Ingezonden tekst dat uiteindelijk is geworden het artikel:
Martens, M.H. (2004). Stimuli fixation and manual response as a function of expectancies. Human factors, 46(3), 410-423. http://dx.doi.org/10.1518/hfes.46.3.410.50402

Under some driving conditions, only a small part of the available attentional resources is directed to the driving task. Especially in a road environment that is highly predictable to the driver (with the driver having strong expectations about what will happen), not too much conscious attention is paid to the driving task. In this respect, Mermall (1970) talks about minimal commitment to the driving task, referring to the situation in which a driver is occupied with himself (e.g. when daydreaming), thereby reducing the interaction with the outer world. He states that drivers "somehow" learn to drive without thinking about it or without being consciously aware of the driving situation. In these situations, a driver passively uses his mental model to select important information from the environment, rather than actively scanning the visual stimuli in the surroundings and update the mental model.

This kind of passive information processing will be referred to in this report as Automatic Visual Information Processing (AVIP), indicating a state in which expectations have replaced a large part of the active information intake compared to a highly attentive person. This automatic information processing requires little attention, leaving attentional resources to be distributed to other areas, for instance other tasks or thoughts. It is a very economic state of information processing, but the state is only adequate if the person's expectations are correct. In case something unexpected happens (that does not correspond with the expectations), one could either miss crucial information completely (fail to look, or look but fail to perceive) or there may be a delay in response time due to the process of re-allocating attentional resources to the visual information in the outside world and interpreting this information in order to make the appropriate response. If this would happen in a traffic situation, the costs of the economic state of

information processing may be failing to notice a changed situation or responding too late, resulting in accidents.

Some evidence for the effect of expectations on searching targets has been provided in static experiments. Meyers and Rhoades (1978) looked at the effect of expectancy on visual scan patterns in non-traffic situations, and showed that searching for an object at a non-predictable location was much slower than searching for an object at a likely location. This implies that subjects direct their visual scan pattern according to where subjects expect information to be, resulting in an effective search if these expectations are correct. Theeuwes (1991) investigated the effect of expectation on top-down (active) visual search of every-day traffic scenes presented on slides. The study showed that expectancies about the location of the target (traffic signs are normally located on the right side of the road) had an effect on the scan behaviour (searching on the right side of the road). Search behaviour seemed to be based on the meaning and content of a scene in combination with the object one searches for. In contrast to Meyers and Rhoades, Theeuwes did not find that subjects adjusted their search strategy when they learned that expected location was not always a good cue for responding, with search strategies remaining the same even in conditions in which the target object is consistently presented at unlikely positions. Subjects always tended to search at the most likely locations, leading to a No-answer if the target is not found in this place. In real driving (compared to the static feature of slides) these effects are expected to be even stronger, especially in conditions in which there is a relatively high visual load, because here the dependency on conceptually-driven feature detection is large.

AVIP in traffic concentrates on passive visual search and on dynamic scenes, in which there is a continuous stream of stimulus material, and not a sequence of pictures. Not too many studies have looked at the kind of visual information that gets perceived in a *dynamic*

environment when people have strong expectations, directing little attention to actively scanning the environment. How do these expectations influence the scanning of the visual environment? Is expected information perceived better since this is in accordance with what drivers expect or is inconsistent information perceived better since this is information with a high informational value? The questions that will be asked are related to these issues:

1) Will eye movement patterns be different if subjects are able to develop expectations of when to expect targets compared to the eye movement pattern of subjects without these expectations?
2) Will targets that are presented in a way that is in contradiction with the expectations be missed and if not, will response times to these targets be higher?

Experiment 1

Method

The assumption behind the idea of AVIP is that if people do not have strong expectations about the environment, they are less certain of where important information may be located and they visually scan all stimuli more actively to look for information. If people develop expectations because of sequential exposure to a certain scene, they feel more certain, not feeling the urge to actively scan their environment. In the first experiment, the hypothesis was tested that people with expectations about what information is relevant and what information is not, will spend more looking at information that is assumed to be relevant. A second hypothesis is that if information is presented that does not correspond with the expectations, the information will be missed or the pattern of spending less time to expected-to-be-irrelevant information will be distorted.

In order to test these assumptions, a lab task was developed that had some correspondence with a simulated driving environment. The task environment consisted of a road, grass along the sides of the road and relevant objects (the stimuli) and irrelevant objects (corresponding to houses or trees in the surroundings). Scenes from the task are shown in Figure 1a and 1b.

