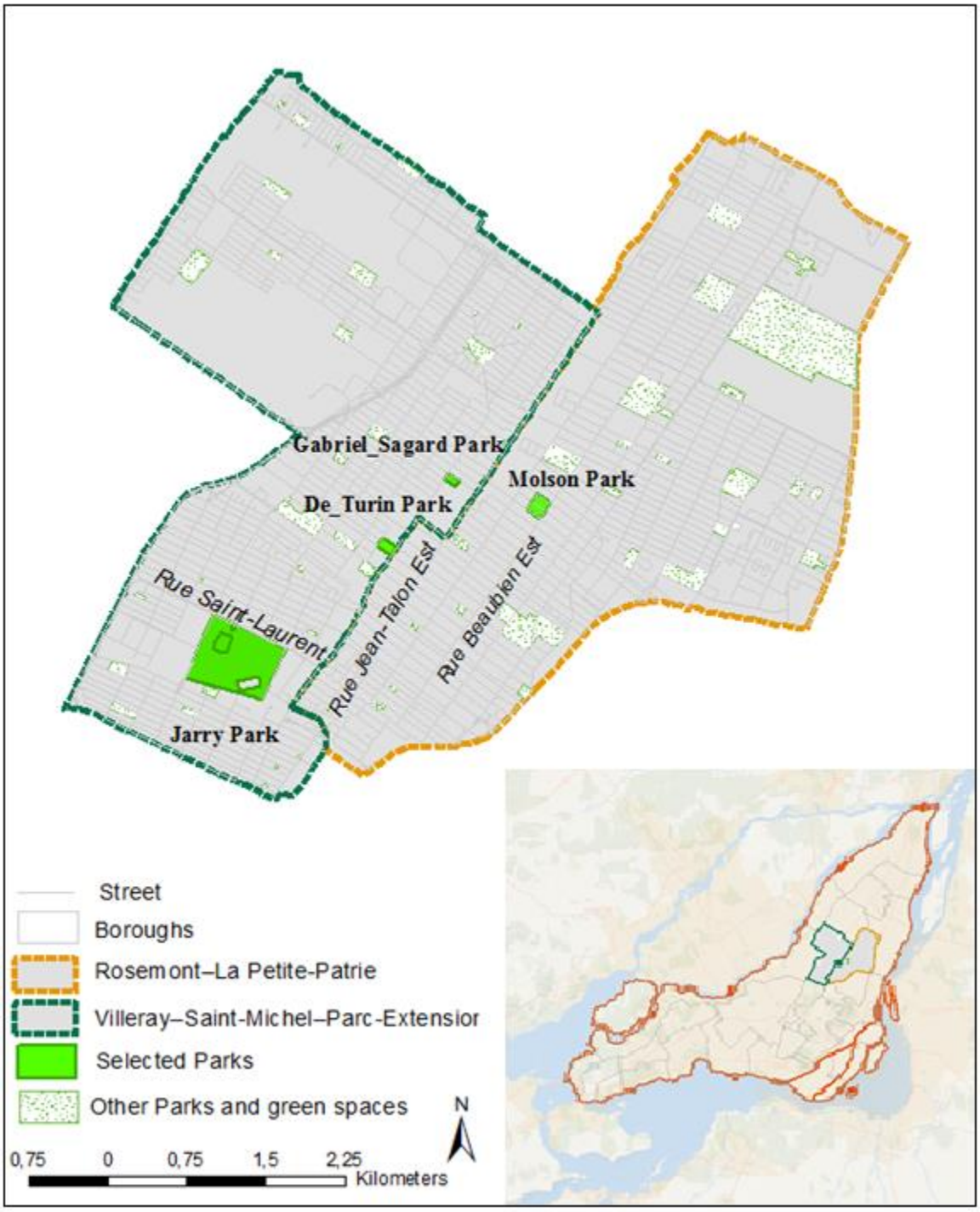

Figure 3.4 Location of Selected Parks
Source: Author (2018)

3.2.2 Selection of intersections and crosswalks

After choosing the parks, we selected specific intersections to conduct our data collection. In this study, intersections closer to playgrounds and those on main streets were considered as most common crosswalks chosen by children based on observation test. After visiting selected intersections, the crosswalks adjacent to the parks which had highest number of child pedestrians and had different features, such as marking and signage, were chosen. During direct field observations, we reported the characteristics of each crosswalk according to our road environment observation form (see Appendix 2).

Accordingly, nine intersections and seventeen crosswalks attached to these intersections were retained for this study (Table 3.2). Most of the crosswalks are located at three or four-way intersections; one crosswalk between an elementary school and Gabriel-Sagard Park was mid-block and not at an intersection.

Table 3.2 Summary of selected crosswalks around parks

Park	***Jarry***	*Crosswalk number*	***De-Turin***	*Crosswalk number*	***Molson***	*Crosswalk number*	***Gabriel-Sagard***	*Crosswalk number*
Crosswalk name	Jarry / Saint-Laurent	1	Jean-Talon / De Lanaudière	8	Beaubien / D'Iberville	11	Sagard	15
	Saint-Laurent / Jarry	2	De Lanaudière / Jean-Talon	9	D'Iberville / Beaubien	12	Sagard / Jean-Talon	16
	Saint-Laurent / Gounod (North)	3	Chambord / Jean_Talon	10	D'Iberville / Elsdale	13	Jean-Talon / Sagard	17
	Saint-Laurent / Gounod (South)	4			Elsdale / D'Iberville	14		
	Saint-Laurent / Villeray	5						
	Saint-Laurent / Gary-Carter	6						
	Gary-Carter / Saint-Laurent	7						

Because of the vastness of Jarry Park, seven crosswalks were selected around it, most of them being closer to the playground area (Figures 3.5 and 3.6). The first two crosswalks selected are located at the intersection of Jarry and Saint-Laurent Streets overlooking the park. The third and fourth crosswalks are located on Saint-Laurent and Gounod Streets near the entrance of the pool in Jarry Park, and the fifth crosswalk is at Saint-Laurent and Villeray Streets. Two other crosswalks around Jarry Park are in Saint-Laurent and Gary Carter and Inverse, very close to the main entrance of the park.

Figure 3.5 Selected crosswalks around Jarry Park
Source: Author (2018)

Figure 3.6 Selected crosswalks around Jarry Park
Source: Photograph by author (2018)

Since De-Turin Park has two playgrounds located near Jean-Talon Street, one unmarked crosswalk near the first playground at the intersection of Jean-Talon/Chambord Streets was selected. The two other crosswalks at the Jean Talon– De Lanaudière intersection were also selected because they are close to a second playground (Figures 3.7 and 3.8).

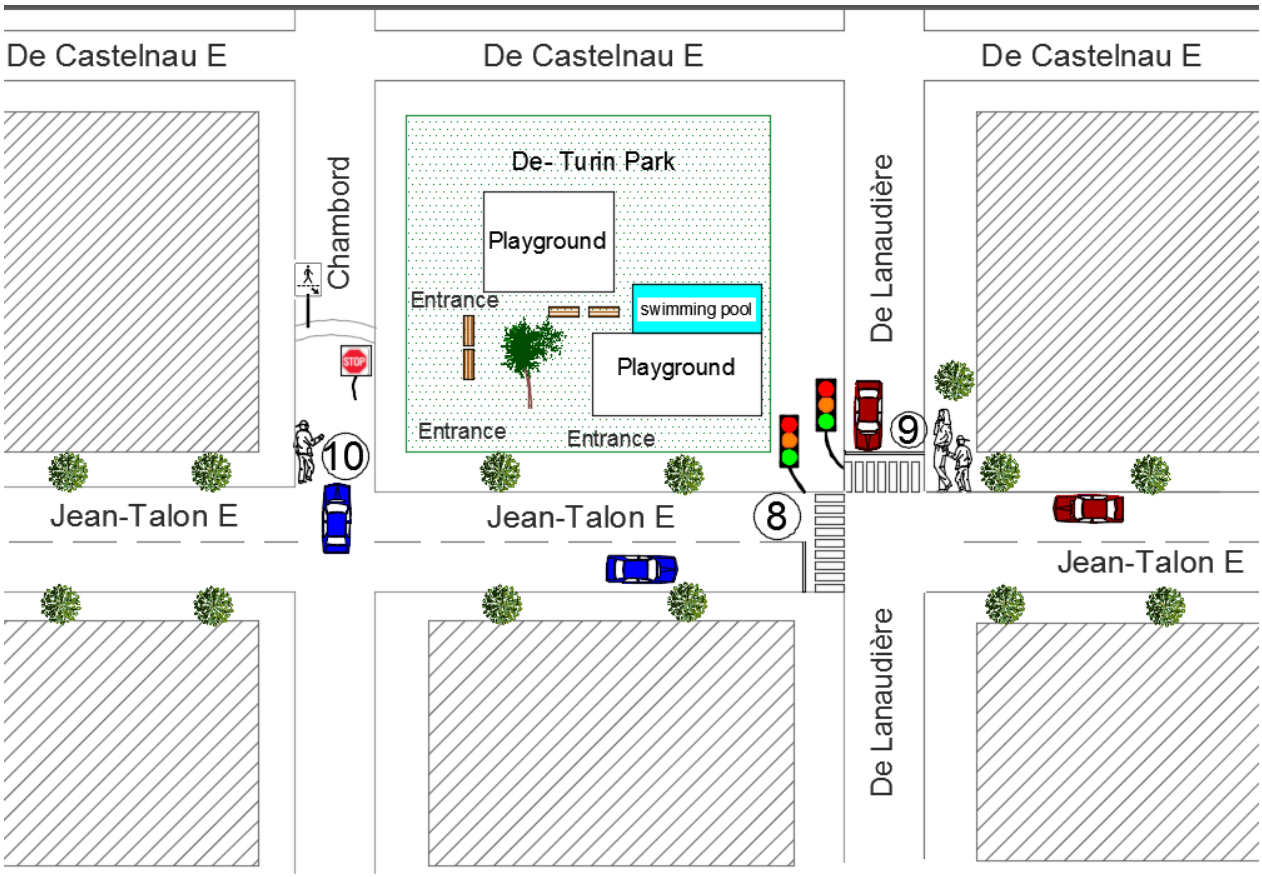

Figure 3.7 Selected crosswalks around De-Turin Park
Source: Author (2018)

Figure 3.8 Selected crosswalks around De-Turin Park
Source: Photograph by author (2018)

In Molson Park, the first two crosswalks at the Beaubien and D'Iberville intersections, south of the park, were selected in order to observe the children who cross these main streets joining Molson Park. Two other crosswalks joined the playground at the D'Iberville and Elsdale intersection, where there is no traffic signal (Figures 3.9 and 3.10).

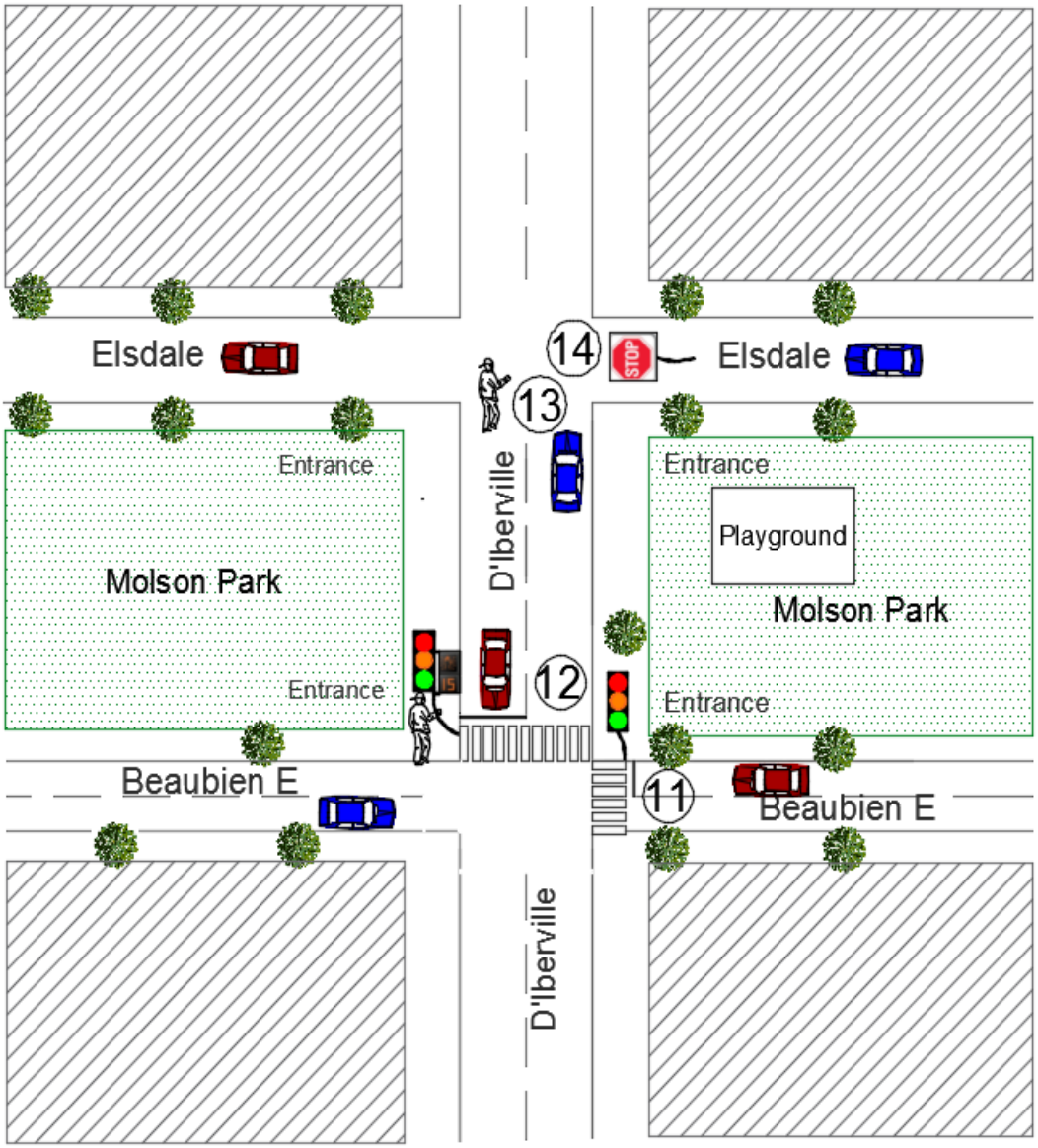

Figure 3.9 Selected crosswalks around Molson Park
Source: Author (2018)

Figure 3.10 Selected crosswalks around Molson Park
Source: Photograph by author (2018)

At Gabriel-Sagard, the crosswalk at mid-block, located between the school (Saint-Barthélemy elementary school) and the park, and two crosswalks adjacent to the park at Sagard and Jean-Talon Street intersections were selected (Figures 3.11 and 3.12).

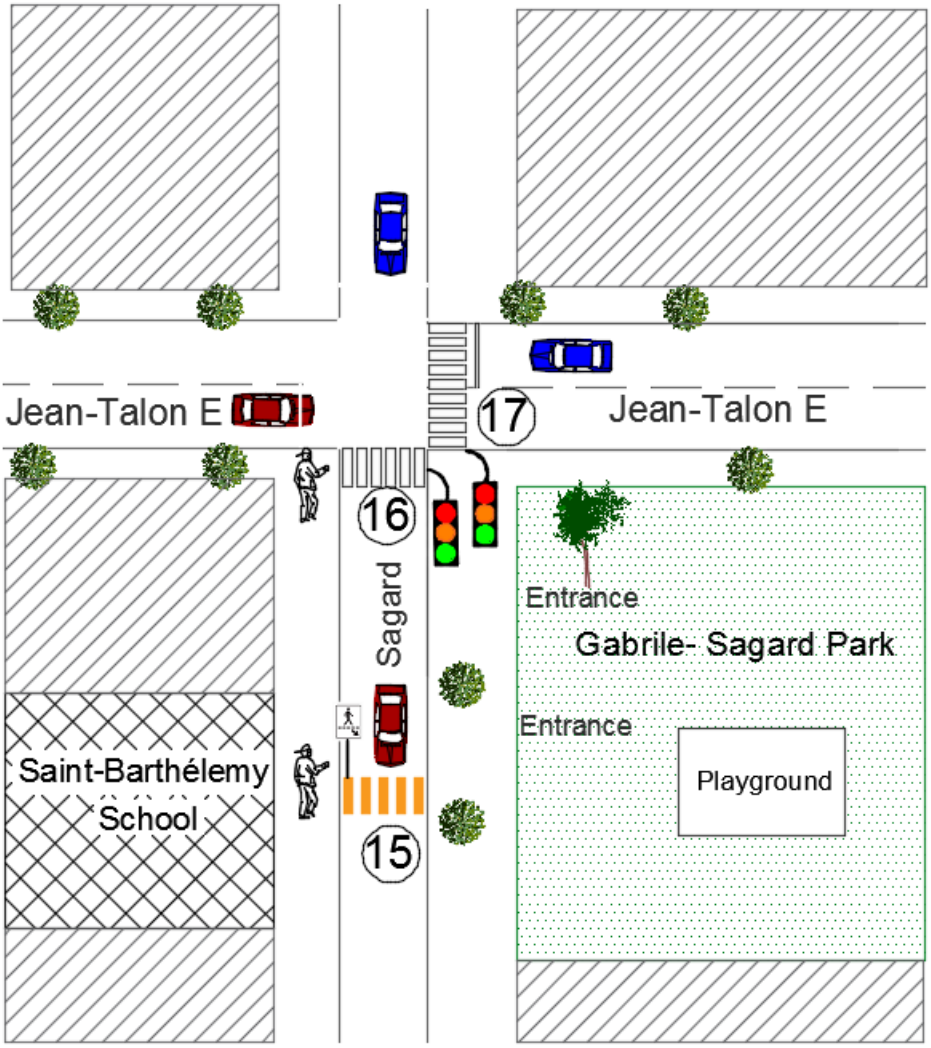

Figure 3.11 Selected crosswalks around Gabriel-Sagard Park
Source: Author (2018)

Figure 3.12 Selected crosswalks around Gabriel-Sagard Park
Source: Photograph by author (2018)

3.3 Creation of the data collection tools: Direct observation of child pedestrian behavior while crossing

We created three observation forms to collect data to answer our research question: one for the individual, situational and child pedestrian behavior while crossing, one for the road environment, and one for the interactions between child pedestrians and vehicles.

