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Editors: Jérôme Gensel, Didier Josselin and Danny Vandenbroucke

Eye Movement Analysis of Elementary School Children in Traffic Environments

Kristof Nevelsteen
KU Leuven/SADL
Celestijnenlaan 200E
Leuven, Belgium
Kristof.nevelsteen@sadl.kulueven.be

Thérèse Steenberghen
KU Leuven/SADL
Celestijnenlaan 200E
Leuven, Belgium
Thérèse.steenberghen@sadl.kuleuven.be

Abstract

Eye movement analysis allows to quantify how adequate traffic environments are for the safety and comfort of specific target groups. This paper presents eye movement analyses of elementary school children for the evaluation of traffic environments. Eye movements and especially fixations provide insight in human cognitive processes. By analysing fixation variables, it is possible to identify crucial traffic environment features for children's assessment of safety and comfort. In general children mostly look at other road users when evaluating a traffic scene. When performing different tasks, although road users remain significant, the attention shifts to more task-related features. There are not a lot of differences in attention allocation between groups of children with different traffic experience. The attention allocation to infrastructure is also examined. It is shown that traffic lights are difficult to interpret for children.

Keywords: fixations, children, traffic environments,

1 Introduction

The point-of-gaze (POG) is the point in space that is imaged on the center of the highest acuity region of the retina (fovea) of each eye [3].

Systems that estimate the POG are primarily used in the analysis of visual scanning patterns. Since visual scanning patterns closely follow shifts in attention focus, they provide insight into human cognitive processes [6]. As such, analysis of visual scanning patterns can be used in the quantification of mood disorders, studies of perception, attention and learning disorders and pilot training, but also in driving research and traffic safety research [9]. When an observer views a static visual scene such as a picture, his or her visual scanning is a discrete process that is broken into periods during which the eye is relatively immobile (fixations), separated by quick jumps of the eye from place to place (saccades). Visual information processing is assumed to take place during fixations, whereas vision is essentially suppressed during saccades [7, 13]. It is generally the case that the part of the visual field falling on the fovea during a fixation corresponds to that area from which the observer is currently abstracting information, or "attending to" [8]. Therefore the analysis of fixations in terms of their locus, sequence and duration can enhance the understanding of cognitive processes of subjects when executing for example traffic related tasks or when they are confronted with unknown traffic environments. In mobility and traffic safety studies the method of eye movements analysis was already successfully used as part of studies on driving behavior and driving accidents. These studies used eye movement for the determination of informative areas while performing a driving task [1] or to compare the visual strategies, and hence the cognitive processes of different groups of drivers [2]. By using fixations researchers have a window to the mind, the processes that guide and steer our attention can however be complex. The physical characteristics (color, orientation and intensity) of a feature play an important role in attracting our attention (bottom up) [4, 11]; red features on a blue background stand out. Besides this, the context of a scene, the task to perform and the historical knowledge of the observer play their part in guiding our attention (top down). Cars ride on the road, not in the air; a pen is often in one's hand and if you have to cross a street you will start by looking in a 'learned' direction [5, 12]. Eye movement studies of children are rare and often focused on the nature of the eye movements itself and the comparison of the view process to adults [10]. The aim of this research is to explore the technique for traffic environment evaluation through better insight in how children perceive these environments. In this paper a study is presented that analyses the fixations of children between 6 and 12 years old when evaluating traffic environments on pictures.

2 Methods

2.1 Subjects

The sample for the study consisted of 466 elementary school pupils between 6 and 12 years old.

Aside from a slight underrepresentation of the 6 years old age group, they were equally distributed over age and gender. Before starting their test, the children answered questions of a small survey regarding their travel mode and travel distance to school. This was used to classify them according their experience with autonomous travelling. All the children lived in semi-rural villages with crowded village centres and calm village centre surroundings.

2.2 Experiment

The children watched and evaluated 16 pictures showing different traffic environments in terms of complexity, either due to the present traffic infrastructure or to the number of road users.

The evaluations of the scenes were guided by asking the children a question during observation; three questions were possible: would you feel safe in this environment? Do all the road users act correctly? Would you cross the street now? In the remainder of the text questions will be called task. The next picture in the series was shown when the child finished his/her evaluation, which means that picture 'viewing time' was unique for every child and every picture. The shown environments were rather rural in nature. Pictures were presented on the screen of a Tobii T120 Eye Tracker. This device uses the pupil centre corneal reflection method (pccr) to estimate the point of gaze of the subject on the screen [3]. The device was recalibrated for every next child. Analysing the eye movements of children as they watch traffic environments provides the opportunity to identify traffic features which play a crucial role in their evaluation of the safety and comfort of a traffic environment. By using pictures it was possible to protect the children from real danger and simultaneously to control the complexity and design of the shown environment; the disadvantage is the loss of realism. Making use of video images would increase the level of realism, but since it is not possible to show the traffic environment in such way that both upcoming and leaving traffic is presented in one view; cars would suddenly appear from behind and would divert the attention of the children to much. Exploring the possibilities of working with 180° scene video images is part of the larger research project.