In order to test the hypotheses, responses and eye movement recordings were used. Eye movement studies have yielded some valuable results in exploring visual scan patterns, especially in dynamic environments. If subjects move their eyes toward a new position, attention will be moved along to that same position (Hoffman & Subramaniam, 1995). Eye movement measures can be a valuable tool for exploring the effect of expectation on visual information perception, or at least reveal something about how expectations affect visual scan patterns. The major advantage of using eye movements as a dependent variable is that eye movements are fairly involuntary, especially if subjects are not instructed to search for specific items in the environment (Bhise & Rockwell, 1973).

Subjects

Thirty subjects participated in the experiment. Their ages varied from 22 to 63 and both male and female subjects were included. All subjects reported to have good visual acuity. Half of the subjects was part of the Predictable condition and half of the group was part of the Random condition. Subjects were paid for their participation.

Task

As is shown in Figure 1, the task environment consisted of a virtual grass field with a virtual road, on which the subjects moved forward. Along the side of the road (on the grass field), all kinds of object shapes were placed, that were not relevant to the task subjects had to

perform (cf. houses along a road). Alongside the road, purple circles appeared on the horizon and they became larger as the subject was moving through the environment alongside the road with a continuous pre-set speed. If an object was close to the subject, it would be on the right side of the road and finally disappear from the screen. Every 1.1 seconds, a purple stimulus passed by. The task of the subjects was to decide whether the closest (and thus largest) object was a circle (distractor) or an oval (target). Objects were always circles, but if they were the closest object to the subject, they could either stay a circle or they could change into an oval. If this change happened, subjects had to press a mouse button to indicate they noticed the target. In case the circle did not change (distractor), they did not have to take any action. The choice of a stimuli that could change into a target or stay a distractor was made in order to make sure that subjects were forced to always look at the largest stimulus. This was necessary in order to have accurate eye movement recordings and to make sure that the stimuli they responded to could be identified. No feedback was given about their performance.

Two experimental conditions were used. Subjects were either part of the 'Predictable condition' or of the 'Random condition'. In the Predictable condition, the order in which the targets (ovals) were presented among the distractors (circles) was predictable, with a target being followed by a distractor, after which another target followed etc. The number of targets was equal to the number of distractors. In the Random condition, the sequence of targets and distractors was random, so subjects could not predict whether the next stimulus was going to be a target or a distractor. Also here, the total number of targets was equal to the number of distractors (and equal to the Predictable condition). In the Predictable condition, subjects are able to develop expectations of what will be a target, whereas it was not possible to develop expectations of that

kind in the Random condition since there is no predictable sequence. Figure 1 shows a static picture of the dynamic scene that the subjects would encounter.

-- Include figure 1 --

Subjects did not have to pay any specific attention to the yellow or orange objects, nor to the road or the grass. If subjects detected a target, they had to press a mouse button. The task was not to respond as quickly as possible but as accurately as possible (therefore, response times were not measured). All subjects received three sessions of 10 minutes, with a 5-minute break in between. In session 1, the Random condition was completely random and the Predictable condition was completely predictable. In session 2, the Random condition was still completely random, but in the Predictable condition, one irregularity was introduced. This irregularity consisted of a target where a distractor would normally have been placed. This happened after about 8 minutes. In session 3, two irregularities were included in the Predictable condition, one extra target instead of a distractor after about 3.3 minutes and one after about 9.3 minutes. The Random condition would also have the extra ovals, but they cannot really be called irregularities since there was no predictable pattern in the presentation order.

Apparatus

A corneal-pupil reflection measurement device (Inducom Inc.) was built into an experimental configuration, suited for measuring eye movements and recording the responses. This video-based system sampled at 50 Hz, with the infra-red light source and the eye camera being situated slightly at the right of the eye level (approximately 0.75m from the subject's eye). A high-speed processor (Scanbeam Inc.) computed the centre of both cornea and pupil reflection and calculated the difference vector. The output of the high-speed processor, consisting of x and y co-ordinates, was entered into a computer (Pentium 166 processor), that mixed the data on-line

with the task environment that was presented and the responses that subjects made. The images were generated by an Accel Galaxy video display adapter and displayed on a 19" SVGA colour monitor. The display resolution was 1280x1024 with a high colour (16 bits) palette at 75 Hz.

Subjects were seated in front of a computer screen with their heads resting in a chin rest, which was located 0.97m from the computer screen. The mouse was used as response button. Subjects could start the experiment by pressing a mouse button.

Results

For eye movement data, the percentage of total fixation time was calculated. The time that a subject looked at the largest and closest stimulus was divided by the total time that this stimulus actually was the largest and closest stimulus. The percentage of total fixation time was defined as 100% if a subject started looking at a stimulus as soon as it was the largest and closest stimulus (this would be after the preceding stimulus disappeared from the screen) and fixated the stimulus until it entirely disappeared from the screen.

