Development of Children's Crossing Skills in Urban Area: Impact of Age and Traffic Density on Visual Exploration

Jordan Solt
University of Lorraine, 2LPN
Luxembourg-ville
Email: solt.jordan@gmail.com

Aurelie Mailloux
Reims hospital, URCA
Reims, France
Email: aurelie.mailloux@univ-reims.fr

Jerome Dinet
2LPN and Chair BEHAVIOUR
Nancy, France
Email: jerome.dinet@univ-lorraine.fr

Samuel Ferreira Da Silva
Lorraine University and Chair BEHAVIOUR
Metz, France
Email: samuel.ferreira-da-silva@univ-lorraine.fr

Muneo Kitajima
Nagaoka University of Technology
Nagaoka, Niigata, Japan
Email: mkitajima@kjs.nagaokaut.ac.jp

Gaelle Nicolas
Lorraine University and Chair BEHAVIOUR
Metz, France
Email: gaelle.nicolas@univ-lorraine.fr

***Abstract*—Pedestrian trauma represents a significant proportion of all road traumas, young pedestrian being over-represented in all these road traumas. From a cognitive point of view, road crossing ability is a high and complex mental activity because the individual has to process dynamic and complex information extracted from his/her surrounding environment, to make a decision (i.e., where and how to cross), and safe pedestrians must possess and utilize advanced cognitive skills. More precisely, there are two major problems for young pedestrians to make the decision about when and where it is safe to cross the street : gap selection and assessment of inter-vehicular gap. An experimental study conducted with forty children aged 3-10 years and twenty-two adults has been conducted to investigate the impact of one individual factor (Age) and one environmental factor (Traffic density) on decision making (i.e., "to cross" or "not to cross a street"), time spent to make decision (in milliseconds) and on visual exploration using eye-tracking techniques of urban scenes displayed on a computerized screen. Main results showed that (i) Traffic density has a significant impact on performance and visual exploration, (ii) Age has a significant impact on time spent to make decision and visual exploration and (iii) there is an interaction between Age and Traffic density.**

***Keywords*—Child; Pedestrian; Visual exploration; Risk; Hazard; Eye-Tracking**

I. INTRODUCTION

Pedestrian trauma represents a significant proportion of all road traumas, young pedestrian being over-represented in all these road traumas. In particular, the safety of child pedestrians is of concern, given that a sizable proportion of pedestrians killed and seriously injured involve children and the special value society places on its youth [1][2].

In section 1, context related to accidents with young pedestrians and factors influencing children's crossing skills are presented. In section 2, method of the experiment conducted with our participants are described. Finally, in section 3, theoretical and methodological implications related to the changes in visual strategy occurring around the age of 7-8 years are discussed.

A. Context

Around the world, the number of pedestrians killed increase. Young pedestrians are particularly concerned by these accidents: According to the official data issued from the Traffic Safety Facts, on average, three children were killed and an estimated 502 children were injured every day in the U.S. in traffic crashes. In 2019 and 2020, there were respectively 181 and 177 children killed in pedestrian accidents. Most were toddlers (between the ages of 1-3) and young children (4-7). In fact, an estimated 1 in 5 children killed in car accidents were pedestrians, i.e., just walking on the sidewalk or crossing a street whatever the country [3][4].

At ages 6-10 years, children are at highest risk of pedestrian collision, most likely due to the beginning of independent unsupervised travel at a time when their road strategies, skills and understanding are not yet fully developed. Whatever the country, research suggests that children between the ages of 6 to 10 are at highest risk of death and injury, with an estimated minimum four times the risk of collision compared to adult pedestrians [5]. Until the age of 6-7 years, children are under active adult supervision, i.e., parents hold their child's hand when crossing roads together. Even if every year many pedestrians are injured or killed in traffic accidents in rural parts of the country [6], pedestrian safety is being considered as a serious traffic safety problem in urban and suburban settings [7][8]. Thus, children more than adults, are at risk as pedestrians, often due to their own actions and behaviors. So the question is: "Why do young pedestrians not adopt safety behaviors specially during street crossing?"

B. Factors Influencing Children's Crossing Skills and Gap Selection

From a cognitive point of view, road crossing ability is a high and complex mental activity because the individual has to process dynamic and complex information from his/her surrounding environment, to make a decision (i.e., where and how to cross). Safe pedestrians must possess and utilize advanced cognitive skills [9][10]. Crossing decisions include whether or not to enter the roadway, the place to cross, the path to take, how fast to travel, and how the driver might react. A sound decision on whether to enter the roadway should be based upon recall (experience) and monitoring of the traffic detected, including the distance, speed, and anticipated direction of vehicles and the opportunities provided by various gaps in traffic [11]. The time that has elapsed while making the decision also needs to be incorporated. Successful crossing performance also requires reliable estimation of the pedestrian's walking speed, peak capabilities, and distance to the other side of the road or a traffic island. Integrating all these aspects is difficult for the child, especially one inexperienced in traffic, and result in a longer decision making time: In fact, a 5 year old child requires about twice as long to reach a pedestrian decision as an adult.'and This leaves even less time to execute an imperfectly planned crossing [9][10][12].