Many previous scholars have used observation methods at crosswalks to examine the behavior of pedestrians in various age categories. For example, Lachapelle and Cloutier (2017) studied elderly pedestrians street crossing behavior at signalized crosswalks through observation to explain the type of street crossing ending (on red light, on red hand or on both). Tom and Granié (2011) directly observed pedestrian rule compliance according to gender, examining temporal and spatial compliance as well as visual search at signalized and un-signalized crosswalks. Cinnamon, Schuurman and Hameed (2011) observed road rule violation in Vancouver through observation of pedestrians and motorists behaviors. Dommes et al. (2015), in addition to questionnaires, used observations to record adult pedestrians' behavior at red light violations; situations at waiting zones; crossing pace; and types of crossing. Markowitz et al (2006) used the observation method before and after installation of pedestrian countdown signals to examine the changes in the number of pedestrian injuries and their temporal compliance. The observation forms for the present study (Appendixes 1-3) are based on the "ESSAIM and PARI, 2013" project (Cloutier et al. 2017; D'Amours Ouellet 2016; Cloutier 2016; Bergeron et al. 2017). Most of the observation form elements were used without any changes comparing to the afore-mentioned ones; however, some new elements related to parks were added, such as distance between intersection and park entrances, etc, in order to better study a park-related elements.

3.3.1 Individual and situational factors

Figure 3.12 presents five different categories for individual and situational characteristics. We first recorded gender and age by categorizing girls and boys in two different age groups: estimated to be between 4-8 (younger children) and 9-12 years (older children) (Figure 3.13). Since we did not ask the pedestrians any questions, those age categories are estimates and relative to each other, based on the height of children.

For situational factors, we recorded several items: if there is a companion with child, the type of supervision, including physical contact (hand, coat), close supervision, or out of reach; gender and

number of adult companions. Also, the total number of other pedestrians waiting to cross at the same time as the child pedestrian (even if they did not seem to know each other, and excluding their companions).

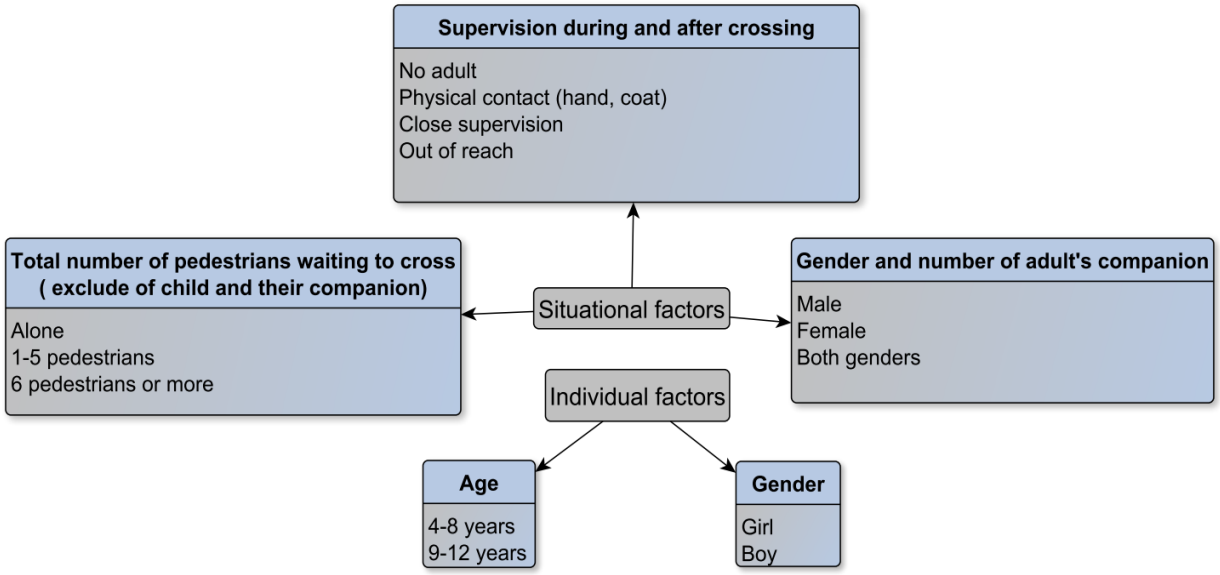

Figure 3.13 Individual and Situational factors in observation grid for crossing behavior
Source: Author (2018)

3.3.2 Behavioral factors

The behavior section of the form (Figure 3.14) was used to record nine different variables: head and eye movement before and during crossings; state of traffic light during and at the end of the crossing; type of crossing (straight line or not); waiting zones (type and tempo); activity before and after crossing; if there was any hesitation before crossing; who was the initiator of the crossing; and direction after the crossing (to the park or not).

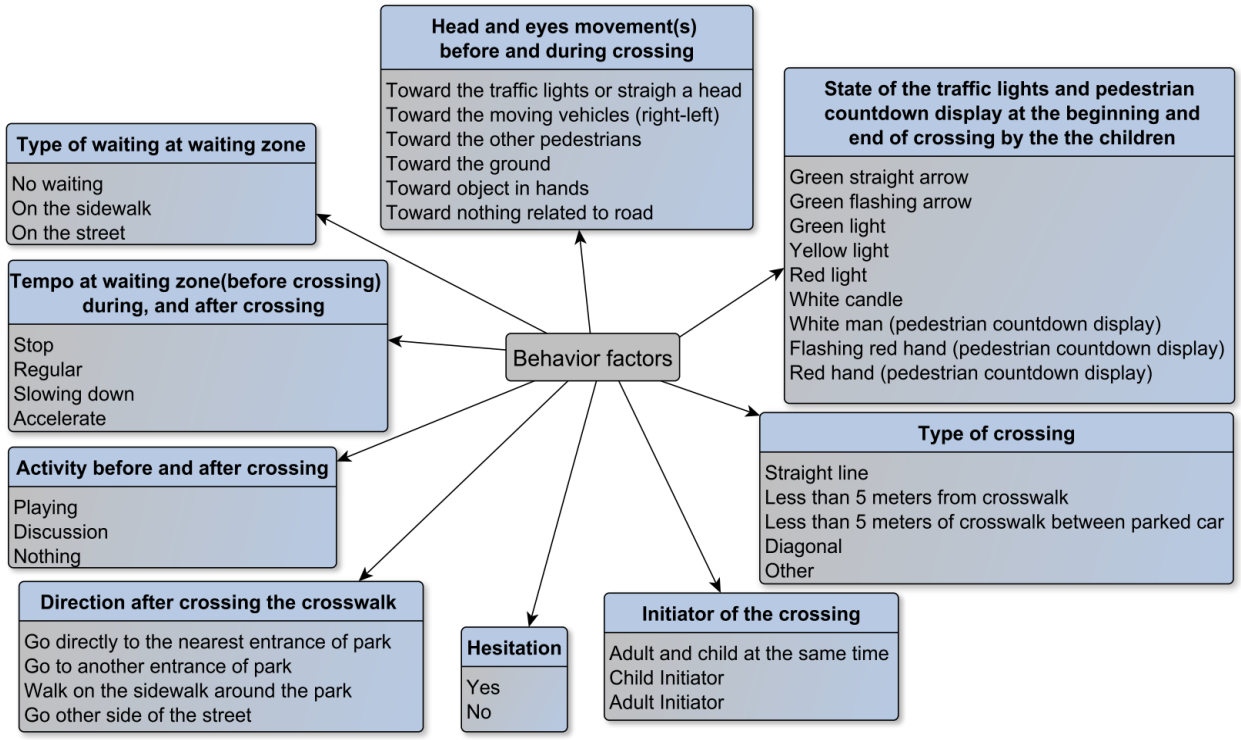

Figure 3.14 Behavior factors in observation grid for crossing behavior
Source: Author (2018)

3.3.3 Observation grid for road environment

Figure 3.15 presents the road environment form, which was used to record nine characteristics of the selected crosswalks and intersections (Appendix 2): presence of traffic calming devices; visibility within 5 meters of the corner; distance between the park entrances and the crosswalks in meters; type of intersection; speed limits (30, 40, 50, 70 km/h or none); number of lanes at the crosswalk; crosswalk width indicating three-difference levels (less than 15m, between 15 -25m and more than 25m); the crosswalk marking (two parallel lines, white zebra, yellow zebra, paving stone or other asphalt coating, or no ground markings); the presence or absence of traffic signals (stop signs, traffic lights and their duration in seconds, pedestrian countdown displays and their duration in seconds, and no signage).

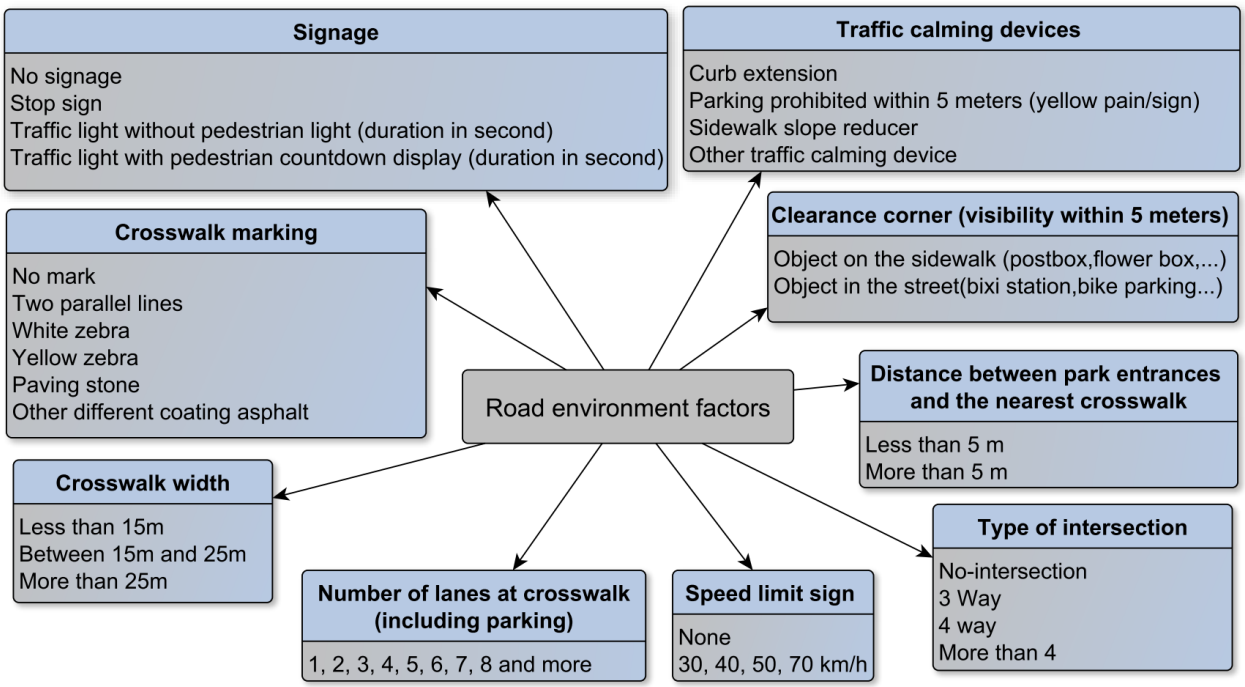

Figure 3.15 Road environment characteristics
Source: Author (2018)

3.3.4 Observation form for vehicle-pedestrian interactions

Whenever the paths of the child and a vehicle would cross while the child was still on the crosswalk, we would record that as an interaction, based on the work cited before in the ESSAIM and PARI project (Appendix 3). We would then record information about the vehicle, its direction, its proximity to the child, and other behaviors during the interaction (Figure 3.16). For this study, we only include a binary variable that indicates whether an interaction occurred (or not) during the crossing, regardless of how dangerous it was. It allows us to study broadly how a vehicle crossing a child's path affects rule compliance.

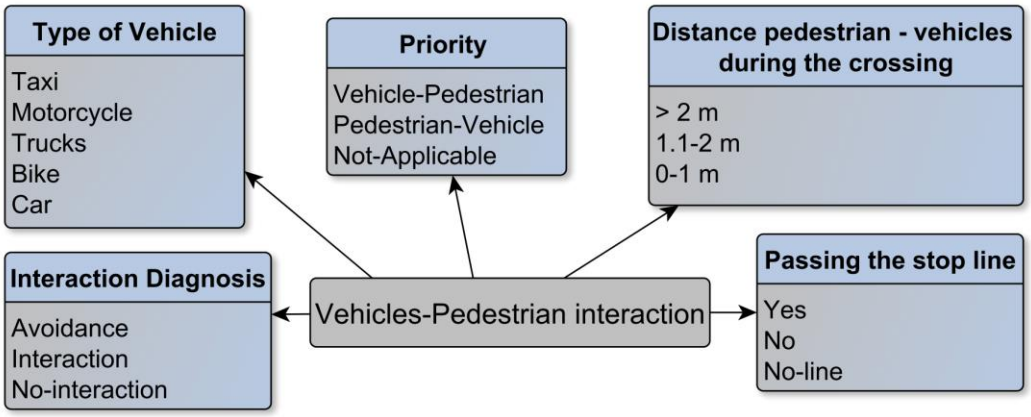

Figure 3.16 Vehicle-Pedestrian interaction variables
Source: Author (2018)

3.4 Data collection

All the observations were recorded on iPads in the Survey123 software developed by ESRI (Environmental Systems Research Institute 2017). Observations were conducted by four trained observers between mid-June and mid-August 2017. These four observers were trained for two days by Marie-Soleil Cloutier, associate professor at “Institut National de la Recherche Scientifique” (INRS). The training observation sessions included elaboration and explanation of the observation form elements and filling out the electronic version of the forms in real-time. At the end, the forms were verified by professor Cloutier in order to ensure appropriate data collection. At crosswalks with a higher traffic volume and number of children, observers were in teams of two: one observer completed the children’s behaviors and the other, the interaction form. In crosswalks with a moderate level of traffic and children, only one observer recorded in both forms (children behavior first, then interaction form, if applicable). Before recording children's behavior and interaction, each crosswalk characteristic was recorded in a separate form.

Since observation process started at the end of the school year, the time of data collection was not very specific and could be done during the daytime almost between 9 am and 7 pm, on weekdays and weekends, in time periods when children were more likely to go to the parks. Crossing situations were recorded with three different tools based on previous work (Cloutier et al. 2017): (1) child pedestrian crossing behaviors, (2) crosswalks characteristics and, if applicable, (3) interactions between the child pedestrian and vehicles.

Crossing behaviors were observed at three specific moment (Figure 3.17): (1): at the curb, (2): on the crosswalk, (3): after crossing. As it was a non-participatory observation, the observer chose a place that would draw the least attention but provide the most visibility of the children and traffic signs If there were more than one child or if there was a group of children, only one child was randomly selected to be observed. In the absence of interaction, the interaction form was not filled out. In total, a minimum of 40 children were observed at each of the seventeen selected crosswalks, with the exception of one crosswalk at Saint-Laurent / Gounod (North), in which only 15 observations were recorded. At the end of each day, the data were properly extracted and backed up.

