Visual attention in a complex task: discrimination of decisional processes with eyes movement patterns.

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Abstract

Visual attention is interrelated with the research of visuals information, especially in complex tasks such as driving. In this task, especially when approaching a crossroads, top-down processes (goal-directed) are dominant. To reach his goal, the driver needs to take decisions, such as Go/NoGo at the crossroads. Therefore, driving is a relevant task to study decisional processes using eyes movement. In our study, we describe the decision-making with three cognitive processes, and postulate three associated oculomotor patterns. These processes are: *information-taking* (collect information to end in a decision); *control* (soundness of the decision); *anticipation* (information-taking attached to the next decision and control, depending on the risk level and the associated attentional resource). Road signs and traffic densities were manipulated in order to modulate the decision. We tested two hypotheses, one before and one after the Go/NoGo decision in the give-way condition: *1/* before the decision, oculomotor patterns are distinct between give-way (*information-taking*), stop (*anticipation*) and priority (*control*); *2/* after the decision, they are similar between priority and give-way with Go decision (*control*), and between stop and give-way with NoGo decision (*anticipation*). Thirty-four participants, equipped with an eye-tracker, drove in a simulator. Saccade amplitudes and fixation durations were in good agreement with our hypotheses. Finally, we focus on the dynamics of the processes.

Method

Thirty-four participants, including 5 women, took part in the experiment. They all had at least 3 years of driving experience (M=15, SD=12), and their average age was 34 years (SD=12). The task was to drive a simulator in a virtual environment. The participants had to cross a sequence of right angle crossroads. They were equipped with SMI eye-tracking glasses. There was 45 trials (9 different conditions, each one presented 5 times), with three roads signs (stop – priority – give-way) and three traffic densities (null – low – high). The experiment took around 1hours.

Speed and acceleration was recorded by the driving simulator, and synchronized with the eye-tracking data (fixation duration and saccade amplitude). We were interested in the last 150 meters before the crossroads, starting at the road sign position. The Go/NoGo decision being constrained by the road sign in the stop and priority conditions, the decision was already made at 150 m. In the give-way condition however, the decision was note made yet at this point. Thus, the decision process is different depending on the driver’s position: *information-taking* before the decision, *control* (Go) or *anticipation* (NoGo) after the decision.

In a first step, we plotted the mean acceleration with respect to the distance to the crossroads in the give-way condition (black curve, Figure 1). The peak of the “Go” decision seems to occur 60m before the crossroad; thus, the data was split in two subsets, before and after 60 meters. Then, four ANOVAs with one factor were conducted for the two oculomotor variables, the fixation duration and the saccades amplitude. The first two ANOVA were computed on mean values, the other two on slopes (increase/decrease rate of the variables, see Figure 1).

In the first road section, from 150 to 60 meters before the crossroads, we compared each of the three road sign conditions: priority, stop and give-way. In the second section, after 60 meters, we compared four conditions: priority, stop, give-way with a NoGo decision (stopping behavior), and give-way with a Go decision. The significance level was set to .05. Unlike the fixation duration, the saccade amplitude were not normally distributed (Kurtosis Test) and we applied a logarithmic transformation before statistical analysis.

Results

In the first road section, the three patterns are distinct as predicted, except for the slope of the saccades amplitude (see Table 1). We explain this result by the stability of the processes with time. In the last 60 meters, the slope shows two distinct patterns as expected, for the two dependent variables. For the mean ANOVA, our hypothesis is only partially validated, which may be linked to the curves crossing in the right part of Figure 1.

		Before 60m			After 60m		
		F	*p*	*η2*	*F*	*p*	*η2*
Saccade amplitude	Mean	27,365	<.05	0,453	11,552	<.05	0,259
	Contrast	$GW_{0,73} > PRIO_{0,69} > STOP_{0,59}$			$GWNG_{0,76} = GWG_{0,73} = STOP_{0,70} > PRIO_{0,66}$		
	Slope	0,955	0,39		110,089	<.05	0,769
	Contrast				$STOP_{0,66} = GWNG_{0,70} > GWG_{-0,77} = PRIO_{-0,69}$		
Fixation duration	Mean	21,765	<.05	0,397	26,044	<.05	0,441
	Contrast	$GW_{0,24} < PRIO_{0,27} = STOP_{0,29}$			$GWNG_{0,22} = GWG_{0,23} < STOP_{0,26} < PRIO_{0,28}$		
	Slope	7,524	<.05	0,186	26,344	<.05	0,444
	Contrast	$GW_{-0,04} = PRIO_{-0,08} < STOP_{0,01}$			$GWNG_{-0,11} = STOP_{-0,18} < PRIO_{0,04} < GWG_{0,18}$		