A vast amount of research suggests that children's development of cognitive skills is significantly related to increased pedestrian safety and that relevant skills improve as children get older [13][14][15]. Of course, it is not a single cognitive skill that influences safety. Instead, it is the combined development of a number of different cognitive processes that are linked to safe pedestrian behavior. Those processes also overlap with other developing skills, such as perceptual (visual and auditory essentially) and motor abilities.

As children develop, specific pedestrian injury risks change [12][15][16][17][18][19]. More precisely, toddlers (ages 1–2) are most likely to be injured in driveways, where drivers moving backward are unable to see them [20], while adolescents are at risk due to walking at night with poor visibility, walking while intoxicated or walking while distracted by phones [21]. Our paper focuses on children between those two phases, in ages 6 through 12. During this stage of development, most pedestrian injuries occur in mid-block areas, where children enter into the middle of the street and are struck by moving vehicles, or at intersections [22]. As Schwebel and his colleagues said, if some incidents are "dart-out" situations where children enter the street quickly, without thought (i.e., to chase a person, toy, or pet, or to meet someone on the other side of the street), the majority of the incidents/collisions are the result of poor judgment by the child, i.e., s/he believes it to be safe, and enters the street when in fact the situation is not safe [19].

Several studies showed that gap selection and assessment of inter-vehicular gap by young pedestrians are two major problems for young pedestrians to make the decision about when and where it is safe to cross the road [23][24][25]. Inter-vehicular gap is both temporal and spatial because these two parameters are crucial to make the decision in relation to available gaps in the traffic [26]. More precisely, judgement of whether a gap in the traffic is sufficient to safely cross requires the determination of the time gap of the nearest vehicle with the planned crossing line and the assessment of whether this time gap exceeds the time required to cross the road. So, children aged below 10 years have relatively poor skills at reliably setting safe distance gap thresholds, and thus do not consistently make safe crossing decisions [27][28][29][30][31][32].

But, very few authors concentrated on visual exploration of young pedestrians during crossing activity. For instance, Whitebread and her colleagues examined the relationships between pedestrian skills and visual search strategies for young pedestrians [33]. According to their findings, major changes in strategy occurred around the age of 7-8 years. This change expressed in the frequency and pattern of looking at different directions, having a sophisticated 'last-minute' checking approach, exhaustive visual search strategy, and the speed of making the crossing decision. In the same way, Tapiro and her colleagues examined children's visual search strategies in hazardous road-crossing situations [29]. A sample of 33 young participants (ages 7-13) and 21 adults observed 18 different road-crossing scenarios in a 180 degrees dome shaped mixed reality simulator. Gaze data was collected while participants made the crossing decisions. Their results showed that age group, limited field of view, and the presence of moving vehicles affect significantly the way pedestrians allocate their attention in the scene. Therefore, the authors deduce that adults tend to spend relatively more time in further peripheral areas of interest than younger pedestrians do. It was also found that the oldest child age group (11-13 years old) demonstrated more resemblance to the adults in their visual scanning strategy, which can indicate a learning process that originates from gaining experience and maturation. Nevertheless, all participants in these previous studies are 7 years old and above. In this experiment, we collect data with eye-tracking from younger pedestrians (3 to 10 years old) to better understand the visual exploration of urban scenes.

II. METHOD

This experimental study conducted with forty children aged 3-10 years and twenty-two adults is aiming to investigate the impact of one individual factor (Age) and one environmental factor (Traffic density) on decision making (i.e., "to cross" or "not to cross a street"), time spent to make decision (in milliseconds) and on visual exploration of urban scenes displayed on a computerized screen. Eye-tracking technique is used to collect precise data about gaze exploration of each participant.

A. Participants

Sixty-two French participants were recruited to participate in this study. Children are issued from four different age groups: Seven pupils are from Grade 1 (boys, 100 percent; mean age = 3.86 years; SD = 0.37 years), nineteen pupils are recruited from Grade 3 (boys, 56.8 percent; mean age = 6.89 years; SD = 0.31 years), fifteen pupils are recruited from Grade 5 (boys, 60 percent; mean age = 9.87 years; SD = 0.51 years), and twenty-one participants are adults (men, 47.6 percent; mean age = 26.71 years; SD = 8.22 years). All children are issued in the same elementary school located in the mid-town.