Data of seven subjects had to be removed from the analysis since there were too many missing eye movement data. This meant that the eye tracker had not been able to measure the eye movements during the entire experiment and therefore too many data were missing. Of those seven subjects, three subjects were part of the predictable condition whereas four of those subjects were part of the random condition. Therefore, the total number of subjects in the random condition was 11 and in the predictable condition 12.

Session 1

Since the data set for the percentage of fixation times was extremely large, five sequential data points within one subject were averaged into one new data point.

An analysis of variance (ANOVA) was used to analyse the percentage of total fixation times. There was a main effect of Stimulus (target or distractor) [$F(1,21) = 32.12$, $p<0.0001$), showing a higher percentage of fixation time for targets compared to distractors. Also a main effect was present of Condition (Random/Predictable) [$F(1,21) = 10.70$, $p<0.0036$), showing longer fixation times for the random condition. There was a 2-way interaction between Stimulus and Condition [$F(1,21)=16.65$, $p<0.0005$], which is shown in Figure 2.

-- Include Figure 2 --

Figure 3 gives an overview of this interaction for the sequential trials. Every indicated point on the horizontal scale is an average of 5 sequential trials.

-- Include Figure 3 --

Figure 2 and 3 show that the difference between percentage of total fixation time for targets and distractors was only present in the predictable condition. In the random condition, in which subjects were not able to develop any expectations on when a target would occur, no difference was found between the distractors and the targets.

In session 1, no irregularities were present in the predictable condition. In the random condition, in 1.98% of the cases subjects in the random condition pressed a mouse button when it was a distractor and in 4.91% of the cases, these subjects did not respond to a target. For the predictable condition, this was 0.90% and 3.89%.

Session 2

The difference between session 1 and session 2 was that after 445 out of the 575 stimuli (about 8 minutes after the start of the trial), an extra target (oval) was shown, which means that for the predictable condition, one circle was replaced by an oval. This extra target is called the irregularity.

In the Predictable condition, 8 out of the 12 subjects did not respond to the appearance of the extra target, probably indicating that they did not notice this. As for the percentage of total fixation time, data were again averaged over 5 sequential trials. No main effect was found of Condition on percentage of fixation times [$F(1,21) = 1.05$, $p<0.32$], indicating the total percentage fixation time did not differ between the random and the predictable condition (which was to be expected, since we only expected a shift in percentage fixation time between stimuli). A main effect was found of Stimulus [$F(1,21)=32.16$, $p<0.0001$], with a higher proportion of fixation times for the targets. Equal to session 1, a 2-way interaction was found for Condition and Stimulus [$F(1,21) = 7.21$, $p<0.014$].

If we only look at the data points around the irregularity, 10 data points before and 10 data points after the irregularity (including the irregularity itself) without averaging these data, results are slightly different. A main effect is found of 'before and after' ($F(1,21) = 12.12$, $p< 0.002$). This effect is represented in the 2-way interaction between condition and before-after [$F(1,21) = 11.10$, $p<0.003$], indicating lower percentage of fixation times after the irregularity only for the predictable condition. This effect was also present if those subjects who did not respond to the irregularity were removed from the analysis.

-- Include Figure 4 --

Session 3

In session 3, two irregularities were used, one after 185 out of the 575 stimuli (about 3.3 minutes) and one after 519 stimuli (about 9.3 minutes). Also here, this meant that what was expected to be a circle in the predictable condition changed into an oval. Of the 12 subjects in the random condition, 5 subjects responded to the first irregularity. All subjects that responded to the

regularity in session 2 also responded to the first irregularity of session 3. For the second irregularity in session 3, also 5 subjects responded. Only one subject who responded to the first irregularity did not respond to the second one.

If we look at the averaged data, no main effect was found of Condition [$F(1,21) = 1.22$, $p<0.28$], which was to be expected. A main effect was found of Stimulus [$F(1,21) = 7.79$, $p<0.01$], with a higher proportion of fixation times for targets compared to the distractors. The 2-way interaction between condition and stimulus, present in Session 1 and 2, was not significant [$F(1,21) = 0.25$, $p<0.63$], indicating that the percentage fixation times to targets and distractors did not differ between the random or the predictable condition.

If we look at the data that were not averaged over 5 trials and assemble the stimuli around the first irregularity (10 before and 10 after the irregularity (including the irregularity itself), there is no main effect of before-after [$F(1,21)$ 1.40, $p<0.25$]. Also, there is no interaction between before-after and condition [$F(1,21) = 1.18$, $p<0.29$]. Only the effect of stimulus was present [$F(1,21) = 114.00$, $p<0.001$], with a higher percentage of fixation time for the targets.
No other main effects or 2-way interactions were present.