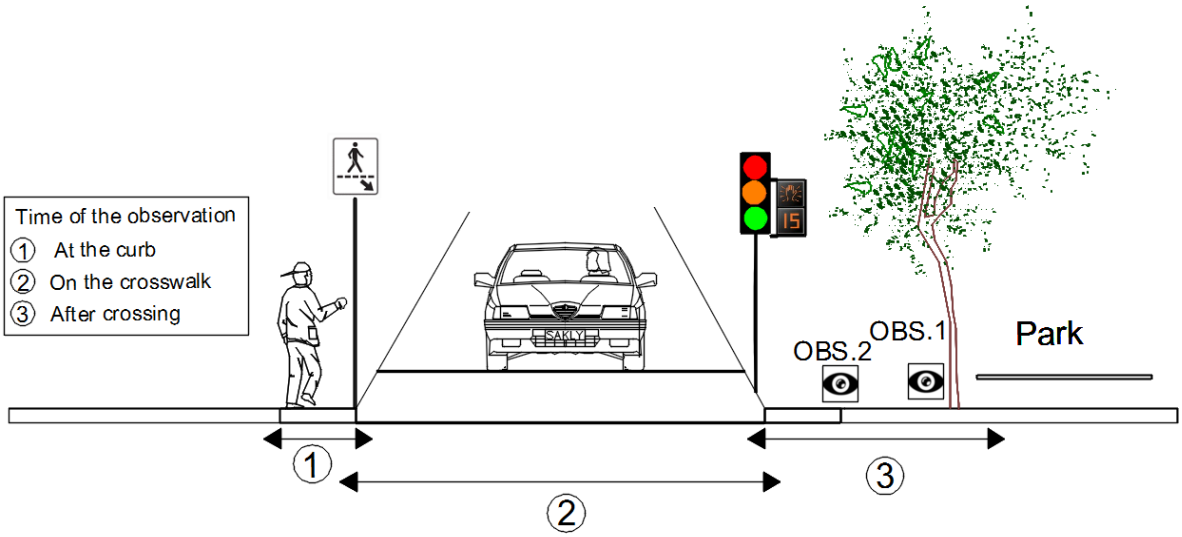

Figure 3.17 Observation Zone
Source : Author (2018)

3.5 Data (re)coding and analysis

To analyze child pedestrian safety rules, we selected the variables presented previously based on the literature review and our proposed ecological model. Dependent variables represent “pedestrian rule compliance”, while the independent variables are associated with child pedestrian behavioral and individual, situational, crosswalk, intersection and park entrance characteristics.

3.5.1 Independent variables

After data cleaning and before any analysis, data were converted to a numeric format. Accordingly, in the Excel file, all proper variables and their attributes were entered in two columns, and coding for variables with two attributes were recorded as “dummy” variables (value 0 or 1). For example, age became two variables (“4-8”=0) and (“9-12”=1). Consecutive integer numbers were assigned to variables attributes. For example, “Initiator of the crossing” with its three attributes were coded as: “no initiator=0” “child"=1” “adult =2”, and likewise for other variables having more than two attributes (see Table 3.3). After finalizing the data, the tables for child behavior and road environment were associated via the crosswalk ID, which was shared. Lastly, the pedestrian–vehicle interaction table was associated to the data using the pedestrian ID.

We should mention that “speed required to cross in time” was created based on initial data for crossings with traffic lights, based on the width of each crosswalk (measured by observers) and the time permitted to cross (green light, white silhouette, and blinking light duration). As explained in Chapter two, previous research has not taken into account the actual pace of a child pedestrian when calculating the speed required to cross an intersection on time. For this study, the speed was fixed at 1m/s –an estimate based on related measures in other studies. This value exceeds the speed of the elderly and is less than the 1.2 m/s speed considered for pedestrians (Alhajyaseen 2012; Marisamynathan and Perumal 2014; Rastogi et al. 2011; Almodfer et al. 2017; Dewar 1992), since many scholars believe that a crossing speed of 1.2 m/s is too fast for most pedestrians (Tarawneh 2001).

Recoding of other variables was undertaken to ease further analysis. Because the crosswalk width influences the safety of the pedestrian, the crosswalks in this study were categorized into three different groups: (1) less than 15m (short), (2) between 15m and 25m (medium), and (3) more than 25m (long).

As to the variables pertaining to parks, two variables were kept although they were not found in previous studies: the distance between the nearest park entrance and the intersection, and if the children entered the park through this entrance. These two variables were considered to better investigate child pedestrians crossing the streets near urban parks.

It should be noted that not all independent variables were simultaneously used in our model (see below).

3.5.2 Dependent variables

To account for a child's application of pedestrian safety rules, four binary composite variables were created to distinguish child pedestrians rule compliance based on visual search, temporal, spatial, and velocity compliance (Table 3.3). Each of those rule compliance indicators is the dependent variable for one mixed-effect logistic regression.

In the current study, temporal rule compliance only applies to crosswalks equipped with pedestrian lights. If children finished crossing on the white silhouette, flashing red hand or even at a green traffic light (if no pedestrian light), they will be considered to have completed the crossing in time. Whereas if a pedestrian was on the red, or on the yellow light at the end of crossing, or on the red hand (if there was a pedestrian light); it means that the pedestrian did not comply with the traffic rule and finished the crossing out of time. Spatial compliance means crossing within the boundaries of a marked crosswalk or going straight across and not diagonally (if no marking) (Granié 2007). Different behaviors such as stopping or not stopping at the curb and running across the road were defined by previous scholars to examine the velocity of pedestrian at crosswalk (Rosenbloom, Ben-Eliyahu and Nemrodov 2008; Granié 2007). In the current study, maintaining a regular pace before and during a crossing is defined as velocity compliance, while accelerated pace before crossing or non-regular pace during crossing is defined as "non-compliance". To the best of our knowledge, there is no specific rule for velocity compliance. In this study, as mentioned in chapter 2, the safe norm road behaviors associated with pedestrian rules presented by Granié (2007) were used and denoted as velocity compliance.

Not looking before crossing is considered an unsafe behavior by Rosenbloom, Ben-Eliyahu and Nemrodov (2008). "Looking before crossing" to check for approaching traffic and "looking while walking" in the Granié (2007) study are considered complying with pedestrian rules. Our visual search compliance variable is based on children looking straight ahead, at a traffic light, or toward the vehicles before crossing. Looking at other pedestrians, objects on hand, the ground or at nothing related to the street, are all signs of non-visual search.

Table 3.3 Composite variables of rule compliance

Mixed effect logistic regression Model No	Type of indicators		Retained variables	Number of recorded observation
1	**Temporal**	Compliance	Crossing ended on: 1: Green light, white man or flashing red hand	568
		Non compliance	0: Red light, yellow light or red hand	
2	**Spatial**	Compliance	Type of crossing: 1: Crossed in straight line	731
		Non compliance	0: Outside the parallel lines or diagonal	
3	**Velocity**	Compliance	Tempo: 1: Regular pace before and during crossing	731
		Non compliance	0: Accelerated pace before crossing or non-regular pace during crossing	
4	**Visual search**	Compliance	Head/eye direction before crossing: 1: Head/eye towards the traffic light, straight ahead or towards the vehicles	731
		Non compliance	0: Head/eye towards the ground, towards other pedestrians, towards an object or towards nothing in particular	

Source: Author (2018)

3.5.3 Statistical analyses

As discussed before, four parks belonging to different categories were chosen in this study. Based on the park sizes and desired crosswalk types, 17 crosswalks were selected. In order to have acceptable sample size, the Green's (1991) general rule of thumb were employed to ensure reliable statistical outcomes (Tabachnick and Fidell 2007). According to this rule, our analysis with 731 observations had enough power of calculation. We also evaluated marginal effect ($p<0.1$) which facilitate interpretation of results (Fullerton and Xu 2016) and warrants further investigations in future research.

After establishing the dependent variables logics, descriptive bivariate analyses provided an overview of the factors related to each of the four rule compliance measures using Chi-squared tests of statistical significance for qualitative variables by SAS software (Statistical Analysis System 2002-201). This analysis confirms whether significant association exists between the

dependent variables (child pedestrian rules compliance) and binary/categorical independent variables.

As the next step, the mixed effect logistic regression models were used, one for each compliance rule. The mixed effects logistic regression can model binary outcome variables with the log odds which are linear combination of predictor variables when data are clustered or for considering both fixed and random effects (Agresti 2013). Since many observations are recorded at each of the crosswalks, mixed-effects regressions enable us to account for the grouping of observations in crosswalks using a random effect. Using a variable for parks as a random effect in mixed-effect logistic regressions did not improve the quality of the models as shown by the AIC (Aikaike Information Criterion). This is why we did not use it in our final model. Multivariate analyses were performed on Stata 12 with the melogit command (Stata Statistical Software 2011). A few variables had to be removed from specific model because they were a direct component of the dependent variable and, thus, an obvious problem of endogeneity would arise. After verifying for multicollinearity with Crammer's V, we excluded three variables: gender of adult (correlated with supervision) and eye movements towards vehicles (correlated with car interaction). Supervision was also recoded for the multivariate analysis into a binary variable indicating whether the child was physically close (contact or within reach) or not (out of reach or no supervision). Table 3.4 describes the independent variables retained in the final models.

Table 3.4 Retained independent variables in the multivariate model

Retained independent variables	*Categories*
Individual characteristics	
Age	0: 4-8 years (Younger children) 1: 8-12 years (Older children)
Gender	0: Girl 1: Boy
Situational characteristics	
Supervision	0: No adult 1: Adult but out of reach 2: Adult within reach or contact
Gender of adult	0: Male 1: Female 2: Both genders
Other pedestrians	0: Alone 1: 1 to 5 people 2: 6 people or more
Car interaction	0: No 1: Yes
Behavior characteristics	
Stopping at the curb before crossing	0: No 1: Yes
Looked towards the vehicles before crossing	0: No 1: Yes
Looked straight ahead/at traffic light before crossing	0: No 1: Yes
Initiator of the crossing	0: No initiator (Adult and child at the same time) 1: Child initiator 2: Adult initiator
Road environment characteristics	
Signage	0: No signage 1: Stop sign 2: Traffic light without pedestrian light 3: Traffic light with pedestrian countdown display
Crosswalk width	0: Less than 15m 1: Between 15m and 25m 2: More than 25m
Speed required to cross in time	0: 1 m/s or less 1: More than 1m/s
Distance between the nearest park entrance and the intersection	0: 5 m or less 1: More than 5 m

Source: Author (2018)

CHAPTER 4: RESULTS: AN EXAMINATION OF CHILD PEDESTRIAN RULE COMPLIANCE AT CROSSWALKS AROUND PARKS IN MONTREAL, CANADA

This thesis has been organized as an article-based manuscript. Hence, this chapter was prepared as an article, and submitted to the Journal of Environmental Psychology. This paper is entitled “An examination of child pedestrian rule compliance at crosswalks around parks in Montréal, Canada” consisting an abstract, introduction, results, discussion, and a brief conclusion. The authors’ name and their respective affiliations are as follows:

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4.1 Abstract

Background: While urban parks are an undeniable popular destination for children, the scientific community has paid very little attention to road safety nearby, in comparison to schools.

Objective: The objective of this study is to examine child pedestrian safety around parks by considering four rule compliance measures: temporal, spatial and velocity compliance and visual search.

Method: Street crossing observations of 731 children were recorded at 17 crosswalks around four parks in Montreal, Canada in the summer of 2017. Information on child behaviors, road features, and pedestrian-vehicle interactions were gathered in three separate forms. Chi-square tests are used to highlight the individual, situational, behavioral and road environmental characteristics that are associated with pedestrian rule compliance. These characteristics are further explored through four different mixed-effects logistics regressions – one for each rule compliance measure, all using the same set of correlates.

Results: About half of our sampled children started crossing at the same time as the adults who accompanied them but more rule violations were observed when the adult initiated the crossing. Many children were observed to be accelerating in the middle of the crossing as the park was nearby. In multivariate models, gender of the child did not have a significant impact on rule compliance. Several variables were positively associated with rule compliance: stopping at the curb before crossing, parental close supervision, and pedestrian countdown signals. Pedestrian-car interaction had a mixed impact on rule compliance: the presence of an interaction is positively associated with visual search but negatively associated with temporal and velocity compliance.

Conclusion: Overall, rule compliance among children was high for each of our indicators, but about two-thirds failed to comply with all four indicators. A few measures, like longer crossing signal and pedestrian countdown display at traffic lights, may help to ease rule compliance and, ultimately, provide safer access to parks.

Keywords: road traffic safety; crossing behavior; child pedestrian; rule compliance; crosswalk; parks

4.2 Introduction

In Canada, traffic collisions are the leading cause of injury-related death for children under 14 years old (Natalie L Yanchar et al. 2012). On average, 30 child pedestrians are killed and more than 2000 are injured every year, as Canada lags behind OECD's top performers for the past years (CCMTA 2013). A great proportion of these collisions occur at road intersections (Siram et al. 2011).

Crossing a street involves a complex series of tasks - i.e. detecting traffic, planning the route, assessing the speed and traffic, making oneself visible - that exacerbates the risk of injury for children (Schieber and Thompson 1996). Hence, because of their small stature and their developing physical and cognitive overall attributes, child pedestrians form a vulnerable road user group at risk of severe injuries with long-term physical and mental impairments (Birken et al. 2006).

Active transportation has undeniable health benefits and commuting to schools, parks and other children's destinations can provide opportunities for physical activity (Frumkin 2003). However, road insecurity while crossing streets is a well-founded reason for children to avoid them or for parents to drive them to destination instead of walking (Ferenchak and Marshall 2017). Among those destinations, much attention in the recent scientific literature has been paid to the road safety around schools (ITF 2012; Boarnet et al. 2005). However, little research and much less effort has been done regarding parks. Yet many children go to parks after schools or on weekends especially in dense urban areas where there are no yards to play (Marcus and Francis 1997). Accordingly, a recent study found that the risk of child's pedestrian fatalities is greater around parks: 1.04 to 2.23 times higher than around schools and 1.16 to 1.81 times higher than any other citywide crossing (Ferenchak and Marshall 2017), recalling the urge to study this important destination.

For children, injury prevention is often based on systematic behavioral rule application (Zeedyk et al. 2001). Low level of compliance with road rules and unsafe behaviors from either drivers or pedestrians are the main reasons for the low level of pedestrians' safety (Şimşekoğlu 2015). In other words, appropriate usage of crosswalks (complying with rules) by pedestrians and motor vehicles users increases the safety of pedestrians (Akin and Sisiopiku 2007). However, if a number of studies cover the prevalence of traffic violations by pedestrians based on specific individual characteristics like age or gender (Rosenbloom, Nemrodov and Barkan 2004; De Ceunynck et al. 2012), compliance to rules during childhood is much less widespread in research, making our understanding limited on how various pedestrian and road environment characteristics may affect

a child's compliance to road safety rules. The current study attempts to fill this gap regarding child pedestrian safety around parks by examining individual, situational, behavioral and road environment characteristics that determine whether the child complies with various road safety rules during street crossings.

4.3 Factors associated with child pedestrian safety and compliance

Past research on child's pedestrian injuries demonstrate that risk factors are related to four categories, and that they have not changed for decades: children road accidents are caused by a combination of individual, situational, behavioral and physical (road) environment characteristics.

4.3.1 Individual characteristics

Demographic characteristics such as age and gender are known as important predictors of child pedestrian injuries (Parachute Canada 2016; Schuurman et al. 2009). Several studies point to the increased road risk posed by younger pedestrian children, explaining it by their lack of traffic knowledge and experience, cognitive and physical ability, and visual acuity (Dunbar, Hill and Lewis 2001; Oxley et al. 2005; Whitebread and Neilson 2000). As for gender, Barton and Schwebel (2007) and Granié (2007) find that boy pedestrians are less likely to comply to road safety rules and more likely to be involved in injury-related accidents.

4.3.2 Situational characteristics

Situational conditions during the crossing can have an effect on safety and compliance (Cinnamon, Schuurman and Hameed 2011). When adults accompany children to and from destination, there is a demonstrated reduction in the risk of injury (Barton and Schwebel 2007; Morrongiello 2005). We make the hypothesis that the parent/caregiver's gender may also have an impact, as adult men are proven to display a more careless attitude and perform more violations (Rosenbloom and Wolf 2002; Harré, Brandt and Dawe 2000). Likewise, the presence of other pedestrians crossing jointly may influence the crossing speed, the timing, the trajectory and the level of attention (Hoogendoorn, Bovy and Daamen 2002).