All participants are French native speakers and the majority (82.1 percents) lives in urban area. Moreover, even if the majority of adult participants (81 percents) have their driving license, they admit to go to work essentially by using public transportation (61.9 percents) or by walk (38.1 percents). All the children are recruited in the same primary school located in the mid-town. All parents agreed to their children participate. No participant has severe visual impairment and no cognitive impairment. There is no difference between groups according to the visual memory and attention capacities (Table 1).

B. Independent and Dependent Variables

In our study, we investigated the impact of one individual factor (Age) and one environmental factor (Traffic density) on three behavioural indicators:

- The decision (i.e., "to cross" versus "not to cross the street");
- The time spent in milliseconds to make this decision;
- The visual exploration of specific Areas of Interest (AoI) of urban scenes displayed on pictures (Figure 1);

Thus, two independent factors were manipulated, the first one being intra-subject ("Age", with four modalities: Grade 1, Grade 3, Grade 5, and adults) and the second one being inter-subject ("Traffic density", with three modalities: Low, Moderate, and High). In other words, our experimental plan was: Participant $<$ Age 4 $>$ * Traffic density 3

C. Material

Assessment of Cognitive Abilities. Each participant was asked to complete several sub-scales extracted from the Wechsler scales to assess their cognitive abilities. For the youngest participants (Grade 1), "Coding scale" and "Digit span scale" extracted from the WPPSI-V have been used. For the two other groups of children (Grade 3 and Grade 5), they are the same sub-tests used but extracted from the WISC-V. For adults, four sub-scales extracted from the WAIS-V have been used: "Digit span scale", "Arithmetic scale", "Coding scale", and "Symbol scale". All these sub-scales were chosen because they are very sensitive to the visual memory and attention capacities.

Urban Scenes. Each participant was individually asked to examine different urban scenes displayed on a computerized screen before to make a decision for each urban scene, i.e., "to cross" or "not to cross the street". Three traffic densities have been used to investigate the impact of this factor on decision-making and visual exploration: Low, Moderate, and High. Figure 1 shows an example for each of these modalities. For each of the traffic density (Low, Moderate, and High), four different urban scenes. These urban scenes were chosen by four judges after they evaluated and categorized a lot of pictures in these three traffic conditions: Low traffic density ("Low"; e.g., one other pedestrian and two vehicles far), moderate traffic density ("Moderate"; e.g., several other pedestrians and different kinds of vehicles), and high traffic density ("High"; e.g., a lot of vehicles near and far).

Each participant was asked to examine 12 different static pictures of urban scenes, the order of presentation being counterbalanced to avoid order effect on responses (i.e., "to cross" or "not to cross the street"). On-line eye-tracking data for each participant were collected during participants examined urban scenes, by using the eye-tracking techniques. The Tobii T120, with a 17 inch monitor integrated, was used to collect visual exploration of urban scenes by our participants.

D. Procedure

The procedure has four distinct and successive steps:

- Training session. First, each participant was invited to seat in front of a computer (Tobii T120, with a 17 inch monitor integrated) and the same instructions are given: (a) different images will appear on the screen, one by one; (b) s/he must to analyse the urban scenes carefully because s/he was asked to decide if s/he crosses or not the street; (c) when s/he made the decision, s/he was asked to say "stop" and s/he can give his/her decision orally. Different pictures (not used in the following experiment) are used during a training session;
- Experimental session for visual exploration and decision-making. If the participant has no problem with the procedure and has no question, the experiment can begin with the urban scenes related to the three conditions (Low, Moderate, High);
- Assessment of cognitive abilities. Just after the end of the experimental session, each participant was asked to complete sub-scales extracted from the Wechsler scales to assess their visual memory and attention capacities;
- Length of time the subject is expected to participate
- Researchers ensured that those participating in research will not be caused distress;
- End of the experiment. Finally, each participant was asked to complete a survey to provide some several demographic information, is thanked and each child receives a packet of sweets.

Note that for children, the experiment was always conducted in the same quiet room located in the school, dedicated to the experiment. The experimenter was always the same.

E. Design and Data Analysis

First, we examined the impact of our two independent variables ("Group age" and "Traffic condition") on the one hand, decision (i.e., "I am crossing" or "I am not crossing"), and on the other hand, time spent to make this decision (in milliseconds). So the design of this first part of analyses is the following factorial design: Group age (4) (Grade 1, Grade 3, Grade 5, Adult) X Traffic density (3) (Low, Moderate, High), with "Age group" as between-subjects factor and "Traffic density" as within-subjects factor.