Table 1: ANOVAs of eye-tracking measures (saccade amplitude and fixation duration) in terms of mean and slope, with respective contrasts for data before and after 60 meters. Give-Way (GW), Give-Way with NoGo decision (GWNG), Give-Way with Go (GWG), priority (PRIO). The mean for each condition is in subscript.

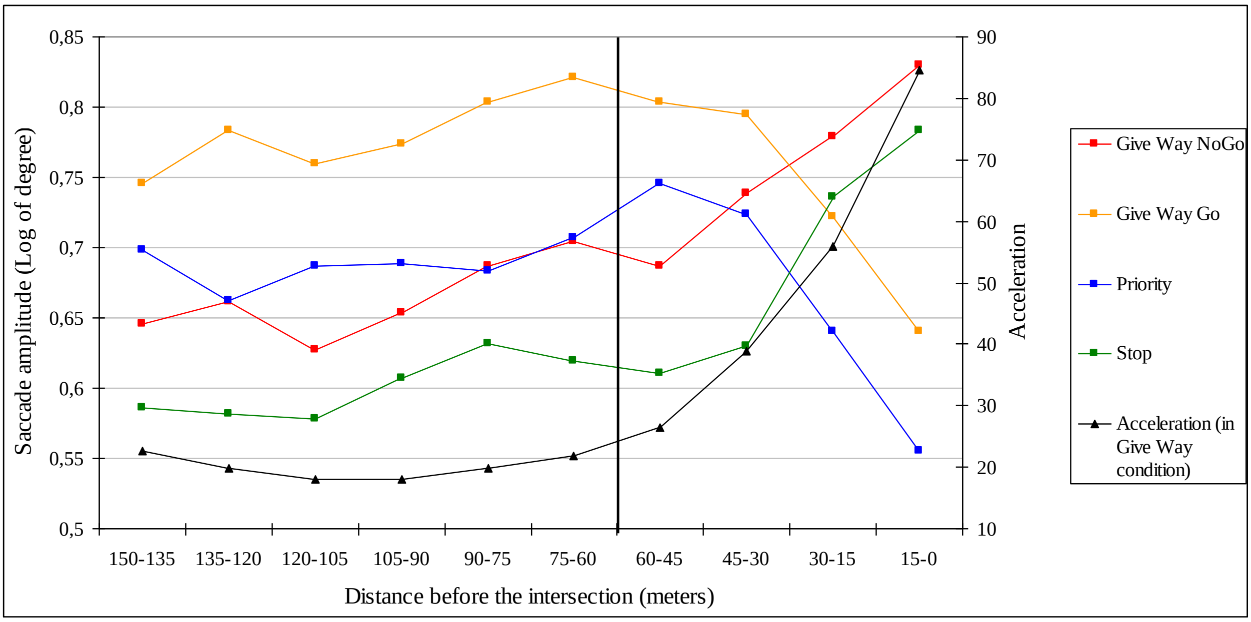

Figure 1: Amplitude of saccade (with a logarithmic transformation) and acceleration profile in the give-way condition, plotted according to the position w.r.t. the crossroads (per 15m sections). The vertical line (60 m) represents the position where the peak of “Go” decisions seems to occur.

Conclusion

We have discriminated three decisional processes with eyes movement patterns in a driving simulation experiment. Nevertheless, for the *anticipation* process, the control process seems to occur more in the beginning, while the anticipative information-taking process occurs more in the end. This highlights the dynamic aspects of decision-making, which would deserve more in-deep oculomotor studies. Another interesting fact is that in the last 60 meters, the difference between priority and Give-Way Go (GWG) can be explained with a higher risk level in the GWG condition, which may have induced an intensification of the attentional process. These two examples confirm, together with our main results, that oculomotor patterns are relevant for an accurate study of decisional processes.