-- Include Figure 5 --

In line with the first irregularity, the analysis of the 10 data around the second irregularity showed no main effect of before-after [$F(19,21) = 1.98$; $p<.0.17$]. No other main effects or 2-way interactions were present. It seems that in session 3, the difference in percentage of fixation times between targets and distractors that was present in session 1 and 2 had disappeared.

Discussion

Hypothesis 1: Difference in eye movement pattern with expectations

The first two sessions showed that there is a difference in the way people scan stimuli if they have expectations about what stimulus will be a target and which one will be a distractor. Session 1 showed that there is no difference in time spent on fixating the targets and distractors if they are presented according to a random pattern, but there is indeed a difference if they are presented according to a predictable order. If the order of presentation is predictable, less time is spent on fixating the distractors. This difference between time spent fixating the targets and distractors for the predictable condition disappeared after some irregularities were introduced, possibly adjusting the expectations.

Hypothesis 2: Missing targets in case of irregularities

Session 2 and 3 were used to see what happens if a target is not presented according to the expectations. In case of Session 2, 8 out of the 12 subjects did not respond to the target at all. This meant that 2/3 of the subjects probably did not notice the target (or at least failed to respond) since they expected to be confronted with a distractor and they spent less time fixating the stimulus. This shows there are indeed some indications that subjects miss (or fail to respond to) information that does not fit into their mental model. For the first irregularity in Session 3, only 5 subjects responded to the extra target. This meant that again, almost 2/3 of the subjects missed the target since they expected a distractor. In case of the second irregularity of session 3, also 5 subjects responded to the irregularity. Although these subjects were not exactly the five responding to the first irregularity of the second trial, 4 out of the 5 subjects were. This only strengthens the assumption that it might be due more to the particular scan pattern of the subjects than due to a change in scan pattern after noticing the first irregularity.

Since the difference in scanning pattern between the random and the predictable condition disappeared in session 3, this is an indication that subjects indeed changed their scanning pattern based on the irregularities. This might be evidence for the fact that subjects gradually changed their scanning strategy after encountering some irregularities to a strategy that was similar to that of the random condition.

Experiment 2

Method

In order to allow a more general interpretation of the data, an extra condition was added in experiment 2. This condition was a predictable condition in which no irregularities were present. Also, the way in which the percentage of total fixation time was calculated was changed. Assuming subjects stop fixating a target as soon as they detect it (since it was already identified), the proportion of the total fixation time will underestimate the fixation time for the targets. By estimating the percentage of fixating time for targets as the proportion of the time until the target is detected, the data are more useful. Also, reponse times (RTs) to the appearance of the targets were measured in experiment 2. By measuring RTs, information can be gathered whether subjects perceive the information if they fixate it. Not pressing the mouse button is an indication for not perceiving the information and RTs are an indication for the delay in information processing.

The second experiment consisted of a similar task and task environment. However, the character of the stimuli was changed in order to see if the same results would be found if the type of stimuli was changed.

Subjects

Twenty-seven subjects participated in the experiment. The subjects' age varied from 18 to 35 and they were all students (male and female). All subjects reported to have normal or corrected to normal visual acuity.

Apparatus

A different eye tracking system was used than the one in experiment 1 .The eye-tracking system was made by Iscan Inc., using the corneal-pupil reflection to record the eye movements. This system was more accurate than the one described in experiment 1. The eye camera with the infra-red light source was positioned slightly below the eye level, approximately 0.75m in front of the subjects right eye. This video-based system sampled at 250 Hz. The output consisted of X and Y co-ordinates, and it was mixed on-line with the moving environment the subjects saw and with the responses they made. Subjects were seated with their head resting in a chin rest, in front of a computer screen, which was located 0.97m from the subject. A mouse button was used for the responses.

Task

For this experiment, the same lab task was used as in experiment 1. However, the character of the stimuli was changed and there were three experimental conditions. Subjects were either part of the predictable condition, the predictable+ condition or the random condition. In the predictable condition, the order in which the targets (in this experiment Os instead of ovals in experiment 1) are presented among the distractors (in this experiment Qs instead of circles in experiment 1) was predictable, with one O being followed by one Q, after which another O follows etc. Treisman and Gelade (1980) and Treisman (1988) stated that if combinations of features are required for object recognition, visual spatial attention is required. They stated that

attention is required when features must be located or combined in order to specify objects. Therefore, in this experiment, we have chosen to make a distractor almost similar to a target, with the only difference being the presence of one feature.