TABLE I
MEAN (AND STANDARD DEVIATION) OF FIXATION DURATION FOR EACH AGE GROUP, TRAFFIC CONDITION FOR EACH AREAS OF INTERESTS (AOI)

	Mean of Memory Span (SD)	Mean of Processing Speed (SD)
Grade 1 ($n = 7$)	8.5 (2.7)	9.5 (3.4)
Grade 3 ($n = 19$)	10.5 (4.5)	12.8 (5.1)
Grade 5 ($n = 15$)	10.9 (2.9)	10.2 (3.9)
Adult ($n = 21$)	9.1 (1.9)	10.6 (2.8)

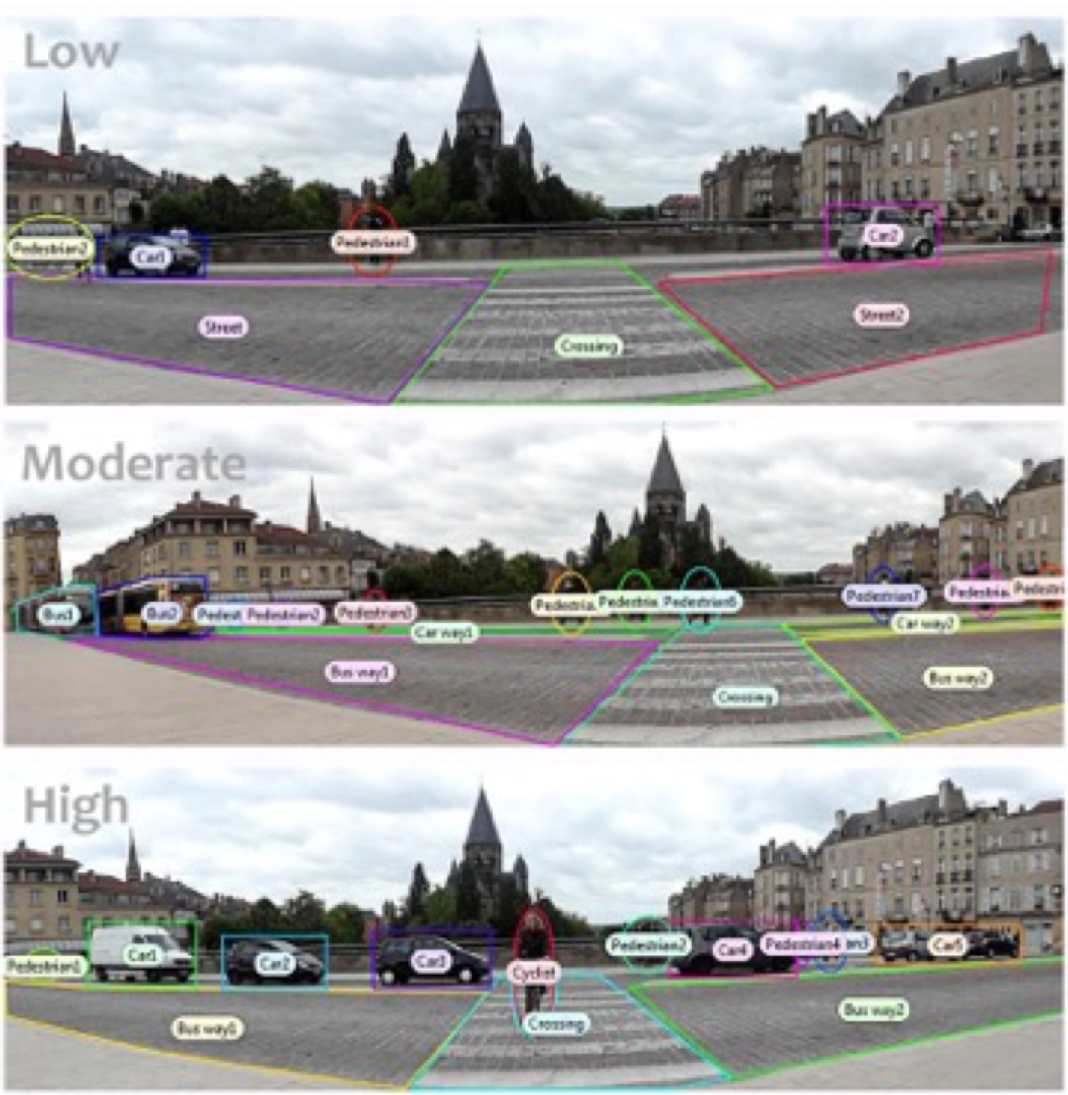

Figure 1. The different Areas of Interest (AoI) in the three Traffic density conditions

Second, we examined the visual exploration on specific Areas of Interest (AoI) predefined for urban scenes (i.e., “Pedestrians”, “Sidewalk”, “Car”, “Car way”, Bus”, “Bus way”, and “Crossing”). Figure 1 shows these six different AoI. The design of this second part of analyses is the following factorial design: Age group (4) (Grade 1, Grade 3, Grade 5, Adult) X Traffic density (3) (Low, Moderate, High) X AoI (6) (Pedestrians, Sidewalk, Car, Car way, Bus”, Bus way, Crossing) with “Age group” as between-subjects factor and “Traffic density” and “AoI” as within-subjects factors.