The term “interaction” usually refers to an event where, without any collision, the paths of both a vehicle and a pedestrian intersect while they are still on the roadway (Trozzi, Manley and Kasparias 2015). As conflicts lead to more collisions (Cloutier, Lachapelle and Howard 2018; Sacchi and Sayed 2016), the occurrence of such interaction may alter the trajectory and which may in turn lead to more collisions (Wazana et al. 1997; Cloutier et al. 2017).

4.3.3 Behavioral characteristics

Tempo displayed before and after the crossing (running or not), not stopping at the curb, not looking before crossing, and attempting to cross when a car is near are considered unsafe behaviors as they reduce the ability to correctly assess traffic situations (Rosenbloom, Ben-Eliyahu and Nemrodov 2008; Tom and Granié 2011; Zeedyk et al. 2001). As behavior and judgement are inherently inconsistent in young age groups, child pedestrians find themselves notably at risk. Crossing in a straight line (not diagonally) and waiting for the next green light at the curb are known to be related to fewer interactions with vehicles and therefore safer (Zhuang, Wu and Ma 2018; Sisiopiku and Akin 2003).

4.3.4 Road environment characteristics

Road characteristics can reduce the probability of pedestrian injuries by providing a safer environment to cross. Accordingly, uncontrolled crosswalks inflate the risk of conflict, especially in urban areas (Hakkert, Gitelman and Ben-Shabat 2002). Crosswalk width also has an impact on safety since wider streets create longer exposure to traffic for pedestrians (Montella and Mauriello 2010), despite the fact that pedestrians tend to cross them faster and more carelessly (Tarawneh 2001; X. Zhang et al. 2013).

As for pedestrian signals, they seem to have an effect on safety as pedestrians are less likely to finish crossing on a red light there (Brosseau et al. 2013). However, other results from countdown timer are highly contradictory: they demonstrate improvement in behavior (Brosseau et al. 2013; Lipovac et al. 2013; Markowitz et al. 2006; Paschalidis et al. 2016), but they also give rise to non-complying behaviors (Huang and Zegeer 2000; Vujanić et al. 2014), and led to an increase in the number of late-starter and late-finisher pedestrians (Wanty and Wilkie 2010). As for child

pedestrians, Fu and Zou (2016) demonstrated that countdown display helped child pedestrians to finish their crossing on time.

Finally, the most common time allowed for a pedestrian to cross in time at a light-controlled intersection (i.e. based on a 1.2 meter per second walking speed) does not consider slower walkers or various contextual characteristics: walking speed varies according to age (children being slower), group size and composition, traffic-control condition or even departure signal (Almodfer et al. 2017; Gates et al. 2006; Li et al. 2013; Marisamynathan and Perumal 2014).

4.4 Methods

4.4.1 Site selection

Four parks (n=4) were selected in Montreal, Canada following the typology developed by Apparicio et al. (2010) which divides parks according to size and number of facilities (Figure 4.1). Adjacent intersections and crosswalks (n=17) were selected to represent a variety of road and distance to the entrance of the park.

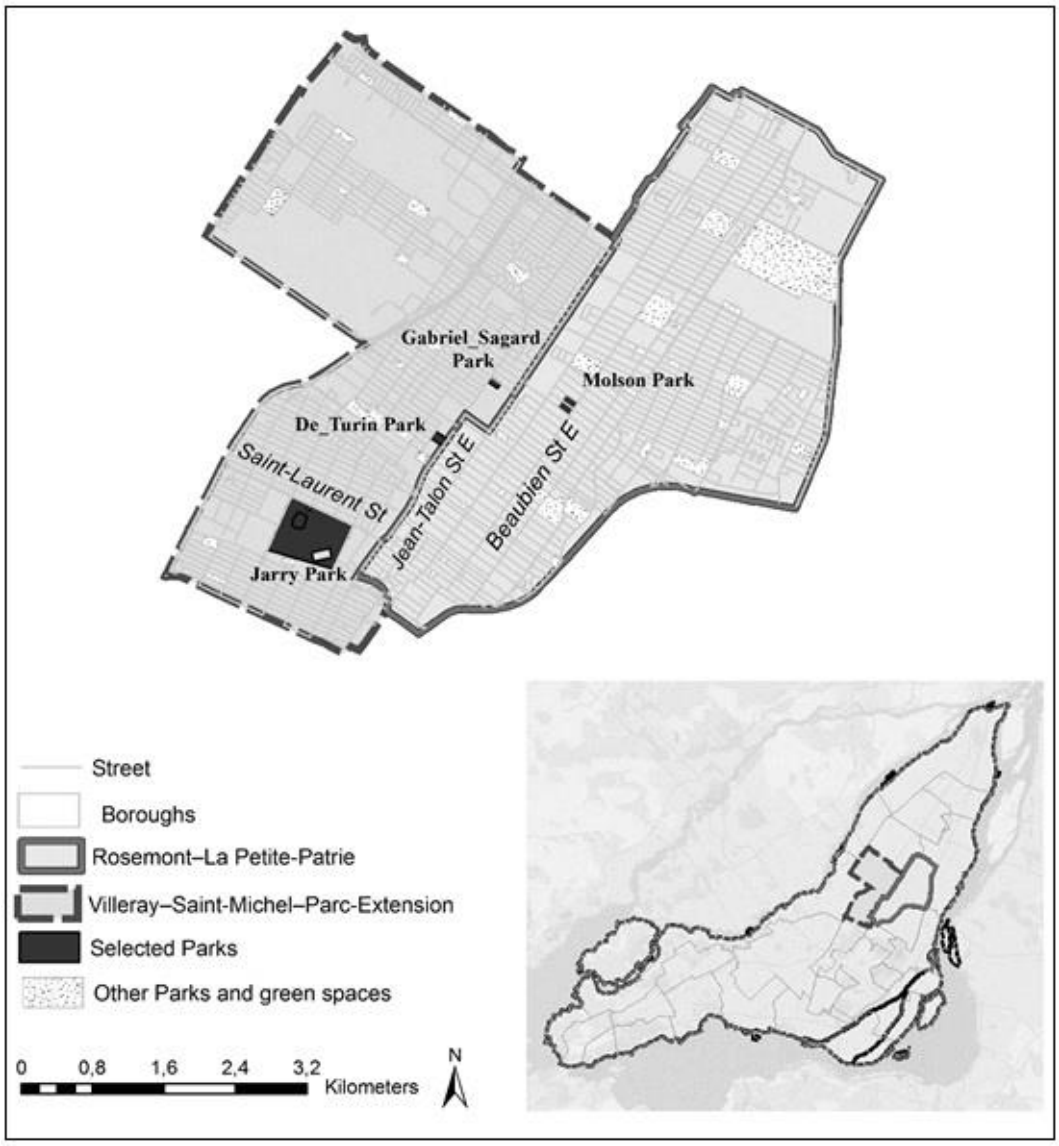

Figure 4.1 Location of selected park in Island of Montreal
Source: Author (2018)

4.4.2 Observation protocol

Observations of child pedestrians crossing toward the park were recorded between June and August 2017, during daytime, on weekdays and weekends. Four trained observers were posted near the sidewalk or in the park toward which the child pedestrian was heading. If there was more than one child or a group of children, only one of them was randomly selected for observation. Most of the time, the observers would work in groups of two. Crossing situations were recorded with three different tools based on previous work (Cloutier et al. 2017): (1) child pedestrian crossing behaviors, (2) crosswalks characteristics and, if applicable, (3) interactions between the child pedestrian and vehicles.

Crossing behaviors were observed at three specific time (Figure 4.2): (1): at the curb, (2): on the crosswalk, (3): after crossing. All the observations were recorded on iPads in the Survey123 software developed by ESRI (Environmental Systems Research Institute 2017). Each child and each crosswalk had a unique ID, which made the link possible between the three forms.

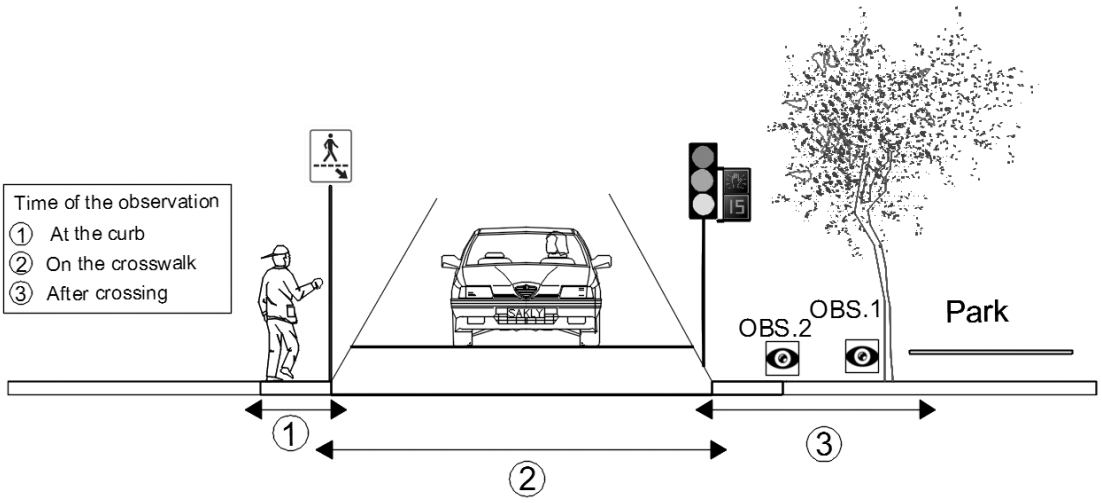

Figure 4.2 Observation protocol for crossing of each child pedestrian
Source: Author (2018)

4.4.3 Crosswalks characteristics

Four crosswalk characteristics are included in the present analysis (Table 4.1): presence and type of traffic control sign (stop sign, traffic light, pedestrian light), crosswalk width (in meter), time

allowed to cross (in second), and distance between the nearest entrance of the park and the crossing (see Figure 4.3 for examples). For street crossings with a traffic light, it was possible to calculate the 'required speed to cross on time': by dividing the crosswalk width by the time allowed to cross (pedestrian or green phase).

Table 4.1 Crossing characteristics and number of crosswalks

Characteristics	Number of crosswalks
Signage	
No signage	2
Stop sign	2
Traffic light without pedestrian light	5
Traffic light with pedestrian countdown display	8
Crosswalk width	
Less than 15m	6
Between 15m and 25m	9
More than 25m	2
Required speed to cross in time	
1 m/s or less	9
More than 1 m/s	4
Distance between nearest entrance and intersection	
5 m or less	15
More than 5 m	2

Source: Author (2018)

Figure 4.3 Example of crosswalk characteristics: a) No signage b) Stop sign c) Traffic light without pedestrian light d) Traffic light with pedestrian countdown display e) Narrow crosswalk f) Wider crosswalk
Source: Author (2018)

4.4.4 Retained individual, situational, and behavioral categories

Table 4.2 presents the characteristics observed in this study. Two individual characteristics were recorded for each pedestrian: age and gender. Age was estimated in two categories: younger (approximately less than 9 years old) represented 56.9% of our sample, and older children (~ 9 to 12 years old). Although we did not conduct systematic observation, our samples were almost equally divided between boys (51.2%) and girls (48.8%). As for situational elements, for children with an adult, we recorded the adult gender and the level of physical proximity; i.e., whether there was a physical contact, and whether the child was within the adult's reach. According to our observation, 84% of children were supervised by adults, which 12.9% of them were out of reach. It is worth noting that half of the children were accompanied by a female adult, while 14.2% of them were with both male and female adults. We also recorded the number of other pedestrians crossing jointly with child pedestrians. Based on our samples, 37.4% of children crossed the street at the same time with other pedestrians (excluding their companion), with a few of them (8.3%) crossing with six other pedestrians or more. In the present study, we only included a binary variable if an interaction with a car occurred during the crossing, meaning whenever child and vehicle's paths would cross while the child was still on the crosswalk. It allows us to study broadly how a vehicle crossing a child's path affects rule compliance. We observed that 81.5% of child pedestrians did not experience any interaction with vehicles while crossing the street.

For intersections with traffic lights, 'Stopping at the curb before crossing' indicates whether the child waited for the next green light. We found that 59.1% of children stopped at the curb; Moreover, only 36.4% of them looked towards the vehicles, while more than half of them (52.7%) looked straight ahead/at traffic light before starting to cross. In this research, we also recorded the 'Initiator of the crossing' referring to the pedestrian, adult or child, who lead the crossing. When there was no obvious initiator, the observer selected 'adult and child at the same time'. In 56.5% of our observations, the adult and the child started to cross at the same time, and in 33.5% of them, the adult was the initiator.

Table 4.2 Retained individual, situational and behavioral categories

Individual characteristics	Categories	n (%)
Age	Younger children	416 (56.9%)
	Older children	315 (43.1%)
Gender	Girl	357 (48.8%)
	Boy	374 (51.2%)
Situational characteristics		
Supervision	No adult	117 (16.0%)
	Adult but out of reach	94 (12.9%)
	Adult within reach or contact	520 (71.1%)
Gender of adult	Male	144 (19.7%)
	Female	366 (50.1%)
	Both genders	104 (14.2%)
Other pedestrians	Alone	457 (62.5%)
	1- 5 pedestrians	213 (29.1%)
	6 pedestrians or more	61 (8.3%)
Car interaction	Yes	135 (18.5%)
	No	596 (81.5%)
Behavior characteristics		
Stopping at the curb before crossing	Yes	432(59.1%)
	No	299(40.9%)
Looked towards the vehicles before crossing	Yes	266 (36.4%)
	No	465 (63.6%)
Looked straight ahead/at traffic light before crossing	Yes	385 (52.7%)
	No	346 (47.3%)
Initiator of the crossing	Adult and child at the same time	413 (56.5%)
	Child Initiator	73 (10.0%)
	Adult Initiator	245 (33.5%)

Source: Author (2018)

4.5 Rule compliance

To account for child application of pedestrian safety rules, we created four binary composite indicators that distinguished child pedestrians based on temporal, spatial and velocity compliance and visual search. Temporal compliance is whenever a child finishes the crossing on time. Spatial compliance is achieved by walking in a straight line. Velocity compliance refers to a crossing made with a regular walking pace. Visual search relates to general eyes movements and attention toward traffic-related elements.

Table 4.3 presents the variables that compose each of the compliance measures and their associated number of observations. Regarding temporal compliance, it should be noted that at traffic lights without a pedestrian light, we considered crossings ending on yellow lights as 'out of time'.

Table 4.3 Number and percentage of outcomes for rule compliance indicators

	Compliance	n (%)	Non-compliance	n (%)
Temporal	**Crossing finished on** Green light, white man or flashing red hand	451 (79.4%)	**Crossing finished on** Red light, yellow light or red hand	117 (20.6%)
Spatial	**Type of crossing** Crossed in a straight line	541 (74.0%)	**Type of crossing** Crossed outside the parallel lines or diagonal	190 (26.0%)
Velocity	**Tempo** Regular pace throughout crossing	527 (72.1%)	**Tempo** Non-regular pace before or during crossing	204 (27.9%)
Visual search	**Eye movements** Eyes towards the traffic light, straight ahead or towards the vehicles before crossing	512 (70.0%)	**Eyes movements** Eyes towards the ground, towards other pedestrians, towards an object or towards nothing in particular before crossing	219 (30.0%)

Source: Author (2018)

4.6 Statistical analyses

First, bivariate analyses provided an overview of the factors related to each of the four rule compliance measures using Chi-squared tests. Relevant relations were further explored through four mixed-effects logit models, one for each compliance rule. Since many observations are recorded at each of the crosswalks, mixed-effects regressions enable us to account for the grouping of observations in crosswalks using a random effect. Multivariate analyses were performed on Stata 12 with the melogit command (Stata Statistical Software 2011). We also evaluated marginal effect ($p<0.1$) which facilitate interpretation of results (Fullerton and Xu 2016) and warrants further investigations in future research.

A few variables had to be removed from specific model because they were a direct component of the dependent variable and, thus, an obvious problem of endogeneity would arise. After verifying for multicollinearity with Crammer's V, we excluded three variables: gender of adult (correlated

with supervision) and eye movements towards vehicles (correlated with car interaction). Supervision was also recoded for the multivariate analysis into a binary variable indicating whether the child was physically close (contact or within reach) or not (out of reach or no supervision).

4.7 Results

More than 700 children (n=731) were observed at the 17 crosswalks. For temporal compliance, only the observations recorded at an intersection with a traffic light are used (n=568). As we can see in Table 4.3, between 70% and 80% of children complied with at least one indicator. However, only a third of the observed child pedestrians complied with all the indicators altogether, both for controlled and uncontrolled crosswalks.