The number of Os was equal to the number of Qs. A stimulus always started at the horizon as a Q (circles in experiment 1), and if it approached, the largest stimulus (nearest to the subject) would either remain a Q (remain a circle in experiment 1) or it would change into an O (change into an oval in experiment 1). Compared to experiment 1, there was no gradual change from distractor to a target (in which a circle turned gradually into an oval) but this would be a change at one moment in time, with the extra leg of the Q disappearing in case of a target. The physical place where a distractor could change into a target could vary a little in order to prevent that subject would know the exact location on forehand.

In the predictable condition, every other Q would turn into an O. In the predictable+ condition, the sessions started out like the predictable condition. The only difference was that in the predictable+ condition, some irregularities were introduced. In Session 2, a Q changed into an O (extra target) after about 5.2 minutes (or 276 stimuli) minutes of the total 7 minutes of the session. According to the predictable order, subjects would expect a distractor. The same irregularity appeared in session 3 after about 2.4 minutes (after 127 stimuli) out of 7 minutes. Here also, an O appeared where normally (according to the predictable pattern) a Q would have appeared. Two irregularities were present in Session 4, one after about 1.2 minutes (65 stimuli) minutes and one after about 6.0 minutes (318 stimuli). Besides these irregularities, the trial of the predictable+ condition followed the same predictable order as in the predictable condition. The sequence of the targets and distractors in the random condition was all completely random, but

the amount of Qs and Os was the same. The same experimental configuration of the first experiment was used, except for a different eye-movement measurement device.

In total, subjects received four trials of 7 minutes each. When the subjects were seated behind the computer screen, they were able to start the first trial themselves by pushing a mouse button. On the screen, they saw the moving environment. Subjects had to make a response every time a Q turned into an O. They were told that Qs could only turn into Os just before they disappeared of the screen. It was stressed that the response had to be as accurate and as fast as possible. Subjects did not need to respond to the Qs that remained a Q (distractors). No feedback was given about their performance. Between the trials, the subjects had a five-minute break.

Procedure

Per subject, the experiment lasted 45 minutes, consisting of four sessions of 7 minutes each. Before the start of the experiment, subjects received a written instruction about the task. After reading the instruction, a preview of a session was given for about one minute, to give the subjects an idea of the environment and the stimuli they were about to see and what they had to respond to.

Before starting the experiment, the eye tracking system had to be adjusted to the subject's position and eyes. Subjects could start the experiment themselves by pressing a mouse button.

Results

Session 1

Percentage total fixation time.

Per stimulus, the percentage total fixation time was computed. If a subject would look at a stimulus when it was the largest one on the screen, and followed it on the screen as it was

getting closer, and stopped looking at the target when pressing the response button, the percentage total fixation time was 100%. For the distractors, the time was 100% if subjects started fixating the distractor as soon as it was the largest on the screen and only stopped looking when it disappeared from the screen. The definition for targets and distractors was different, since for a distractor there was still a chance that it would change into a target.

For the percentage of fixation time, no main effect was present of Condition [$F(2,24) = 2.31$, $p<0.12$]. There was a main effect of Stimulus [$F(1,24) = 37.40$, $p<0.0001$], with a higher percentage of total fixation times for targets compared to distractors. A 2-way interaction was found between Condition and Stimulus [$F(2,24) = 7.79$, $p< 0.0023$], which is shown in Figure 6. The Figure shows there was only a difference between fixation times of targets and distractors in the predictable and the predictabe+ condition, not for the random condition.

-- Include Figure 6 --

Response times.

Response times were calculated as the time between a Q turning into an O and clicking the mouse button. For Session 1, there was a main effect of Condition [$F(2,23) = 3.65$, $p<0.04$], with longer RTs to targets (about 60 msec) for the random condition. This effect is shown in Figure 7.

-- Include Figure 7 --

Session 2

In session 2, one irregularity was present in the predictable+ condition after 276 stimuli.

Percentage total fixation time.

In session 2, no main effect was present of Condition [$F(2,24) = 0.26$. $p<0.77$]. There was an effect of Stimulus [$F(1,24) = 26.15$, $p<0.00003$], with longer fixation times for the targets compared to distractors. There was a 2-way interaction between Condition and Stimulus [$F(2,24) = 4.90$, $p<0.016$], indicating a difference in fixation times between targets and distractors for the predictable and the predictable+ condition, whereas this difference is not present in the random condition. These results are similar to the results obtained in session 1.

In order to see whether the scan pattern of subjects in the predictable+ condition changed after introducing the irregularity, the data of the 10 stimuli before the irregularity and the 10 stimuli after were analysed. No main effect was present of the factor Before-After [$F(1,24) = 1.07$, $p<0.31$], indicating that the overall scan patterns after the irregularity do not differ from that before the irregularity. No 3-way interaction was present between Condition, Stimulus and Before-After, something that was expected if the scan pattern only changed for the predictable+ condition.

Response times.