F. Ethics

All adults’ participants provided written informed consent for their participation in this study, and all legal parents of children provided the same informed consent. Moreover, the responsible of the school provided also her consent. Before providing the written consent, all adults’ participants, legal parents of children and the director of the school where the research has been conducted received the same information relating to the following points:

- A statement that participation is voluntary and that refusal to participate will not result in any consequences or any loss of benefits that the person is otherwise entitled to receive;
- The precise purpose of the research;
- The procedure and material involved in the research;
- Benefits of the research to society and possibly to the individual human subject;
- Length of time the subject is expected to participate
- Researchers ensured that those participating in research will not be caused distress;
- Subjects’ right to confidentiality and the right to withdraw from the study at any time without any consequences;
- After the research is over, each participant (adults or children) are able to discuss the procedure and the findings with the psychologist.

III. Results

The experiment based on eye-tracking techniques aimed to investigate the impact of one individual factor (Age) and one environmental factor (Traffic density) on three behavioural indicators related to competencies of very young pedestrians (aged 3-10 years). Several interesting results have been obtained.

A. Impact of Age group and Traffic Density on Decision-Making

The decision made by each participant (“I cross” versus “I do not cross”) in front of each urban scene has been collected (Table 2). For each if the three Traffic density conditions (Low, Moderate, High), statistical analyses revealed only one significant impact of Age group in high traffic condition ($F(3\text{-}58) = 2{,}858$, $p = .045$).

B. Impact of Age group and Traffic Density on Decision-Making Time

As Table 3 shows, the time spent to make decision decreased with age. Statistical analyses confirmed that Age group had a significant impact on this time spent to make decision ($F(3\text{-}58) = 8{,}75$, $p < .001$). Time spent to make decision for the youngest participants (Grade 1, Mean = 8829,68) was superior than time spent by all the other participants (Grade 3, M = 5240,98, $F(3\text{-}58) = 2{,}934$, $p = .005$; Grade 5, Mean = 4694,68, $F(3\text{-}58) = 3{,}265$, $p < .005$; Adults, Mean = 2797,82, $F(3\text{-}58) = 4{,}996$, $p < .001$). In the same way, time spent to make decision for participants aged to 6-7 years (Grade 3, Mean = 5240,98) was superior than time spent for adults (Mean = 2797,82), the difference being significant ($F(3\text{-}58) = 2{,}789$, $p = .007$). Finally, time spent to make decision for participants in grade 5 (Mean = 4694,68) was superior than time spent adults (Mean = 2797,82), the difference being significant ($F(3\text{-}58) = 2{,}028$, $p = .047$) Traffic condition had also a significant impact on time spent to make decision ($F(2\text{-}116) = 7{,}67$, $p = .001$). As Table 2 shows, time spent to make decision in low traffic condition (Mean = 4311,31) was inferior than time spent in high traffic condition (Mean = 5278,16), the difference being significant ($F(2\text{-}116) = 7{,}67$, $p = .002$). Finally, there was a interaction between Age group and Traffic condition ($F(6\text{-}116) = 2{,}73$, $p = .016$) on the time spent to make a decision.

C. Impact of Age Group and Traffic Density on Global Visual Exploration

There was a global impact of Age group on total fixation duration (Table 4; $F(3\text{-}58) = 8{,}475$, $p < .001$). Specifically, Age group had a significant impact for Low traffic density ($F(3\text{-}56) = 2{,}980$, $p = .039$) and Moderate traffic density ($F(3\text{-}56) = 9{,}422$, $p = .001$) but had no impact on High traffic density ($F(3\text{-}50) = 2{,}695$, $p < .056$):