4.7.1 Bivariate analysis

Table 4.4 presents the descriptive statistics for all the rule compliance indicators and for each individual, situational, behavioral and road environment characteristics. Younger children were crossing in straight line (spatial compliance) more often than the older ones, although they were paying less attention visually to the road-related elements (visual search). There was no statistical difference between boys and girls.

As for situational characteristics, the majority of children (84%) were accompanied by adults; among them, 71% holding hands or within reach. The presence of an adult is positively associated with spatial compliance and negatively related to visual search. The gender of the adult only seems to have an impact on visual search, as the children accompanied by female adults are more likely to look at road-related elements. The presence of other pedestrians crossing jointly has a positive relationship with temporal and velocity compliance, but having groups of six or more is negatively associated with spatial compliance.

If there is a car interaction, the child is less likely to cross on time (temporal compliance) and less likely to adopt a regular pace throughout the crossing (velocity compliance). However, he/she is more likely to comply with the visual search and spatial compliance indicators.

With respect to behavioral factors, 59% of children stopping at the curb before crossing positively associated with all rule compliance measures except visual search (not significant). Children who

were looking straight ahead or at the traffic light before the crossing were more likely to follow spatial compliance.

Almost half of children crossing with an adult did not have a noticeable initiator while 40% of crossings were initiated by the adult and 12% by the child. When a child initiated the crossing, he or she was less likely to comply with velocity compliance. When an adult initiated the crossing, the child was less likely to comply with temporal compliance and visual search.

The presence of a pedestrian countdown display (47% of crosswalks and 32% of crossings) was almost always associated with more rule compliance while the absence of signage is associated with less rule compliance. An outstanding 93% of children who crossed at an intersection with a pedestrian countdown display finished the crossing on time. This proportion dropped to 70% for the children who crossed at a traffic light without a pedestrian signal. A child crossing a street with a pedestrian light was less likely to walk in a straight line than a child crossing a street with only a traffic light. Crosswalks of mid-sized width associated with more spatial compliance and visual search, and negatively related to temporal compliance. Higher required speed to cross in time is negatively associated with temporal compliance: 13% of children did not finish the crossing on time at crosswalks with speed under 1 m/s, when this proportion reaches 46% at crosswalks with speed over 1 meter/second.

Finally, a greater distance between the nearest entrance of the park and the crossing had a positive relationship with spatial compliance and a negative relationship with velocity compliance.

Table 4.4 Descriptive statistics

	Temporal		Spatial		Velocity		Visual	
	Compliance	χ^2	Compliance	χ^2	Compliance	χ^2	Compliance	χ^2
Individual characteristics								
Age		0,77		0,002***		0,877		0,001***
4 to 8	265(79.9%)		326(78.4%)		298(71.6%)		272(65.4%)	
9 to 12	186(78.9%)		215(68.3%)		224(71.1%)		240(76%)	
Gender		0.608		0.138		0.420		0.513
Girl	224(80.3%)		273(76.5%)		250(70.0%)		246(68.9%)	
Boy	227(78.6%)		268(72.7%)		272(72.7%)		266(71.1%)	
Situational characteristics								
Supervision		0.938		0.001***		0.001***		0.014**
No adult	51(78.5%)		69(59.0%)		78(66.7%)		95(81.2%)	
Adult but out of reach	59(80.9%)		70(74.5%)		35(37.2%)		66(70.2%)	
Adult within reach or contact	341(79.3%)		402(77.3%)		409(76.7%)		351(67.5%)	
Gender of adult		0.110		0.200		0.400		0.030**
Male	103(85.1%)		104(72%)		106(73.6%)		94(65.3%)	
Female	220(76.4%)		290(79.2%)		258(70.5%)		262(71.6%)	
Both genders	77(81.9%)		78(75%)		80(76.9%)		61(58.7%)	
Other pedestrians		0.001***		0.001***		0.009***		0.330
No other pedestrians	229(74.1%)		350(76.6%)		313(69%)		329(72.0%)	
1 to 5 people	166(83%)		165(77.5%)		156(73.2%)		142(66.7%)	
6 people or more	56(93.3%)		26(42.6%)		53(86.9%)		41(67.2%)	
Car interaction		0.001***		0.079*		0.076*		0.001***
Yes	70(68%)		108(80.0%)		88(65.2%)		110(81.5%)	
No	381(81.9%)		433(72.7%)		434(72.8%)		402(67.4%)	
Behavior characteristics								
Stopping at the curb before crossing		0.001***		0.014**		0.006***	299(69.2%)	0.557
Yes	319(85.8%)		334(77%)		325(75.2%)		213(71.2%)	
No	132(67.4%)		207(69%)		197(65.9%)			
Looked straight ahead/at traffic light before crossing		0.722		0.002***		0.256		
Yes	250(78.9%)		303(78.7%)		268(69.6%)		-	
No	201(80.1%)		238(68.8%)		254(73.4%)		-	
Looked towards the vehicles before crossing		0.127		0.499		0.001***		
Yes	140 (75.7%)		193 (72.6%)		170 (63.9%)		-	
No	311 (81.2%)		348 (74.8%)		352 (75.7%)		-	
Initiator of the crossing		0.019**		0.135		0.001***	311(75.3%)	0.001***
No initiator	253(84%)		296(71.7%)		294(71.2%)		61(83.6%)	
Child	48(77%)		60(82.2%)		35(47.9%)		140(57.1%)	
Adult	150(74%)		185(76%)		193(78.8%)			
Physical environment characteristics								
Signage		0.001***		0.001***		0.002***		0.06*
No signage	-		56(69.1%)		48(59.3%)		52(64.2%)	
Stop sign	-		53(64.6%)		50(62.0%)		65(79.3%)	
Traffic light without pedestrian light	232 (69.9%)		282(84.9%)		241(72.6%)		222(66.9%)	
Traffic light with pedestrian countdown display	219 (92.8%)		150(63.6%)		183(77.5%)		173(73.3%)	
Crosswalk width		0.046**		0.001***		0.240		0.077*
Less than 15m	147 (84.5%)		192(64.9%)		207(69.9%)		195(65.9%)	
Between 15m and 25m	229 (73.4%)		303(85.8%)		250(70.8%)		261 (74.0%)	
More than 25m	75 (91.5%)		46(56.1%)		65(79.3)		56(68.3%)	
Required speed to cross in time		0,001***						
1 m/s or less	378(87.5%)		-		-		-	
More than 1 m/s	73(53.7%)		-		-		-	
Distance between the nearest entrance and intersection		0.150		0.001***		0.016**		0.141
5 m or less	213(88.8%)		214(67.5%)		241(76.0%)		213(67.2%)	
More than 5 m	238(74.1%)		327(79.0%)		281(67.9%)		299(72.2%)	

* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$

Source: Author (2018)

4.7.2 Mixed-effects logistic models

To account for the clustering of observations by crosswalks, our binary measures of rule compliance (yes/no) were modeled in four different mixed-effect logistic regressions with the same set of variables for each (see Table 4.5). An odds ratio over one means the variable increased the odds of complying with the measure.

For *temporal compliance*, not many individual and situational variables were significant except the car interaction, which is decreasing the odds of crossing on time. Out of all the variables, stopping at the curb (waiting for the next green light) has the strongest odds of being associated with finishing the crossing on time (temporal compliance). The presence of a pedestrian countdown display also increases the odds of finishing on time by 3.6. However, an adult initiating the crossing decreases the odds by more than 40%. As expected, a higher required speed to cross on time is negatively associated with temporal compliance: a speed of more than 1 m/s reduces the odds of finishing on time by 70%.

As for *spatial compliance*, the physical presence of an adult and the interaction with a car increases the odds of crossing in a straight line; however, having big groups of pedestrians crossing jointly (i.e. six or more) reduces the odds of complying with the measure. Spatial compliance shows increased odds with behavior like stopping at the curb before crossing and looking at the traffic and the light before crossing. A medium-sized crosswalk (between 15 and 24 meters) and a traffic-light controlled intersection also increase the odds of complying spatially.

With regards to *velocity compliance*, older and supervised children have stronger odds of keeping a constant speed throughout the crossing. Using crosswalks with traffic lights and, if so, stopping at the curb before crossing also increase these odds. However, the odds of keeping a constant speed are 65% less for a crossing initiated by a child.

Visual search increased odds of rule compliance for older children. The same can be said for crossings with car interactions, for crosswalks of mid-sized width or for intersections with stop signs or pedestrian countdown display. While the child initiating the crossing increases his odds of looking at road-related elements by 1.8, the adult initiating the crossing has the reverse effect, decreasing his odds by half.

Table 4.5 Mixed-effects logistic models of rule compliance (Odds ratios)

	Temporal	Spatial	Velocity	Visual
Age				
Younger [Ref.]				
Older	0.964	0.765	1.581**	1.465**
Gender				
Girl [Ref.]				
Boy	0.779	0.913	1.150	0.964
Supervision				
No [Ref.]				
Yes	0.901	1.817***	3.305***	1.017
Other pedestrians				
Alone [Ref.]				
1-5 people	1.383	1.083	0.838	0.807
6 people or more	1.830	0.434**	1.285	0.855
Car interaction				
No [Ref.]				
Yes	0.468***	1.657*	0.560**	2.370***
Stopping at the curb before crossing				
No [Ref.]				
Yes	3.796***	1.458*	1.456*	0.754
Looks at the traffic light/straight ahead				
No [Ref.]				
Yes	0.862	1.562**	0.829	-
Initiator of the crossing				
None [Ref.]				
Child	0.731	1.725	0.356***	1.789*
Adult	0.526**	0.960	1.186	0.469***
Crosswalk width				
Less than 15m [Ref.]				
Between 15m and 25m	-	2.307***	0.887	1.88**
More than 25m	-	0.947	0.978	1.03
Signage				
No signage [Ref.]				
Stop sign	-	1.658	1.569	2.186*
Traffic light without pedestrian light	-	2.080*	2.003**	1.119
Traffic light with pedestrian countdown display	3.577***	0.840	1.924*	2.376**
Required speed to cross in time				
1 m/s or less [Ref.]				
More than 1 m/s	0.301***	-	-	-
Distance between nearest entrance and intersection				
5 m or less				
More than 5 m	1.813	1.010	0.712	1.490*
Constant	8.910***	0.745	0.704	1.124
Crossing site constant	0.000	0.071	0.000	0.000
Number of groups	13	17	17	17
Number of observations	568	731	731	731
Chi square	89.81	71.59	77.63	64.86
AIC	477.346	762.471	819.083	851.139

* p < 0.1 ** p < 0.05 *** p < 0.01

Source: Author (2018)

4.8 Discussion

4.8.1 Age: the only significant individual factor

Age was found to be the only significant individual factor in child pedestrian rule compliance. The older children tended to show a more effective visual search and a more constant walking pace, which is similar to other research results (Dunbar, Hill and Lewis 2001; Oxley et al. 2005; Whitebread and Neilson 2000). Neither the gender of the child nor the one of the accompanying adult had a significant impact.

4.8.2 Adult companion and car interaction affect child pedestrians rule compliance

As for situational factors, our results are consistent with previous research studies on supervision: children who are physically close to adults are more likely to keep a regular pace (Rosenbloom, Ben-Eliyahu and Nemrodov 2008) and walk in a straight line (Granié 2007). These findings are reasonable as the physical supervision from an adult creates an inhibitory control on a child's behaviors. To the best of our knowledge, there is no previous research study that examines the impact of the crossing initiator– adult or child – on rule compliance. Our results provide evidence that whenever adults initiate the crossing, children are less likely to pay attention to road-related elements and are less likely to finish the crossing on time. This might be owed to the fact that children supervised, as opposed to children alone, may sometime display careless behaviors because they rely on the adults for their safety (Rosenbloom, Shahar and Perlman 2008; Granié 2007; van der Molen 1982). Likewise, whenever children initiate the crossing, they are more likely to perform a visual search because, hypothetically, they become responsible for their own safety. Seemingly, children who initiate the crossing are also more likely to change their walking pace. It can be hypothesized from our field observations that these children, already excited about going to the park, initiate the crossing and accelerate throughout it in order to reach it faster.

As shown by other research (Langbroek et al. 2012; Pasanen and Salmivaara 1993), car interaction and red light violation have direct association: we found that car interaction decreases the chance of finishing a crossing on time, which might be due to children changing their behavior in order to avoid or manage the interactions with the vehicles. As such, children who experienced a conflict with approaching vehicles considerably increased their visual search. Indeed,

pedestrian-vehicle conflict risk can be compensated by an appropriate visual search (Langbroek et al. 2012). Along the same lines, we found that interactions increase odds of spatial compliance which may also be explained as a compensatory safe behavior from children since the proper usage of (marked) crosswalks can reduce interaction with vehicles (Sisiopiku and Akin 2003). Finally, we found that children were more likely to change their walking pace when they experienced a traffic interaction, which has also been reported by Pasanen and Salmivaara (1993).

4.8.3 Stopping at the curb and looking at road-related elements: two significant factors before crossing

Children who stop at the curb have more time and make better and more reasonable crossing decisions. These results are consistent with others saying that stopping at the curb and waiting for the next green light before crossing increases the odds of finishing the crossing on time and allows the pedestrian to walk at a constant speed without having to rush (Koh, Wong and Chandrasekar 2014). Looking at road-related elements prior to the crossing is also in line with previous studies: pedestrians who are visually aware are more likely to comply with the rules (Thomson et al. 1996; Tom and Granié 2011).

4.8.4 Road elements: many significant factors

Several road elements have the significant associations with the four forms of compliance, but their magnitude were not the highest. As expected, children are more likely to finish on time at shorter crosswalks. When it came to wider crosswalks, they are more likely to have better visual search and walk in a straight line (which is also significant at crossings with traffic lights), which echoes previous research stating that children are more conservative in their behaviors when they are exposed to faster and denser traffic (Abrashev et al. 1999; Cloutier et al. 2017; Montella and Mauriello 2010; Noland and Quddus 2004).

Since the Manual of Uniform Traffic Control Devices for Canada (MUTCD) (1998) and other similar manuals recommend 1.2 m/s as the suggested speed to cross a street with traffic signal, it was no surprise that children were less likely to meet temporal compliance at signalized crosswalks

where the required speed was over 1 m/s. Indeed, many scholars believe that a crossing speed of 1.2 m/s is too fast for most pedestrians (Tarawneh 2001).

Our results depict that higher level of signage such as pedestrian countdowns is generally associated with more rule compliance, which is in line with previous research (Markowitz et al. 2006). Countdown display seems to have a considerable impact on temporal compliance: when informed of the time left to cross in time, pedestrians may accelerate their walking speed accordingly in order to finish on time (Fu and Zou 2016; Wanty and Wilkie 2010). At intersections with traffic lights, children were more likely to walk in a straight line, which reinforces the idea that when exposed to heavier traffic, children adopt behaviors that are deemed more careful.

4.8.5 What role for the park as a destination

Although urban parks are undeniably popular destinations for children, the scientific community has paid very little attention to them in comparison to schools when studying pedestrian road safety. Although our results did not directly capture a significant park effect, it seems to have a singular impact on child pedestrians' behaviors. During our observations, parks had stimulating, yet less predictable, effects on child pedestrians' crossing behavior, such as sudden acceleration, and more agitated eye movements. For example, out of the 28% of children who changed their walking tempo during the crossing, the vast majority were accelerating (84%) towards the park. Moreover, out of the 17% of children who were running in the park after the crossing, 75% were already running beforehand, right in the middle of the street. Granié (2007) found the opposite when studying child pedestrians near schools: 68% of them did not run while crossing towards schools.

4.9 Conclusion

This study explores child pedestrians' crossing behaviors on roads around parks through an observational survey of individual, situational, behavioral and road environment predictors of pedestrian rule compliance. Despite the very limited literature on child pedestrian rule compliance, let alone child pedestrian rule compliance around parks, past studies that focused on adult safety at street intersections allowed us to create an analytical framework to fill this gap.

Although our results are informative and relevant to child pedestrian injury prevention, they have two limitations. First, for many predictors, any assumption of causality would be hazardous. For instance, whenever a car interaction arises, did it make the child more visually aware, or was the car interaction just a light collateral of what would have otherwise been a more severe conflict had it not been for the visual awareness of the child? Second, we assume that there is a correspondence between rule compliance and children's safety; however, we did not find any conclusive results showing that children who comply with pedestrian rules are safer. Consequently, another question is raised: to what extent are the child pedestrians who comply with road rules safer? This issue can be addressed in future research by considering all road users in one framework and by focusing on pedestrian-vehicle conflicts.