In the predictable+ condition, 4 out of the 9 subjects did not respond at all to the irregularity. For session 2, the assumption was that the RT for the irregularity in the predictable+ condition would be higher than the mean RT for that session. In order to test this hypothesis, 15 RTs were compared for those subjects who did respond to the irregularity with the average RT in the entire session. With this, 7 RTs were the RTs just before the irregularity, 1 was the irregularity itself and 7 more after the irregularity. A t-test for dependent samples (comparing the mean with individual response times) showed that there was only a significant difference between the mean RT to the session and the RT to the irregularity itself ($p<0.01$], indicating

subjects who did notice the irregularity responded slower than they normally did to targets (mean delay for all subjects was 330 ms). The other RTs (before and after the irregularity) did not differ from the mean RT. Also, the RTs for the random or the predictable condition did not show any difference from the mean RT around the time of the irregularity. Figure 8 shows the RTs for the predictable+ condition around the irregularity.

-- Include Figure 8 --

Session 3

Percentage total fixation time.

In session 3, 2 out of 9 subjects in the predictable+ condition did not respond at all to the irregularity. For Session 3, for which again an irregularity was introduced for the predictable+ condition after 127 stimuli (the second irregularity in the complete experiment), there was no main effect of Condition [$F(2,24) = 0.57$, $p<0.57$], which was the same as in the other sessions, and which was also to be expected. There was a main effect of Stimulus [$F(1,24) = 31.58$, $p<0.00001$], and again a 2-way interaction between Condition and Stimulus [$F(2,24) = 7.16$, $p<0.004$]. The interaction shows that for the predictable and the predictable+ condition, more time is spent on the targets than on the distractors. This difference is not present for the random condition (as was also found in session 1 and 2).

If the scan patterns close to the irregularity are analysed (10 trials before and 10 after the irregularity), no effect is present of Before-After [$F(1,24) = 3.57$, $p<0.07$]. No 3-way interaction was found between Condition, Stimulus and Before-After, which was to be expected if subjects would change their scanning pattern after noticing the irregularity. This effect was not present, not even if the subjects that did not notice the irregularity were excluded from the analysis.

Response times.

For session 3, the same analysis was done for the RTs around the irregularity. Altogether, 1 out of the 9 subjects did not respond to the irregularity. RTs before and after the irregularity were analysed and all RTs (including the RT to the irregularity) were compared to the mean RT in the entire session. Also in this case, only the RT to the irregularity was significantly higher (with an increase of about 200 ms) than the mean RT in that condition ($p<0.039$). The other RTs were not significantly different from the mean RT. This increase in RT was not present for the predictable condition around the time of the irregularity, nor for the random condition. Figure 9 shows the RTs for the predictable+ condition around the time of the irregularity.

-- Include Figure 9 --

Session 4

Percentage total fixation time.

In this session, again no main effect of Condition was found [$F(2,24) = 2.08$, $p<0.14$]. Again a significant effect of stimulus [$F(1,24) = 28.83$, $p<0.00002$] with higher fixation times for the targets, and a significant interaction between Condition and Stimulus [$F(2,24) = 6.09$, $p<0.007$], with the higher fixation times for targets only being present in the predictable and the predictable+ condition.

If the 10 trials before and after the first irregularity were analysed, no main effect was present of Before-After [$F(1,24) = 0.04$, $p<0.84$}, nor any interaction between Condition, Stimulus and Before-After [$F(2,24) = 0.48$, $p<0.62$]. The same holds for the second irregularity with no main effect for Before-After [$F(1,24) = 3.44$, $p<0.08$], although there is a tendency towards longer fixation times after the irregularity. There was no interaction between Condition, Stimulus and Before-After [$F(2,24) = 0.22$, $p<0.89$].

Response times.

Two out of 9 subjects in the predictable+ condition did not respond at all to the extra target. For the RTs around the time of the first irregularity in session 4 for those subjects who did respond, RT to the irregularity and the one after the irregularity were significantly higher than the mean RT in that session ($p<0.03$ and $p<0.02$ for an increase of 150 and 130 ms, respectively). Two RTs before the irregularity, RTs were even lower than the mean RT. The RTs for the three conditions around the first irregularity are shown in Figure 10.

-- Include Figure 10 --

Again, 2 subjects did not respond at all to the second irregularity. Of those subjects who did respond, the RTs to the extra target were also larger compared to the mean RT ($p<0.02$ for the irregularity, $p<0.008$ for the first target after the irregularity for an increase of 310 ms and 230 ms, respectively). The RTs before the irregularity were all not significantly slower than the mean. The RTs around the irregularity of the predictable+ condition are shown in Figure 11.