- For Low traffic density condition, mean fixation duration for children recruited in Grade 1 was higher compared to Adults (respectively, Mean = 0.3614 and Mean = 0.2665; $t(56) = 2{,}183$, $p = .033$). In the same way, children recruited in Grade 3 have more longer fixation duration compared to Adults (respectively, Mean = 0.3514 and Mean = 0.2665; $t(56) = 2{,}639$, $p = .011$). Adults had the fastest fixings but that was significant only that in comparison with Grade 1 and Grade 3;
- For Moderate traffic density condition, adults (M = 0.29) had shorter fixation duration compared to Grade 1 (respectively, Mean = 0.29 and Mean = 0.3692; $t(56) = 2{,}293$, $p = .026$) and compared to Grade 3 (Mean = 0.3579; $t(56) = 2{,}656$, $p = .01$). Children issued from Grade 5 spent significantly less time to make decision than Grade 1 (Mean = 0.3692; $t(56) = 3{,}950$, $p = .000$), compared to Grade 3 (Mean = 0.3579) ($t(56) = 4{,}76$, $p = .000$) and compared to adults (Mean = 0.29) ($t(56) = -2{,}345$, $p = .023$);
- For High traffic density condition, only one Age group was concerned by significant differences: Children issued

TABLE II
NUMBER (AND PERCENTAGE) OF PEDESTRIANS CROSSING THE STREET FOR EACH AGE GROUP AND THE THREE TRAFFIC DENSITY CONDITIONS (LOW, MODERATE, HIGH)

	Low	Moderate	High
Grade 1 ($n = 7$)	3 (42.8)	2 (28.5)	1 (14.9)
Grade 2 ($n = 19$)	12 (63.6)	2 (10.5)	0 (-)
Grade 2 ($n = 15$)	10 (66.6)	3 (20)	3 (20)
Adult ($n = 21$)	9 (42.8)	3 (14.2)	5 (23.8)

TABLE III
MEAN (AND STANDARD DEVIATION) OF TIME SPENT TO MAKE DECISION (I.E., "TO CROSS" *versus* "NOT TO CROSS") FOR EACH AGE GROUP AND EACH TRAFFIC DENSITY CONDITION (LOW, MODERATE, HIGH)

	Low	Moderate	High	Mean (SD)
Grade 1 ($n = 7$)	7854 (6399)	7183 (5081)	11450 (10673)	8829 (6812)
Grade 3 ($n = 19$)	4921 (2292)	5337 (1803)	5464 (3140)	5240 (2030)
Grade 5 ($n = 15$)	3804 (1616)	4454 (2175)	5825 (3902)	4694 (1981)
Adult ($n = 21$)	2940 (1708)	2791 (1245)	2661 (1592)	2797 (1345)
Total mean (SD) (N = 62)	4311 (3066)	4469 (2672)	5278 (5025)	-

TABLE IV
MEAN (AND STANDARD DEVIATION) OF TOTAL FIXATION DURATION FOR EACH AGE GROUP AND THE THREE TRAFFIC DENSITY CONDITIONS (LOW, MODERATE, HIGH)

	Low	Moderate	High	Mean (SD)
Grade 1 ($n = 7$)	0.316 (0.08)	0.362 (0.06)	0.408 (0.124)	0.379 (0.09)
Grade 2 ($n = 19$)	0.351 (0.145)	0.357 (0.10)	0.321 (0.14)	0.343 (0.13)
Grade 5 ($n = 15$)	0.303 (0.07)	0.266 (0.06)	0.267 (0.12)	0.265 (0.08)
Adult ($n = 21$)	0.266 (0.05)	0.290 (0.04)	0.278 (0.04)	0.297 (0.06)
Total mean (SD) (N = 62)	0.320 (0.09)	0.311 (0.07)	0.318 (0.11)	-

from Grade 1 spent significantly more time to make decision compared to Grade 5, compared to Grade 1 (respectively, Mean = 0.4081 and Mean = 0.2673; t(50) = 2,521, p = .015) and compared to Adults (Mean = 0.05893; t (50) = 2,54, p = .014). In other words, in the high traffic density condition, children issued from Grade 1 were the slowest.

D. Impact of Age and Traffic Density on Examination for Each Area of Interest (AoI)

As Figure 2 shows, visual fixation duration time was significantly superior for two of the different Areas of Interest (AoI) predefined: the car way (F(3-43) = 4,191, p = .011) and the crossing (F(3-55) = 3,891, p = .014).

Moreover, Age group had a significant impact on distribution of fixation time only for these two of the different Ares of Interest (AoI) predefined. Fixation duration time on the car way was superior for Grade 1 compared to Grade 5 (respectively, Mean = 0,3625 and Mean = 0,2444; t(43) = 2,426, p = .02) and compared to Adults (Mean = 0,2311; t(43) = 2,626, p = .012). And fixation duration time on the car way was superior for Grade 3 compared to Grade 5 (respectively, Mean = 0,3291 and Mean = 0,2444; t(43) = 2,329, p = .025) and compared to Adults (Mean = 0,2311; t(43) = 2,569, p = .014). The pattern of results was identical for the crossing. Fixation duration time on the car way was superior for Grade 1 compared to Grade 5 (respectively, Mean = 0,3729 and Mean = 0,2713; t(55) = 2,3, p = .025) and compared to Adults (Mean = 0,2478; t(55) = 2,932, p = .005). And fixation duration time on the car way was superior for Grade 3 compared to Adults 5 (respectively, Mean = 0,3248 and Mean = 0,2444; t(55) = 2,425, p = .019).