CHAPTER 5: DISCUSSION

Considering the pedestrian rule compliance, the current study provides insights into how different factors including individual, situational, behavioral, and road environment characteristics might affect children's behavior who cross the roads next to parks. The most important results found in this study will be discussed and elaborated in detail in the following sections.

5.1 Age category: the only significant individual factor

In our study, age category was found to be the only individual factor influencing child pedestrians rule compliance. The older children tended to show a more effective visual search and a more constant walking pace, which is similar to other research results (Rosenbloom, Ben-Eliyahu and Nemrodov 2008; Whitebread and Neilson 2000). This finding makes sense since older children are more experienced and knowledgeable compared to younger ones, which makes them better at perceiving road conditions. Neither the gender of the child nor the one of the accompanying adult had a significant impact.

5.2 Adult companion and car interaction affects child pedestrians rule compliance

As for situational factors, our results are consistent with previous research studies on supervision: children who are physically close to adults are more likely to keep a regular pace (Rosenbloom, Ben-Eliyahu and Nemrodov 2008) and walk in a straight line (Granié 2007). These findings are reasonable as children who are physically close to their adults better followed their supervisors while crossing the road. To the best of our knowledge, there is no previous research investigating the influence of the crossing initiator (either child or adult) on rule compliance.According to our results, whenever adults initiated the crossing, children were less likely to pay attention to road-related elements and were less likely to finish the crossing on time. This might due to the fact that children supervised, as opposed to children alone, may sometime display careless behaviors because they rely on the adults for their safety (Rosenbloom, Shahar and Perlman 2008; Granié 2007; van der Molen 1982).

Likewise, whenever children initiated the crossing, they were more likely to perform a visual search and to change their walking pace because, hypothetically, they became responsible for their own safety. It can be hypothesized from our field observations that these children, already excited about going to the park, initiated the crossing and accelerated to reach it faster.

As shown by other research (Langbroek et al. 2012; Pasanen and Salmivaara 1993), car interaction and red light violation have direct association: we found that car interaction decreases the chance of finishing crossing on time, which might be due to the children executing more cognitive tasks while crossing to manage the interaction with the vehicles. As such, children who experienced a conflict with approaching vehicles considerably increased their visual search in order to be more aware of the traffic elements. Indeed, pedestrian-vehicle conflict risk can be compensated by an appropriate visual search (Langbroek et al. 2012). Along the same lines, we found that interactions increase odds of spatial compliance which may also be explained as a compensatory safe behavior from children since the proper usage of (marked) crosswalks can reduce interaction with vehicles.(Sisiopiku and Akin 2003). Finally, we found that children were less likely to have velocity compliance when they experience a traffic interaction, which has been also reported by Pasanen and Salmivaara (1993).

5.3 Stopping at the curb and looking at road-related elements: two significant factors before crossing

Children who stop at the curb have more time and make better and more reasonable crossing decisions. These results are consistent with others saying that stopping at the curb and waiting for the next green light before crossing increases the odds of finishing the crossing on time and allows the pedestrian to walk at a constant speed without having to rush (Koh, Wong and Chandrasekar 2014). Looking at road-related elements prior to the crossing is also in line with previous studies: pedestrians who are visually aware are more likely to comply with the rules (Thomson et al. 1996; Tom and Granié 2011).

5.4 Road elements: many significance factors

Several road elements have the most significant associations with the four form of compliance, but their magnitude were not the highest. . As expected, children are more likely to finish on time

at shorter crosswalks. When it came to wider crosswalks, they are more likely to have better visual search and walk in a straight line (which is also significant for crossing with traffic lights), which echoes previous research stating that children are more conservative in their behaviors when they are exposed to faster and denser traffic., (Abrashev et al. 1999; Cloutier et al. 2017; Montella and Mauriello 2010; Noland and Quddus 2004).

Since the Manual of Uniform Traffic Control Devices for Canada (MUTCD) (1998) and other similar manuals recommend 1.2 m/s as the suggested speed to cross a street with traffic signal, it was no surprise that children were less likely to meet temporal compliance at signalized crosswalks where the required speed was over 1 m/s. Indeed, many scholars believe that a crossing speed of 1.2 m/s is too fast for most pedestrians (Tarawneh 2001).

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5.5 What role for the park as destination?

Although urban parks are undeniably popular destinations for children, the scientific community has paid very little attention to them in comparison to schools when studying pedestrian road safety. Although our results did not directly capture a significant park effect, it seems to have a singular impact on child pedestrians' behaviors. During our observations, parks had stimulating, yet less predictable, effects on child pedestrians' crossing behavior, such as sudden acceleration, and more agitated eye movements. For example, out of the 28% of children who changed their walking tempo during the crossing, the vast majority were accelerating (84%) towards the park. Moreover, out of the 17% of children who were running in the park after the crossing, 75% were already running beforehand, right in the middle of the street. Granié (2007) found the opposite when studying child pedestrians near schools: 68% of them did not run while crossing towards schools.

5.6 Limitation of the study

As in any observational research, the current study has limitations associated with the methodology and data analysis. As one of the main limitations, there were few previous studies on this topic, nor any statistical resources about child pedestrian injuries on roads surrounding the parks which prevented us from appropriate validation of our results.

Our observation type also limited our study. Since we employed non-participatory observations, some factors such as pedestrians' age category and quality of their visual search were estimated. The other item that drew our attention during the observation was recording children's "head and eyes movements" factor. Practically, it was impossible to make sure whether children are looking at the coming vehicles or at other non-related objects. In order to tackle these drawbacks, a short talk after completion of each observation could be helpful in considering better estimations in future research.

There are also some limitations in our analysis protocol. For instance, we only considered 4 parks which were almost in the inner city. Moreover, we studied only some crosswalks and intersections adjacent to the park, not all of them. Although, these limitations do not allow us to generalize our results to different situations, the models were strong due to enjoying adequate number of observation (731 for 17 crosswalks). Generally speaking, crossing a road is a complex process in which many factors are involved. As some of these factors happen simultaneously, it is not possible to determine proper causal relationships between them. Nevertheless, our results are informative on several aspects.

CONCLUSION

This study explores child pedestrian rule compliance through a field observation. To achieve our objectives, we examined individual, situational, behavioral and road environment characteristics. Previous studies conducted for adults helped us to assess the compliance of pedestrian rules, and we adapt them to the child pedestrian context since little has been done on this specific population. Our results demonstrate that certain characteristics could noticeably affect children rule compliance. However, complexity of road crossing process makes it challenging to find which factor is dominant. Our findings point to the need for safer road environment near urban parks, such as countdown display, and adjusting the allowed time of traffic lights based on speed of children.

There are some items to be investigated more in future research. First, the urban parks can be selected from different neighborhood to better generalize the results to different regions. Secondly, we assumed that there is a correspondence between rule compliance and children's safety; however, we did not find any conclusive results showing that children who comply with pedestrian rules are safer. Consequently, another question is raised: to what extent are the child pedestrians who comply with road rules, safer? This issue can be addressed in future research by considering all road users in one framework, and by focusing on pedestrian-vehicle conflicts. Thirdly, as previously mentioned, there is not a specified required speed reference for child pedestrians in the literature. Hence, more research can be conducted to appropriately estimate this variable.

APPENDIX 1: BEHAVIOR OBSERVATION FORM

# observation	Heure	Météo	Date	Nom de Park	Rue traversée	Direction rue traversée	Nom enquêteur	ID Piéton

Avant la traversée

Activités à l'approche de la traversée	
Joue	
Discute	
Aucune	

Zone d'attente du piéton		
	Réglementaire (sur le trottoir)	
	Non-réglementaire (sur la chaussée)	
	Sur le terre-plein	
	Pas d'attente	

FAUX DÉPART	*oui*
	Non

Nombre de piétons se présentant pour traverser en même temps que l'enfant choisi (exclu l'enfant choisi sr ses accompagnateurs)		
	Aucun	
	1 personne	
	2 personnes	
	3 à 5 personnes	
	6 personnes et plus	
	Groupe sous supervision (scolaire, camp jour)	

Tempo du sujet avant la traversée (à l'approche)		
	S'arrête	
	Ralentit	
	Accélère	
	Rythme de marche régulier	

Mouvement(s) de tête et regard avant la traversée		
	Vers le feu/ droit devant	
	Vers les véhicules en circulation (gauche-droit)	
	Vers les autres piétons (enfants ou adultes)	
	Vers le sol	
	Vers un objet dans ses mains	
	Rien en lien avec la route	

Nombre de véhicules qui passent avant la traversée	
0	
1 à 3	
4 à 6	
7 à 9	
10 et plus	

Au début de la traversée

État du feu au début de la traversée du piéton		
	Flèche verte « tout droit »	
	Flèche verte clignotante	
	Feu vert	
	Feu jaune	
	Feu rouge	
	Chandelle blanche (priorité bus)	
	Non-applicable	

État du feu au début de la traversée du piéton		
	Bonhomme blanc	
	Main rouge clignotante	
	Main rouge	
	Non-applicable	

Initiative de la traversée		
	Enfant initiateur	
	Parent initiateur	
	Non applicable	

Pendant la traversée

Mouvement(s) de tête et regard pendant la traversée		
	Vers le feu/ droit devant	
	Vers les véhicules en circulation (gauche-droit)	
	Vers les autres piétons (enfants ou adultes)	
	Vers le sol	
	Vers un objet dans ses mains	
	Rien en lien avec la route	

Tempo du sujet Pendant la traversée (à l'approche)		
	S'arrête	
	Ralentit	
	Accélère	
	Rythme de marche régulier	

Supervision Pendant la traversée		
	Pas de supervision	
	enfant hors de portée	
	Supervision rapprochée, enfant à portée de main	
	Contact physique (main, manteau)	

À la fin de la traversée

État du feu à la fin de la traversée du piéton	Flèche verte « tout droit »	
	Flèche verte clignotante	
	Feu vert	
	Feu jaune	
	Feu rouge	
	Chandelle blanche (priorité bus)	
	Non-applicable	

Lieu de la traversée	Passage piéton (pp)	
	Moins de 5 mètres du pp	
	Moins de 5 mètres du pp entre véhicules stationnés	
	Pp et diagonal (termine ou commence hors du pp)	
	AUTRE : (ex : entre véhicules en mouvement)	

État du feu à la fin de la traversée du piéton	Bonhomme blanc	
	Main rouge clignotante	
	Main rouge	
	Non-applicable	

Après la traversée

Direction de l'enfant après la traversée	Se dirige vers l'entrée du parc la plus proche	
	Se dirige vers une entrée du parc	
	Marche sur le trottoir autour du parc	
	Continue dans une autre direction (s'éloigne du parc)	

Supervision après la traversée	Pas de supervision	
	enfant hors de portée	
	Supervision rapprochée, enfant à portée de main	
	Contact physique (main, manteau)	

Activités après la traversée	Joue	
	Discute	
	aucune	

Tempo du sujet après la traversée	Vite (court)	
	Normal	
	Lent	
	Très lent	

Information sur l'enfant

Âge
4-8
9-12
Sexe
Garçon
Fille

Nombre d'accompagnant(s) adulte(s)	
Nombre d'accompagnant(s) Enfant(s)	

Sexe adulte(s) accompagnant	Homme(s)	
	Femme(s)	

Source : *ESSAIM and PARI, (2013) Project and (Cloutier et al. 2017; D'Amours Ouellet 2016; Cloutier 2016; Bergeron et al. 2017*

APPENDIX 2 : ROAD ENVIRONMENT OBSERVATION FORM

# Observation	Heure	Météo	Date	Nom de Park	Rue traversée	Direction rue traversée	Nom enquêteur

ID Parc	Jarry	
	De-Turin	
	Molson	
	Gabriel-Sagard	

Type d'intersection	*No d'intersection*	
	3 voies	
	4 voies	
	5 voies	

Rue à sens unique	Oui
	Non

Signalisation

Feu signalisation	Durée de la flèche verte (sec)	
	Durée verte clignotante (sec)	
	Durée du feu vert (sec)	
	Durée du trafic jaune (sec)	
	Durée de la chandelle blanche (priorité bus) (sec)	

Panneau d'arrêt	Toutes les directions	
	Sur la traversée	
	L'autre direction	

Feu piéton	Durée de l'homme blanc des piétons (sec)	
	Durée de la main clignotante des piétons (sec)	
	Durée de la main rouge du piéton (sec)	

Décompte numérique	Oui	Non
Bouton d'appel	Oui	Non
Aucune signalisation	Oui	Non

Marquage de la traversée

Deux lignes parallèles	Oui	Non
Zébré blanc	Oui	Non
Zébré jaune	Oui	Non
Pavé ou autre revêtement différent du bitume	Oui	Non
Aucun marquage au sol	Oui	Non

Vitesse affichée (km/h)	30	
	40	
	50	
	70	
	N.A.	

Largeur de la traversée et Rue

Largeur de la traversée (m)	
Largeur de la Rue(m)	
Nombre de voies au passage pour piétons (incluant le stationnement)	

Piste cyclable

Piste en site propre	Oui	Non
Piste sur rue (marquage et délimitateur)	Oui	Non
Non	Oui	Non

Apaisement de circulation

Saillie de trottoir	1 côté	2 côtés		Aucun
Piste sur rue (marquage et délimiteur)	1 côté	2 côtés		Aucun
Stationnement interdite à moins de 5 m	1 côté	2 côtés		Aucun
Autre apaisement de circulation	Dos d'âne	Passage piéton	Bollard	Terre-plein central

Dégagement des coins (visibilité à 5 mètres)

Objets sur le trottoir : bacs à fleur, boite postale, etc.	1 côté	2 côtés	Aucun
Objets dans la rue : station bixi, stationnement vélo, etc.	1 côté	2 côtés	Aucun

Le plus proche entrée du parc

Distance entre l'entrée du parc et le passage pour piétons (m)			
Présence de lumière près de l'entrée(m)	Oui	Non	Aucun

Source : *ESSAIM and PARI, (2013) Project and (Cloutier et al. 2017; D'Amours Ouellet 2016; Cloutier 2016; Bergeron et al. 2017*

APPENDIX 3 : VEHICLE INTERACTION OBSERVATION FORM

# observation	Heure	Météo	Date	Nom de Park	Rue traversée	Direction rue traversée	Nom enquêteur	ID Piéton

Interactions entre usagers (n'importe quel usager qui CROISE la ligne de traversée PENDANT que le piéton y est)

	Véhicule 1	Véhicule 2	Véhicule 3	Véhicule 4
Type	auto vélo moto et 2 roues quadri-porteur camions taxi skate-roller-trottinette Autobus (tous)	auto vélo moto et 2 roues quadri-porteur camions taxi skate-roller-trottinette Autobus (tous)	auto vélo moto et 2 roues quadri-porteur camions taxi skate-roller-trottinette Autobus (tous)	auto vélo moto et 2 roues quadri-porteur camions taxi skate-roller-trottinette Autobus (tous)
Dépassé la ligne d'arrêt (minimum : capot)	oui non N/A (pas de ligne)	oui non N/A (pas de ligne)	oui non N/A (pas de ligne)	oui non N/A (pas de ligne)
Mouvement du véhicule	Tout droit virage à gauche virage à droite	Tout droit virage à gauche virage à droite	Tout droit virage à gauche virage à droite	Tout droit virage à gauche virage à droite
Distance véhicule-piéton lors du « croisement »	0 à 1 mètre 1,1 à 2 mètres Plus de 2 mètres	0 à 1 mètre 1,1 à 2 mètres Plus de 2 mètres	0 à 1 mètre 1,1 à 2 mètres Plus de 2 mètres	0 à 1 mètre 1,1 à 2 mètres Plus de 2 mètres
Priorité	Piéton => Véhicule Véhicule=>Piéton N.A.	Piéton => Véhicule Véhicule=> Piéton N.A.	Piéton => Véhicule Véhicule=> Piéton N.A.	Piéton => Véhicule Véhicule=> Piéton N.A.
Diagnostic de conflit (voir exemples)	Sans interaction (véhicule présent mais laisse passer complètement ou va dans la même direction)	Interaction (croisement de mouvement quand le piéton est encore sur la chaussée)	Évitement (un des usagers doit faire manœuvre d'évitement) ou collision	

/

Source : *ESSAIM and PARI, (2013) Project and (Cloutier et al. 2017; D'Amours Ouellet 2016; Cloutier 2016; Bergeron et al. 2017*

APPENDIX 4 : SYNTHÉSE DU MÉMOIRE EN FRANCAIS

Introduction

L'activité physique est importante pour la santé des enfants dans la mesure où elle leur favorise une croissance et un développement sain. Nous remarquons aujourd'hui que la participation des enfants à l'activité physique diminue. Les enfants marchent moins et passent moins de temps pour se rendre à une destination précise. Au Canada par exemple, le transport actif (tels que la marche ou le vélo) a diminué de 25% à 19% entre 1998 et 2005 (Turcotte, 2008). Cette diminution comprend le transport scolaire actif chez les enfants de 6 à 12 ans (L'Agence métropolitaine de transport 1998, 2003).