-- Include Figure 11 --

Discussion

Just like in experiment 1, the assumption was tested that subjects with expectations about when to expect a target and when to expect a distractor will scan their environment differently than subjects who do not have these expectations. A second assumption was that if something happens that is not in correspondence with these expectations, this information will either be missed or RTs will be increased.

Hypothesis 1: Different scanning pattern based on expectations.

In all sessions, a difference can be found in the way subjects scan the stimuli in the different conditions. In the condition in which subjects are not able to develop any expectations on what stimulus will be a target and which one will be a distractor, no difference was found in the time spent looking at the targets or the distractors. For the two conditions in which the targets and distractors were presented according to a predictable pattern (the predicatable and the predicatable+ condition), subjects spent less time fixating the distractors compared to the time fixating the targets. There was no clear change of scanning pattern in the predictable+ condition after the irregularities.

Hypothesis 2: Missing information or longer RTs in case of irregularities.

This assumption could only be tested by including some irregularities in the predictable+ condition. In the predictable condition, no irregularities were included and in the random condition, the irregularity was not really an irregularity since there was no predictable pattern to begin with.

The first irregularity was missed by 4 out of the 9 subjects, who did not respond to the target at all. The second irregularity was missed by 1 out of the 9 subjects. The third and the fourth irregularity were missed by 2 subjects. Altogether there was one subject who did not notice (or respond to) any of the irregularities. When we look at the response times of those subjects who did respond to the irregularity, increased response times were found. On average, an increase in response times of 330 ms was found for the first irregularity. This can also be called the "cost" of expecting something that doesn't turn out to be true. For the second irregularity, this cost is about 200 ms and for the third 150 ms and for the last irregularity 310 ms. These costs are very high when the nature of the average RT is considered. Sometimes (in case of the first irregularity) these RTs are almost double their seize. This indeed does confirm

the hypothesis that targets that are not presented according to the expectations of the subject are either missed or RTs to these targets are increased. This cost of developing expectations is reflected in a decrement of fixation times: The cost of spending less time to stimuli that are not considered to be important.

General Discussion

The combined results of experiment 1 and 2 showed that for both types of stimuli (changing shape in experiment 1 and disappearing feature in experiment 2), subjects scan their environment differently if they have expectations about what stimuli will be the targets and what will be the distractors. In the predictable condition, less time is spent to distractors. Response times are also faster if the stimulus that one expects to be a target is a target indeed. For those subjects that do not have expectations about the stimuli, the same amount of time is spent to targets and distractors and RTs to targets are higher compared to a predictable condition. However, if some information is included that is not in congruence with the expectations people have, this information is either missed or the RT to the appearance of the targets is high, with responses even being slower than in the random condition.

These results show that the hypotheses in the introduction were correct. More time is spent on what is considered to be important and less time is spent to what is considered to be irrelevant. Although this is a very efficient way of using knowledge (or what is considered to be knowledge) in order to divide our attention, it may be very inefficient if this knowledge does not turn out to be true. Important items can be missed, and even if they are noticed, correct responses are very slow. This phenomenon may have huge negative consequences in real life, for instance

in driving situations or in monitoring tasks. Since driving experience develops expectations of traffic situations, this phenomenon may also take place in traffic. If people who work at the customs of an airport have specific expectations of what they may find in suitcases, deviant information may be missed easily. More research will have to be done in order to investigate this phenomenon in other (real life) situations. Also, more knowledge has to be gathered about what can be done in order to break through these expectations and turn this Automatic Visual Information Processing into an active visual information intake.

Acknowledgement

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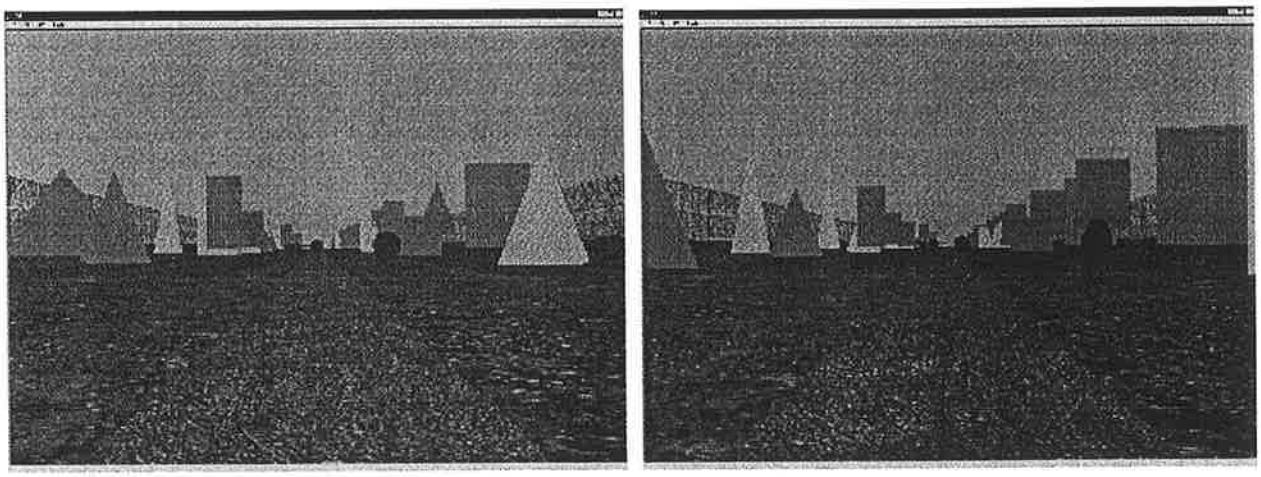