Even if there were the only significant differences, some interesting tendencies can be remarked in the Figure 2 for other AoI such as "Pedestrians", "Cars" and "Bus way". For these three other AoI, fixation duration time for Adults group is always inferior.

There exist some significant interactions between Age group and Traffic density condition on these fixation duration means for the two main AoI ("Car way" and "Crossing"):

- For Low traffic density condition, fixation duration for younger participants (recruited in Grade 1) was significantly superior than fixation duration for children recruited in Grade 3 specially for "Car way" (respectively,

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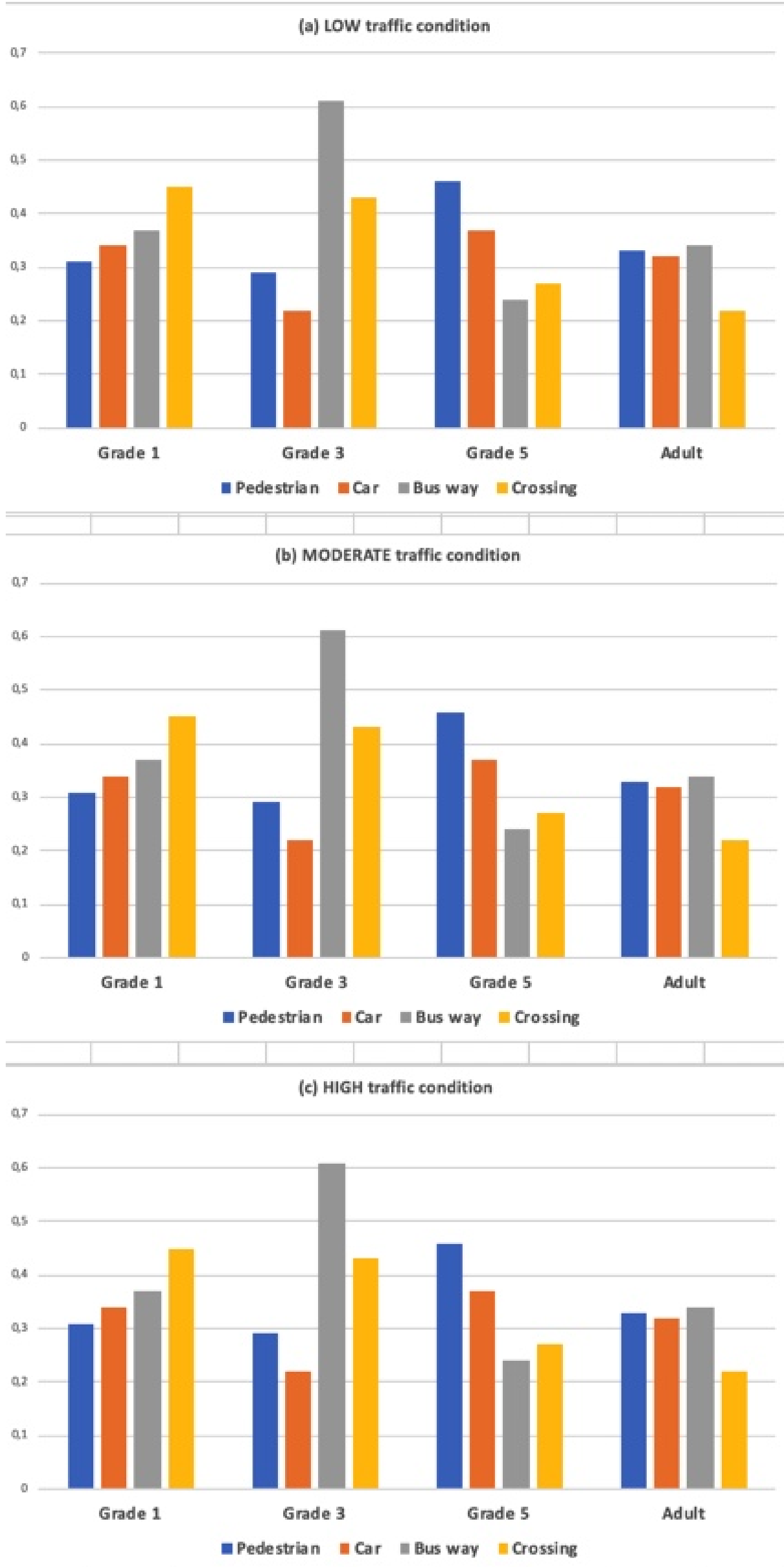