Malgré les avantages de l'activité physique, la plupart des parents conduisent leurs enfants à l'école, au parc et au terrain de jeu, au lieu de les laisser marcher (Tremblay, Brownrigg et Deans, 2008). La perception des parents par rapport au risque de circulation semble élevée. Ce qui les amène à choisir d'autres moyens de transport pour leurs enfants (Cloutier, Bergeron et Apparicio 2011), et réduire par la suite leur activité physique. La sécurité routière apparait comme la raison principale pour laquelle les parents conduisent leurs enfants à un lieu particulier. Entre 1994 et 2003, par exemple, le Canada a enregistré des décès liés à des blessures impliquant des piétons, dont 18% pour des enfants de 5-9 ans et 14% des enfants de 10-14 ans (Cloutier, Bergeron et Apparicio 2011). Par la suite, le Canada a opté pour une série de programmes nationaux de sécurité routière visant à réduire le nombre de décès dans les collisions routières (Transport Canada 2011). Ayant pour objectif d'atteindre des conditions de sécurité optimales pour les êtres humains (Maurice et al.1997), la promotion de la sécurité apparaît nécessaire. Maurice et al. (1997) soulignent qu'en connaissant les facteurs de risque d'une activité, les accidents pourraient être contrôlés. D'après ces auteurs, la sécurité a deux dimensions différentes l'une est objective et évaluée en fonction des paramètres de comportement et d'environnement; l'autre est plutôt subjective, basée sur le sentiment de sécurité ou d'insécurité au sein de la population. De plus, la «sécurité» est définie comme étant les besoins psychologiques de l'homme pour améliorer sa santé (Maslow 1968).Selon Maslow (1968), la sécurité et la santé d'une société sont basées sur les comportements et les conditions environnementales.

Utilisons le terme « blessures involontaires », plutôt que le terme « accidents » (Davis et Pless, 2001), Il apparaît que la possibilité de blessures involontaires dépend de plusieurs facteurs (NICE,

2016). Les principaux facteurs qui sont étudiés dans cette recherche sont les facteurs individuels, situationnels, comportementaux, environnementaux, et enfin les facteurs liés aux règles de conformité de la route.

Pour les facteurs individuels, l'âge et le sexe apparaissent comme d'importants prédicteurs des blessures chez les enfants (Schuurman et al. 2009). Traverser la rue exige des comportements complexes qui ne sont pas suffisamment développés chez les enfants (CCATM, 2013). Plusieurs études ont indiqué que les enfants piétons les plus jeunes sont plus à risque que ceux plus âgés (Whitebread et Neilson, 2000). Ainsi, le taux de blessures chez les garçons semble plus élevé que chez les filles. Les garçons sont moins susceptible de se conformer aux règles de sécurité routières (Connelly et Isler 1996, Barton et Schwebel 2007).

Les facteurs situationnels pendant la traversée ont une influence sur la sécurité et la conformité des piétons (Cinnamon, Schuurman et Hameed 2011). Ces facteurs concernent l'accompagnement des enfants (enfant accompagné ou non, le sexe du compagnon, etc.), la présence de l'enfant avec d'autres piétons et l'interaction.

En effet, certaines études antérieures ont montré que les enfants accompagnés par un adulte dégagent moins le comportement à risque (Fu et Zou 2016, Zeedyk et Kelly 2003). D'autres recherches ont constaté que la présence d'un adulte n'a pas d'influence sur la diminution des comportements à risque (comme ne pas regarder ou s'arrêter avant de traverser, etc.). En ce qui concerne le sexe d'un compagnon adulte, des travaux ont estimé que le comportement à risque est plus fréquent chez les hommes (Rosenbloom et Wolf 2002, Brandt et Dawe 2000).

Ainsi, certaines études ont montré que le nombre de piétons attendant en même temps sur le trottoir (avant la traversée) peut influencer le comportement à risque lors de la traversée. Alors que d'autres recherches ont constaté le contraire (Havard et Willis 2012 ; Yagil 2000).

L'interaction est définie comme la présence de deux usagers de la route (piéton et véhicule) en même temps et dans un même lieu (De Ceunynck et al 2012). Selon certains auteurs, la traversée en ligne droite, la recherche visuelle adéquate et le rythme régulier de la marche diminuent le risque d'interaction entre les piétons et les véhicules (D Akin et Sisiopiku 2000 ; Langbroek et al. 2012).

Les facteurs liés aux comportements sont souvent étudiés dans le domaine de la sécurité des piétons (Cinnamon, Schuurman et Hameed 2011). Il apparait que le rythme de marche avant et après la traversée influence le risque de blessures ou aussi de décès (Fontaine et Gourlet 1997). La recherche visuelle avant et pendant la traversée est ainsi définis comme des facteurs affectant

la sécurité des piétons. Cette recherche visuelle consiste à regarder vers les feux de circulation, les véhicules en mouvement, les autres piétons et le sol (Rosenbloom, Ben-Eliyahu et Nemrodov 2008). De plus, selon Sisiopiku et Akin (2003), si les piétons traversent la rue en ligne droite aux passages pour piétons, ils peuvent éviter l'interaction avec les véhicules. Afin de traverser en sécurité, nous nous attendons à ce que les piétons choisissent d'attendre sur le trottoir le moment adéquat pour s'engager sur la chaussée (Zhuang, Wu et Ma 2018). En effet, les piétons qui traversent avant ou après que le bonhomme soit rouge sont plus susceptible d'être impliqués dans un accident (King, Soole and Ghafourian 2009).

En ce qui concerne les facteurs environnementaux, les passages non contrôlés peuvent créer un conflit entre les piétons et les véhicules dans les zones urbaines. Néanmoins, la présence d'une signalisation à des intersections avec une limite de vitesse de plus de 30km/h réduit de 50 % la probabilité du risque (Gårder 1989). Pour les traverses dotées d'un compte à rebours, un grand nombre de piétons se conforment aux signaux, contrairement aux passages pour piétons sans compte à rebours (Lipovac et al, 2013). Ainsi, la largeur des traverses est utilisée comme l'un des paramètres permettant de définir le confort du piéton dans une traverse avec signalisation (Darcin Akin 2000). Pour la vitesse de marche, elle varie selon l'âge, la taille et la composition du groupe, l'état de santé, l'incapacité, le signal de départ, etc. (Gates et al. 2006).

Enfin, la conformité aux règles de la route est mesurée par la recherche visuelle avant de traverser (Granié 2007), la conformité temporelle (finir la traversée à temps) (Jin et al. 2013), la vélocité (garder une vitesse constante) (Ishaque et Noland 2008), la conformité spatiale (la traversée en ligne droite, ou entre les lignes parallèles) (Granié 2007, Sisiopiku et Akin 2003).

Considéré comme la destination la plus importante des enfants après l'école (Timperio et al. 2004, les parcs constituent l'un des principaux lieux favorisant l'activité physique (Andrew, 2008, Ho et al. (2003). Cependant, parmi les raisons qui empêchent les gens à fréquenter les parcs, nous trouvons les problèmes de santé, le manque d'argent et de temps, l'accessibilité, les installations inappropriées et, surtout, les problèmes de sécurité (Cordell et al.1999).

Certains facteurs, comme la proximité des parcs, le manque d'infrastructures, la criminalité et la faible sécurité routière, sont considérés comme des obstacles à l'utilisation d'un parc (Active Transportation Alliance 2014). Les résultats de l'étude de Christie et al. (2009) sur les risques de blessures de la route pour les enfants des zones défavorisées ont montré que les parents ont estimé que les parcs possèdent ne sont pas suffisamment sécuritaire et sont inaccessibles aux

enfants. Néanmoins, les parcs peuvent être améliorés en possédant des clôtures et en étant plus accessibles avec de meilleures traversées et de meilleurs éclairages.

Il est important de signaler que plusieurs travaux ont été réalisés sur la sécurité des enfants piétons vers l'école, alors que la recherche sur ce sujet autour des parcs reste restreinte. Cette recherche vient combler cette lacune en étudiant le comportement des enfants piétons en traversant les intersections autour des parcs. Nous nous basons sur le modèle du design écologique de Sallis, Prochaska (2006). L'objectif de cette étude est d'évaluer les caractéristiques liées à l'individu, à la situation, au comportement et à l'environnement physique. Ces caractéristiques vont nous permettre d'évaluer le degré de conformité des enfants aux règles de la sécurité routière.

Méthodologie

Afin de répondre à notre objectif, Nous avons opté pour une méthode quantitative. Quatre différents parcs montréalais ont été sélectionnés (n = 4), tels que parc Jarry, parc De-Turin, Parc Molson et Parc Gabriel-Sagard. Cette sélection a été faite selon le modèle à quatre catégories développé par (Apparicio 2010) et qui classe ces lieux selon la taille et le nombre d'installations. Les intersections sélectionnées pour notre étude sont celles les plus proches des terrains de jeux et des rues principales. Les traverses retenues sont celles qui comportent un nombre important de piétons et qui sont marqués par une densité de circulation et une variété de caractéristiques (comme la présence d'un panneau de signalisation, la largeur du passage pour piétons, la distance par rapport à l'entrée du parc, etc.). Au total, 17 passages pour piétons ont été choisis pour cette analyse (tableau 1).

Basé sur le projet MAPISE (La marche à pied pour les aînés, 2014), nous avons utilisé pour notre recherche la technique d'observation indirecte pour repérer les comportements des enfants piétons. Les grilles d'observation adoptées pour notre travail s'appuient sur le projet «ESSAIM et PARI, 2013»- inspiré par l'étude de Cloutier et al. (2017), D'Amours Ouellet (2016), et Bergeron et al. (2017). Ces grilles ont été développées à partir de différents concepts et d'une revue de littératures. Trois grilles différentes ont été utilisées; (1) grille d'observation pour les comportements des enfants âgés entre 4-8 et 9-12 ans lors de la traversée et, dans le cas échéant, (2) grille d'observation pour les caractéristiques de l'environnement routier, (3) grille d'observation des interactions avec des véhicules (annexe 1,2,3).

L'observation a été effectuée entre mi-juin et mi-août 2017 par deux observateurs formés. Les grilles d'observations ont été intégrées sur une tablette numérique à travers l'application Survey123 par ESRI (Environmental Systems Research Institute 2017). D'abord, chaque traverse a été analysée selon ses caractéristiques routières. Ensuite, dans le cas des traverses avec un volume important de circulation et un nombre d'enfants plus élevé, un observateur a complété la grille d'interaction, et un autre a observé les comportements des enfants piétons. S'il y a eu plus d'un enfant ou groupe d'enfants, un seul d'entre eux a été choisi au hasard pour l'observation. Un identifiant unique a été attribué pour chaque enfant et chaque traverse. Cet identifiant permet le lien entre les trois grilles. Au moins 731 données ont été collectées pour l'analyse quantitative.

Tableau 1: Les traverses sélectionnées autour des parcs

Park	*Jarry*	*Crosswalk number*	*De-Turin*	*Crosswalk number*	*Molson*	*Crosswalk number*	*Gabriel-Sagard*	*Crosswalk number*
Crosswalk	Jarry / Saint-Laurent	1	Jean-Talon / De Lanaudière	8	Beaubien / D'Iberville	11	Sagard	15
	Saint-Laurent / Jarry	2	De Lanaudière / Jean-Talon	9	D'Iberville / Beaubien	12	Sagard / Jean-Talon	16
	Saint-Laurent / Gounod (North)	3	Chambord / Jean_Talon	10	D'Iberville / Elsdale	13	Jean-Talon / Sagard	17
	Saint-Laurent / Gounod (South)	4			Elsdale / D'Iberville	14		
	Saint-Laurent / Villeray	5						
	Saint-Laurent / Gary-Carter	6						
	Gary-Carter / Saint-Laurent	7						

Source : Auteur (2018)

Les variables indépendantes ont été sélectionnées en fonction de la revue de littérature et des grilles d'observation. Elles sont présentées en quatre différentes catégories : telles que les caractéristiques individuelles, situationnelles, comportementales et environnementales (Tableau 2). La logique des prédicats pour la «conformité temporelle» basée sur le Code de la sécurité routière du Québec (QHSC) (2017) consiste à repérer les enfants qui ont terminé le passage à temps ou hors du temps. Comme l'explique le tableau 3, si les enfants finissent leur passage quand le bonhomme blanc est encore affiché, quand la main rouge est clignotante ou même quand le feu est vert, leur passage est considéré à temps et dans les délais légaux.

Tableau 2 : Variables indépendantes conservées dans le modèle multivarié

Retained independent variables	*Categories*
Individual characteristics	
Age	0: 4-8 years (Younger children) 1: 8-12 years (Older children)
Gender	0: Girl 1: Boy
Situational characteristics	
Supervision	0: No adult 1:Adult but out of reach 2: Adult within reach or contact
Gender of adult	0:Male 1:Female 2:Both genders
Other pedestrians	0: Alone 1: 1 to 5 people 2: 6 people or more
Car interaction	0: No 1: Yes
Behavior characteristics	
Stopping at the curb before crossing	0: No 1: Yes
Looked towards the vehicles before crossing	0: No 1: Yes
Looked straight ahead/at traffic light before crossing	0: No 1: Yes
Initiator of the crossing	0: No initiator (Adult and child at the same time) 1: Child initiator 2: Adult initiator
Road environment characteristics	
Signage	0: No signage 1: Stop sign 2: Traffic light without pedestrian light 3: Traffic light with pedestrian countdown display
Crosswalk width	0: Less than 15m 1: Between 15m and 25m 2: More than 25m
Speed required to cross in time	0: 1 m/s or less 1: More than 1m/s
Distance between the nearest park entrance and the intersection	0: 5 m or less 1: More than 5 m

Source: Auteur (2018)

Dans le cas contraire, ils sont considéré comme n'ayant pas respecté les règles relatives aux piétons et ayant terminé la traversée en dépassant le temps réglementaire (tableau 3).

Pour la «conformité spatiale», basée aussi sur le Code de la sécurité routière du Québec (QHSC ,2017), les piétons doivent traverser la rue en ligne droite. Dans la présente étude, les enfants qui traversent le passage pour piétons (traverse) en ligne droite répondent à la conformité spatiale.

Par contre, les enfants qui traversent les passages pour piétons (ou la traverse) en diagonale sont considérés comme étant «non spatialement conformes» (tableau 3). Les comportements de la marche les plus sécuritaires liés à la vélocité des piétons sont inspirés par les règles des piétons développées par Granié (2007). Ces comportements comprennent : «marcher et ne pas courir sur le trottoir (marche)», «marcher à un rythme régulier» et «marcher et ne pas courir pendant la traversée (vitesse de la traversée)». Pour notre étude, le maintien d'un rythme régulier, avant et pendant la traversée, est définie comme «conformité de vitesse». Alors que le rythme accéléré avant la traversée ou le rythme irrégulier pendant la traversée est défini comme «non-vélocité»

(Tableau3).

Tableau 3 : Variables composites de la conformité aux règles, type d'analyse

Mixed effect logistic regression Model No	Type of indicators		Retained variables	Number of recorded observation
1	**Temporal**		Crossing ended on:	568
		Compliance	1: Green light, white man or flashing red hand	
		Non compliance	0: Red light, yellow light or red hand	
2	**Spatial**		Type of crossing:	731
		Compliance	1: Crossed in straight line	
		Non compliance	0: Outside the parallel lines or diagonal	
3	**Velocity**		Tempo:	731
		Compliance	1: Regular pace before and during crossing	
		Non compliance	0: Accelerated pace before crossing or non-regular pace during crossing	
4	**Visual search**		Head/eye direction before crossing:	731
		Compliance	1: Head/eye towards the traffic light, straight ahead or towards the vehicles	
		Non compliance	0: Head/eye towards the ground, towards other pedestrians, towards an object or towards nothing in particular	

Source: Auteur (2018)

Ne pas regarder avant de traverser est l'un des indices de comportement dangereux utilisés par Rosenbloom, Ben-Eliyahu et Nemrodov (2008). Pour la «recherche visuelle», cela suppose que si les enfants regardent droit devant un feu ou vers les véhicules avant de traverser, ils appliquent une recherche visuelle. Regarder les autres piétons, les objets en main, le sol ou rien du tout lié à la rue, sont des signes de la recherche non-visuelle des enfants avant de commencer à traverser la rue.