2.3 Data Analysis

Fixations are identified form the eye movement data derived from the Eye-Tracker device.

If a segment of the signal is of constant or slowly changing mean value due to drift, it is classified as a fixation; an abrupt change in the mean is a saccade. The center of a fixation has a (x,y) coordinate and a timestamp from which the location, duration and sequence can be derived. When viewing a scene, the eye fixates on the referent currently being processed by the working memory of the brain [6]. The analysis of the location of fixations reveals those features that are most significant for completing a task on a scene. The duration and count of the fixations tell something about the cognitive processing time of a feature and so also about the interpretation difficulty of that feature. First, significant features were identified based on the fixation locations. The fixations durations, fixations counts and times to first fixations of those features were then statistically analyzed, to identify differences between groups of features, groups of children, and tasks (questions asked). The results were used to evaluate traffic environment features in terms of their significance for children's perception and interpretation of safety and comfort.

3 Results

3.1 Identification of significant features

All informative features of the 16 pictures with at least one fixation of a subject were listed then joined in 20 different categories which were based on similarity. For example, traffic signs with different meanings were grouped together in the category 'traffic signs.

Mean values presented in table 1 were calculated using equation 1.

$$\mu = \frac{\Sigma X_1^n}{N} \qquad (1)$$

Where μ = mean value, ΣX_1^n = sum of the variable values of all fixations (1…n) of a category and N = number of subjects. The last column of table 1 presents the percentage of subjects that fixated on the features of a category. Mean fixation count and fixation duration, as well as the percentage of participants that fixated peaks for cyclists, pedestrians and cars. Simultaneously, the mean time to first fixation is low for these feature categories. Features from these categories are seen early, long and often and thus are significant features for children when evaluating a traffic environment (e.g. fig.1). Almost all children have fixated on features from the above mentioned categories. The range of first fixation duration values is small, but also for this variable the significant features score high, accompanied by the categories 'traffic lights' and 'children playing'. Within the categories not containing features related to road users, 'bicycle' (i.e. parked bicycles) score high on fixation count, first fixation duration and participants but low on time to first fixation.

Figure 1: Example of high fixation counts on cyclists and pedestrians (red is high, green is low)

Table 1: mean values of fixation variables

Category	ffd (s)	fc	fd (s)	ttff (s)	P (%)
cyclists	0.35	11.1	4.31	0.92	97.93
pedestrians	0.42	5.5	2.23	3.62	89.21
vehicle	0.31	4.99	1.67	2.8	88.68
children playing	0.45	3.68	1.44	2.08	85.41
cars	0.35	3.82	1.39	4.57	72.19
traffic light	0.4	2.86	1.36	3.8	68.35
obstacle	0.33	3.38	1.14	4.79	72.53
cycling lane	0.29	2.98	0.99	4.68	55.41
bicycle	0.33	3.9	0.98	3.07	83.26
street	0.25	3.41	0.96	5.03	60.39
public features	0.33	2.57	0.85	6.91	53.64
crossing	0.26	2.66	0.85	4.71	54.66
parking	0.28	3	0.85	5.86	58.3
zebra crossing	0.26	3.09	0.84	5.67	58.8
traffic sign	0.31	2.26	0.73	6.8	37.64
traffic info	0.27	2.4	0.68	4.72	57.3
infrastructure	0.28	2.3	0.59	6.18	44.27
horizon	0.23	1.72	0.47	6.78	25.15
private features	0.25	1.62	0.44	9.04	25.98
nature	0.22	1.59	0.34	4.31	42.92

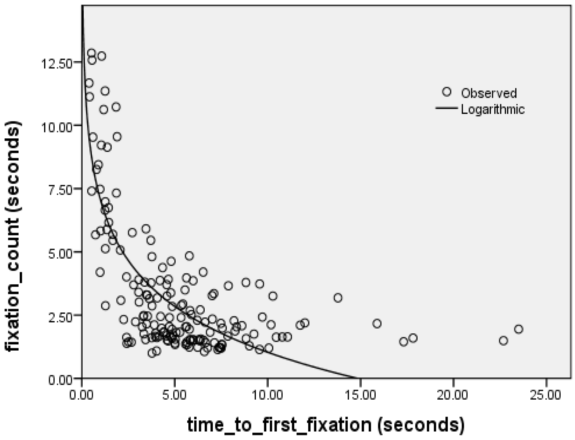
ffd = first fixation duration, fc = fixation count
fd = fixation duration, ttff = time to first fixation
P = participants, % = percentages, s = seconds
Private features (e.g. mailboxes, toys,…)

3.2 Fixation variable relations

Both fixation duration and fixation count are high for the significant feature categories which is logical since fixation duration is a summation of the individual durations of fixations on a feature.