Figure 2. Mean of visual fixation duration for each Age Group (Grade 1, Grade 3, Grade 5, Adult), Traffic Condition (LOW / MODERATE / HIGH) for each Areas of Interests (AOI : Pedestrian / Car / Bus way / Crossing)

Mean = 0,45 and Mean = 0,263; t(54) = 2,023, p = .048);

- In the same way, for Moderate traffic density condition, fixation duration for younger participants (recruited in Grade 1) was also significantly superior than fixation duration for children recruited in Grade 3 (respectively, Mean = 0,768 and Mean = 0,438; t(55) = 3,218, p = .002);
- Finally, for High density traffic condition, fixation duration for children issued from Grade 1 was also superior than fixation duration specially for "cars" (respectively, Mean = 0,430 and Mean = 0,290; t(56) = 2,019, p = .048). The crossing site was extensively explored by the youngest participants (Grade 1, Mean = 0,442) compared to Adults (Mean = 0,229; (t(50) = 2,413, p = .020) and compared to children recruited in Grade 5 (Mean = 0,374; (t(50) = 2,857, p = .006).

IV. Discussion

Several interesting results have been obtained in this experiment. First, the Traffic density has a significant impact on decision made by all the participants. When there is much information in the urban scene (High traffic condition), less participants decide to cross the street, whatever the Age. Second, the Age has a significant impact on time spent to make decision. The decision-making time decreases when the age increases. This result confirms the fact that the age has a strong impact on decision making in pedestrians' skills a process which develops and becomes increasingly effective with the age [34][35][36]. Third, there is an interaction between Age and Traffic density: The decision-making time decreases when the age increases specially when there is much information in the urban scene (i.e., High traffic density condition).

From a theoretical point of view, our results show how the pedestrian's skills would be dependent on the development of at least two simultaneous capabilities: visual exploration strategy and cognitive processing abilities. First, the visual sampling strategies tend to be systematic in younger, not focusing on specific areas or strategic areas and, with age, the visual exploration strategy is specified and is interested in the peripheral areas of the visual field [29]. This development led to a more accurate and relevant information extraction from visual environment in urban areas [23][24][25]. Second, cognitive development allows greater information processing capacity [13][14][15][15], thus taking a more rapid and effective decision. From a theoretical point of view the use of poor visual strategy combined with a cognitive inability to process so many information that explains more time decision-making among young pedestrians in a dense traffic environment.

Several methodological limits prevent us to generalize the results obtained. First, the experiment was conducted inside the school, which resulted in to cause a feeling of observation. The pupils often sought to provide "the good answer" whereas we are interested in their own answer. If the experiment were led in the school, it was a question above all of preserving a medium familiar and reassuring for the pupils. Second, stimuli used in our experiment were only visual and the information in peripheral vision necessarily decreased by the size of the screen. But, for ethical and technical reasons, it was not possible to carry out the experiment in real outdoor environment. Third, stimuli used in our experiment were static (i.e., pictures): So, in our actual new studies, dynamic stimuli (i.e., videos) will be used to introduce dynamic factors, such as motion of vehicles and motion of other pedestrians in the scene. Moreover, even if visual information are crucial, we will add sounds in the experimental material to place participants in a more naturalistic setting. Our study tends to demonstrate on the one hand, that the development of pedestrian skills is essentially based on visual exploration of surrounding environment and on the other hand, these skills increase with the development of more general cognitive abilities

V. Conclusion and Future Works

By using an experimental approach and eye-tracking techniques, our study aimed to investigate the impact of one individual factor (Age) and one environmental factor (Traffic density) on three behavioural indicators related to competencies of very young pedestrians (aged 3-10 years): (i) the decision (i.e., "to cross" versus "not to cross the street"), (ii) the time spent in milliseconds to make this decision and (iii) the visual exploration of urban scenes displayed on pictures.

This study is the first one to our knowledge which investigates visual exploration of urban scenes for very young children (under 4 years old). Using eye-tracking technique is interesting for several reasons. Visual exploration is a irrepressible behavior. Specifically, for young children with limited language capacity, the use of eye-tracking allows comparison with older children and adults. As we reported previously, To our knowledge, no study has looked at the visual exploration of such young pedestrians (under 4 years). Young audiences are more difficult to approach ethically. Younger cannot be put in a situation in real conditions, accompanied due to their motor skills development.

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