Après avoir effectué les logiques de variables dépendantes, un tableau d'analyse descriptive bivariée a été créé à l'aide du logiciel SAS (Statistical Analysis System 2002-201) pour résumer les données et construire une vision globale des variables indépendantes, liées à chacune des quatre règles de conformité. Ensuite, le «Crammer's V» a été réalisé pour vérifier la multicolinéarité entre les variables (Annexe 5).

Les modèles de régression logistique avec effets mixtes sont utilisés dans des modèles statistiques pour indiquer des groupes de variables binaires. Comme de nombreuses observations ont été effectuées pour chacune des traverses, des régressions logistiques avec effets mixtes ont été réalisées. Ces régressions permettent d'évaluer les corrélations significatives tout en s'assurant que les effets fixes des traverses sont traités comme tels. Enfin, l'analyse multivariée a été faite sur Stata 12 (Stata Statistical Software 2011) avec la commande melogit.

Résultats

Comme nous pouvons le voir dans le tableau 4, entre 70% et 80% des enfants se conforment, séparément, aux différentes règles (la conformité temporelle, spatiale, la vélocité et la recherche visuelle). Cependant, sur les 731 observations enregistrées, 37% des enfants ont respecté les règles spatiales, de vitesse et visuelles. Sur les 568 enfants ayant utilisé une traverse réglée par des feux, seulement 34% ont respecté les quatre mesures.

Tableau 4 : Variables composites de la conformité aux règles

	Compliance	n (%)	Non-compliance	n (%)
Temporal	**Crossing finished on** Green light, white man or flashing red hand	451 (79.4%)	**Crossing finished on** Red light, yellow light or red hand	117 (20.6%)
Spatial	**Type of crossing** Crossed in a straight line	541 (74.0%)	**Type of crossing** Crossed outside the parallel lines or diagonal	190 (26.0%)
Velocity	**Tempo** Regular pace throughout crossing	527 (72.1%)	**Tempo** Non-regular pace before or during crossing	204 (27.9%)
Visual search	**Eye movements** Eyes towards the traffic light, straight ahead or towards the vehicles before crossing	512 (70.0%)	**Eyes movements** Eyes towards the ground, towards other pedestrians, towards an object or towards nothing in particular before crossing	219 (30.0%)

Source: Auteur (2018)

Le tableau 4.4 mentionné dans chapitre 4, présente les statistiques descriptives de la conformité et de la non-conformité des quatre mesures (temporelle, spatiale, de vitesse et visuelle) pour chaque caractéristique; individuelle, situationnelle, comportementale et environnementale.

L'âge semble avoir un faible impact sur la conformité aux règles. Les enfants plus jeunes traversent en ligne droite plus souvent que les plus âgés, mais ils accordent moins d'attention visuelle aux éléments liés à la route. Il n'y a pas de différence statistique dans le respect des règles entre les garçons et les filles.

Nous remarquons aussi que la présence d'un adulte, qu'ils soient proches ou non, est positivement associée à la conformité spatiale. Néanmoins, cette présence est négativement liée à la conformité visuelle. Les enfants accompagnés de femmes ont plus de chances de faire la recherche visuelle avant de traverser, que ceux accompagnés d'hommes adultes, et plus encore que les enfants accompagnés des deux sexes. La présence d'autres piétons traversant en même temps que l'enfant a une relation positive avec la conformité temporelle et la conformité de la vitesse. Cependant, les groupes de plus de 6 personnes sont négativement associés à la conformité spatiale. Dans le cas d'une interaction avec une voiture, l'enfant est moins susceptible de traverser à temps (conformité temporelle), mais plus susceptible de se conformer visuellement et spatialement, alors qu'il ne peut pas garder une vitesse constante.

En ce qui concerne les facteurs comportementaux, notre observation sur le terrain a montré que 76% des enfants ont attendu le prochain feu vert aux intersections signalisées. L'attente du prochain feu vert est positivement associée à toutes les mesures de conformité aux règles, à l'exception de la recherche visuelle, où aucune différence statistique n'est observée. Les enfants qui ont regardé droit devant ou au feu avant le passage ont été plus susceptibles de marcher en ligne droite. Pour l'initiation à la traversée, lorsqu'un enfant a initié la traversée, il a été beaucoup plus susceptible d'accélérer et donc de ne pas respecter la mesure de la vitesse. Lorsqu'un adulte initie la traversée, l'enfant est moins susceptible de respecter les mesures temporelles et visuelles. Garder une vitesse constante tout le long du passage, a une relation positive avec la conformité temporelle.

Pour les caractéristiques des traverses, la présence d'un affichage de compte à rebours pour piétons est généralement associée à une plus grande conformité aux règles. Tandis que l'absence de signalisation est associée à une conformité aux règles moins importante. Un pourcentage remarquable de 93% des enfants, traversant une intersection avec un compte à rebours pour piétons, ont terminé le passage à temps. Le seul cas où un piéton n'est pas positivement associé à la conformité est le cas de la mesure spatiale, car un enfant traversant une rue avec un feu pour piétons a moins chance de marcher en ligne droite qu'un enfant traversant une rue dotée seulement d'un feu pour voiture. La conformité temporelle est fortement associée à la vitesse requise pour traverser à temps. Si seulement 13% des enfants n'ont pas terminé la traversée, aux passages pour piétons, à temps avec « une vitesse inférieure à 1 m / s », cette proportion atteint 46% aux passages pour piétons à «une vitesse supérieure de 1 m / s». La plus grande distance entre l'entrée la plus proche du parc et l'intersection a une relation positive avec la conformité spatiale et une relation négative avec la conformité de vitesse.

Quant aux catégories des traverses, nos mesures binaires de la conformité aux règles ont été modélisées dans quatre différentes régressions logit avec effets mixtes, avec le même groupe de variables pour chacune. Le rapport des cotes supérieur à 1 signifie que la variable augmente les chances de se conformer à la mesure (tableau 5).

Pour la conformité temporelle, peu de variables individuelles et situationnelles étaient significatives, à l'exception de l'interaction avec la voiture qui diminue les chances de traverser à temps. Parmi toutes les variables, « attendre le prochain feu vert » a les plus grandes chances d'être associé à la « fin du passage à temps ». La présence d'un affichage de compte à rebours pour piétons augmente également de plus de 3,5 les chances de finir à temps la traversée.

Cependant, un parent ou un compagnon qui commence la traversée diminue les chances de finir à temps. Comme prévu, une vitesse requise supérieure pour traverser est négativement associée à la conformité temporelle.

En ce qui concerne la conformité spatiale, il n'y a pas d'associations significatives relatives aux corrélats individuels. La présence physique d'un adulte et l'interaction avec une voiture augmentent les possibilités de traverser en ligne droite. Cependant, six autres piétons – ou plus- qui traversent en même temps réduisent les chances de traverser en ligne droite. La conformité spatiale a favorisé certains comportements, tels que l'attente du prochain feu vert et l'observation de la circulation et de la lumière avant de traverser. Une traverse de taille moyenne (entre 15 et 24 mètres) et une intersection à feux de circulation, mais sans feu pour piétons, augmentent également la conformité spatiale.

Pour la conformité de vitesse ou la vélocité, les enfants plus âgés et les enfants accompagnés ont plus de chances de maintenir une vitesse constante tout au long de la traversée. Utiliser des traverses avec feux de circulation et attendre le prochain feu vert, augmente également ces chances. Cependant, l'interaction avec la voiture est négativement associée à la vitesse constante, les chances de maintenir une vitesse constante sont 2.8 (0.35) fois moins pour une traversée initiée par un enfant que pour une traversée sans initiateur.

En ce qui concerne la recherche visuelle, les enfants plus âgés ont plus de chances de pratiquer la recherche visuelle avant de traverser, et l'interaction avec la voiture est positivement associée à la recherche visuelle. De même, la recherche visuelle a augmenté les probabilités de conformité pour les traverses de largeur moyenne ou pour les intersections avec des panneaux d'arrêt ou des feux avec un compte à rebours pour piétons. Quant à l'initiateur de la traversée, si l'enfant initie la traversée, cela augmente les chances de regarder les éléments liés à la route de 1,8. Par contre, si l'adulte initie le passage cela provoque un effet inverse, diminuant la cote de 2,1. La distance à l'entrée la plus proche du parc n'est pas très significative pour les mesures, sauf pour la recherche visuelle où une distance plus élevée augmente la probabilité de 1,5 à l'intervalle de confiance de 90%.

Tableau 5 : Modèles logit avec effet mixte de la conformité aux règles (rapport des cotes)

	Temporal	Spatial	Velocity	Visual
Age				
Younger [Ref.]				
Older	0.964	0.765	1.581**	1.465**
Gender				
Girl [Ref.]				
Boy	0.779	0.913	1.150	0.964
Supervision				
No [Ref.]				
Yes	0.901	1.817***	3.305***	1.017
Other pedestrians				
Alone [Ref.]				
1-5 people	1.383	1.083	0.838	0.807
6 people or more	1.830	0.434**	1.285	0.855
Car interaction				
No [Ref.]				
Yes	0.468***	1.657*	0.560**	2.370***
stopping at the curb before crossing				
No [Ref.]				
Yes	3.796***	1.458*	1.456*	0.754
Looks at the traffic light/straight ahead				
No [Ref.]				
Yes	0.862	1.562**	0.829	-
Initiator of the crossing				
None [Ref.]				
Child	0.731	1.725	0.356***	1.789*
Adult	0.526**	0.960	1.186	0.469***
Crosswalk width				
Less than 15m [Ref.]				
Between 15m and 25m	-	2.307***	0.887	1.88**
More than 25m	-	0.947	0.978	1.03
Signage				
No signage [Ref.]				
Stop sign	-	1.658	1.569	2.186*
Traffic light without pedestrian light	-	2.080*	2.003**	1.119
Traffic light with pedestrian countdown display	3.577***	0.840	1.924*	2.376**
Required speed to cross in time				
1 m/s or less [Ref.]				
More than 1 m/s	0.301***	-	-	-
Distance between nearest entrance and intersection				
5 m or less				
More than 5 m	1.813	1.010	0.712	1.490*
Constant	8.910***	0.745	0.704	1.124
Crossing site constant	0.000	0.071	0.000	0.000
Number of groups	13	17	17	17
Number of observations	568	731	731	731
Chi square	89.81	71.59	77.63	64.86
AIC	477.346	762.471	819.083	851.139

* p < 0.1 ** p < 0.05 *** p < 0.01

Source: Auteur (2018)

Discussion

Dans notre étude, les enfants les plus âgés ont tendance à montrer une recherche visuelle plus efficace et un rythme de marche plus constant, ce qui confirme les résultats d'autres recherches (Rosenbloom, Ben Eliyahu et Nemrodov 2008, Whitebread et Neilson 2000). Ce constat semble logique puisque les enfants plus âgés sont plus expérimentés et mieux informés que les plus jeunes, ce qui les rend plus aptes à percevoir les conditions routières.

En ce qui concerne la supervision, nos résultats semblent en cohérence avec les études précédentes : les enfants physiquement proches des adultes sont plus susceptibles de garder un rythme régulier (Rosenbloom, Ben Eliyahu et Nemrodov 2008) et de marcher en ligne droite (Granié 2007). Ces résultats sont raisonnables car les enfants qui sont physiquement proches des adultes ont bien suivi ces superviseurs en traversant la route.

Selon nos résultats, chaque fois que les adultes initient la traversée, les enfants appaîssent moins susceptibles de prêter attention aux éléments liés à la route et de terminer le passage à temps. Également, quand les enfants initient la traversée, ils sont plus susceptibles d'effectuer une recherche visuelle et de changer leur rythme de marche car, hypothétiquement, ils deviennent responsables de la sécurité du groupe. On peut émettre l'hypothèse que ces enfants, ayant hâte d'arriver au parc, ont initié la traversée et accéléré pour l'atteindre plus rapidement.

Comme le montrent d'autres recherches (Langbroek et al. 2012 ; Pasanen et Salmivaara, 1993), l'interaction avec les véhicules ainsi que l'infraction pour la lumière rouge sont directement associées : l'interaction avec les véhicules diminue la conformité temporelle, ce qui peut être expliqué par le fait que enfants, en traversant la rue, utilisent plutôt leur système cognitif afin de pouvoir gérer l'interaction avec les véhicules. Ainsi, les enfants qui ont eu un conflit avec les véhicules qui s'approchent ont considérablement augmenté leur recherche visuelle afin d'être plus conscients des éléments liés à l'environnement routier. En effet, le risque de conflit piéton-véhicule peut être compensé par une recherche visuelle appropriée (Langbroek et al. 2012). Nous avons également constaté que cette interaction augmente les chances de conformité spatiale, ce qui n'est pas conforme au résultat précédent, affirmant que l'utilisation appropriée des traverses (marqués) peut réduire l'interaction avec les véhicules (Sisiopiku et Akin 2003). Enfin, nous avons constaté que les enfants étaient moins susceptibles de respecter la vitesse lorsqu'ils se trouvent en interaction avec les véhicules, ce qui a également été soulevé par Pasanen et Salmivaara (1993).

Nos résultats ont démontré que les enfants qui s'arrêtent au bord du trottoir avant de traverser ont plus souvent un rythme de passage régulier, ce qui est conforme aux études précédentes (Koh, Wong et Chandrasekar 2014).

Comme attendu, les enfants ont plus la chance de finir à temps à des traverses plus courtes. Dans le cas des traverses plus larges, les enfants dégagent une meilleure recherche visuelle et sont plus susceptibles de marcher en ligne droite (ce qui est également important pour traverser dans des intersections dotées des feux de circulation), ce qui nous renvoie à des études antérieures montrant que les comportements des enfants sont plus conservateurs lorsqu'ils sont exposés à une circulation plus rapide et plus dense ou à des collisions de véhicules (Abrashev et al., 1999, Cloutier et al., 2017, Montella, Mauriello et Eng, Noland et Quddus, 2004). Nous avons également constaté que les enfants accélèrent leur vitesse de marche pour finir à temps lorsqu'il y a un compte à rebours, ce qui est similaire pour les adultes (Fu et Zou 2016, Wanty et Wilkie 2010, Markowitz et al. 2006).

Bien que les parcs urbains soient les destinations populaires pour les enfants, les scientifiques leur ont accordé très peu d'attention par rapport aux écoles. Les parcs semblent avoir des effets stimulants, mais moins prévisibles, sur le comportement des enfants piétons durant la traversée, comme l'accélération brusque et les mouvements oculaires rapides et agités. Bien que nos résultats n'aient pas soulevé- directement- un effet significatif du parc, ce dernier apparaît avoir un impact particulier sur les comportements des enfants piétons. Par exemple, sur les 28% d'enfants qui ont changé leur rythme de marche pendant la traversée, la grande majorité (84%) accélère. De plus, sur les 17% d'enfants qui courent dans le parc après la traversée, 75% ont commencé à courir en traversant la rue.

Conclusion

Cette étude examine la conformité aux règles relatives aux enfants piétons à travers une observation sur le terrain. Pour atteindre nos objectifs, nous avons analysé les caractéristiques individuelles, situationnelles, comportementales et celle de l'environnement routier. Des études antérieures menées pour les adultes nous ont aidés à évaluer la conformité aux règles relatives aux piétons et nous les avons adaptées au contexte des enfants piétons, car peu d'études ont été faites sur cette population spécifique. Nos résultats ont démontré que certaines caractéristiques pourraient affecter sensiblement la conformité aux règles des enfants. Cependant, la complexité

du processus de « traverser la rue » rend difficile la détermination du facteur dominant. Nos résultats soulignent la nécessité d'un environnement routier plus sûr à proximité des parcs urbains, comme l'affichage du compte à rebours et l'adaptation de la durée autorisée des feux de circulation à la vitesse des enfants.

Enfin, quelques éléments pourraient être étudiés et approfondis dans des recherches futures. Tout d'abord, les parcs urbains peuvent être sélectionnés à partir de différents quartiers afin de mieux généraliser les résultats à différentes régions. Deuxièmement, nous avons supposé qu'il existe une correspondance entre la conformité aux règles et la sécurité des enfants. Cependant, nous n'avons trouvé aucun résultat démontrant que les enfants qui se conforment aux règles relatives aux piétons sont plus en sécurité. Par conséquent, une autre question est posée: dans quelle mesure les enfants piétons qui se conforment aux règles de la route sont-ils plus sains? Cette question peut être abordée dans les recherches futures en considérant tous les usagers de la route dans un cadre unique, et en mettant l'accent sur les conflits entre les piétons et les véhicules. Troisièmement, comme mentionné précédemment, il n'y a pas de référence de vitesse requise pour les enfants piétons dans la littérature. Par conséquent, des recherches peuvent être menées pour estimer cette variable de manière appropriée.

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