Dividing fixation duration by fixation count reveals the feature categories that have long individual fixation durations. 'Traffic lights' and 'playing children' top the ranking followed by the three significant categories (Cyclists, pedestrians and cars). Features from the three significant categories are viewed more frequent and so longer in total but not on individual fixation basis. A logarithmic regression exists between fixation count and time to first fixation with an R^2 of 0.59 ($p<0.001$, CI = 0.99) (fig. 2). So often attended features are also attended early in the viewing process. The significant correlations that exist between the remaining variables are very weak at a 95% CI. Interesting is the absence of a correlation between time to first fixation and first fixation duration. Features catching the attention early are not necessarily viewed for a long time first.

Figure 2: logarithmic regression between fc and ttff



3.3 Task differences

When viewing a picture, subjects were asked to perform a task as explained in section 2.2.

Independent samples t-test revealed significant differences between means of the fixation variables of task 1 and 3, not between task 1 and 2 or 2 and 3. Mean fixations tend to be shorter, less often but earlier when performing task 3. Different feature categories play an important role in different tasks. Road users like cars, cyclists and pedestrians are significant features in all three tasks, similar to the findings of section 3.1, but there are differences as well. When performing task 3 (would you cross in this situation?), features from the category 'vehicle' have long first fixation duration, lowest time to first fixations, long fixation duration and highest fixation count, which makes them the most significant features performing task 3. Also 'zebra crossings' and 'playing children' are import feature categories for that task. In task 2 the categories with road users top the rankings and when performing task 1 the presence of traffic lights is evaluated as being important to evaluate the scene.

3.4 Group differences

Differences (by age, gender and experience with autonomous travelling) in fixation counts and time to first fixation were investigated using ANOVA t-test (for age and experience) and independent-samples t-test (for gender).

All fixations of subjects on any feature in all pictures were in the t-tests. Few significant (99% CI) differences in fixation counts or time to first fixation were discovered between age groups, gender groups or experience groups. Only for the time to first fixation on some features clear differences exist between some groups, but the features wherefore this is true didn't belong to a specific feature category (e.g. no systematic differences when looking at cyclists).

Analyzing the tasks however, revealed differences between age groups and differences between experience groups significant at the 99% CI. Older children evaluate traffic environments and actions of road users more correctly than

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their younger friends. The more experienced children have a more nuanced view on traffic environments.

4 Discussion

Since fixations are a window to the mind, analysis of these fixations is beneficial for the evaluation of traffic environments in terms of safety and perception of subjects or subjects groups.

In general this method offers a chance to evaluate current traffic environments towards their safety and user friendliness for a specific target group in an objective quantitative way. The eye movement analysis is used here to enhance knowledge on spatial perception. This can help for the design and evaluation of environments according the way they are perceived by the people that live in them. While classic methods such as surveys, interviews and focus group discussions are not so straightforward with children, eye movements provide a way to look at the world through their eyes. When perceiving a traffic scene children have special attention for other road users like cyclists, pedestrians and cars. Even when the task demands an evaluation in terms of safety perception, the road users in the pictures receive most frequently attention. Since the items where subjects fixate on are also the items currently processed by them, it seems that children's guide in evaluating a traffic environment are other road users. Road users are the first features children see, and they are regularly re-fixated during the rest of the observation period. Within the categories including road users, cyclist and pedestrians (the humans) are more attractive than cars except when the task demands that those features are analysed (e.g. a crossing task). The attractiveness of human road users is best evidenced by the high fixation counts and short time to first fixation of 'playing children'. Although playing children are not relevant in judging whether a scene is safe or not, this category scores high. So 'playing children' are basically a distraction for other children.

Infrastructure features become more important during later stages in the evaluation process and this is true for any task. From the infrastructure features 'traffic lights' catch most attention of children and have the longest individual fixation durations, meaning that the processing time for this category is long. This could mean that traffic lights are difficult features to understand for children and that they need sufficient time to process them. When a feature is fixated regularly, it is also fixated early in the viewing process. Children attend to all the features they feel are interesting early, and re-fixate them in a later stage.

Basic statistical comparison did not reveal much difference in attention allocation of different groups of children. Future research of the sequence of fixation may reveal the differences better. Differences can be expected because the result of the evaluation task differs significantly and so interpretation is different, which should result in fixation differences as well. 'Road users' dominate the evaluation of traffic environments by children more than infrastructure does. This is a key finding of this research: The behaviour of other road users is more important than infrastructure i.e. traffic signs in how children interpret and assess a traffic environment, and in their decision to perform a task such as crossing a street.

To understand relations between infrastructure items, images without road users could be used.

5 Conlcusions

In general, fixation variables provide a good measure of the information content of viewed regions and suggest the strategies being used by the viewer in processing information from that region.

Analysis of fixation variables is therefore a promising method to identify significant elements or features during the evaluation of traffic scenes. Children tend to use other road users as a guide in their traffic environment evaluation, which implies that everybody has an example function when being in public traffic spaces. On the other hand the results show that road users can be a distraction as shown by the playing children which received a lot of attention. Road users dominated this study but potential was shown to study traffic environments with no road users. Significant infrastructural features could be exposed by applying the same methods. Future research can focus on exploring the limits of the method and reflect on the applicability for reshaping traffic space according to the needs of subjects or subject groups.

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