(a) (b)

Figure 1

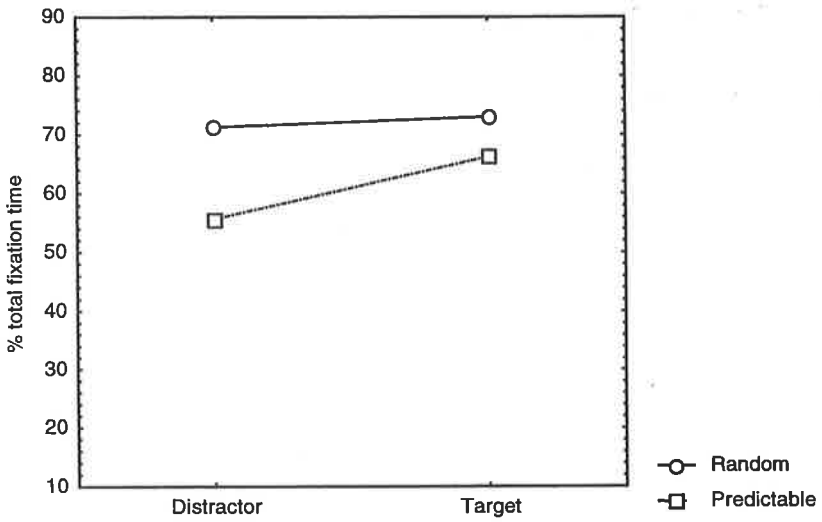
90
80
70
60
50
40
30
20
10
% total fixation time
Distractor
Target
Random
Predictable

Figure 2

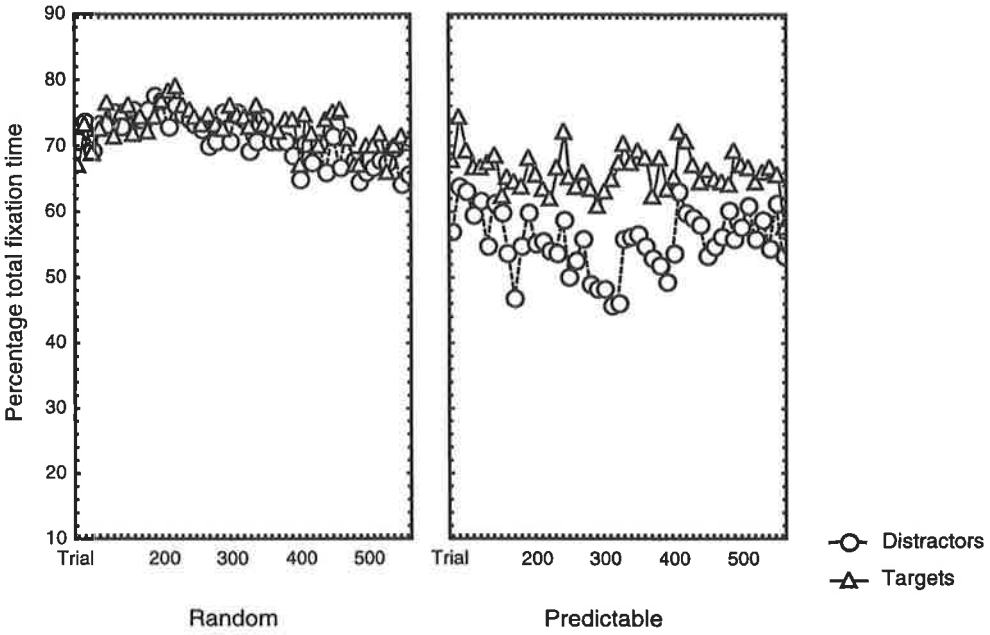
Percentage total fixation time
90
80
70
60
50
40
30
20
10
Trial
200
300
400
500
Random
Predictable
Distractors
Targets

Figure 3

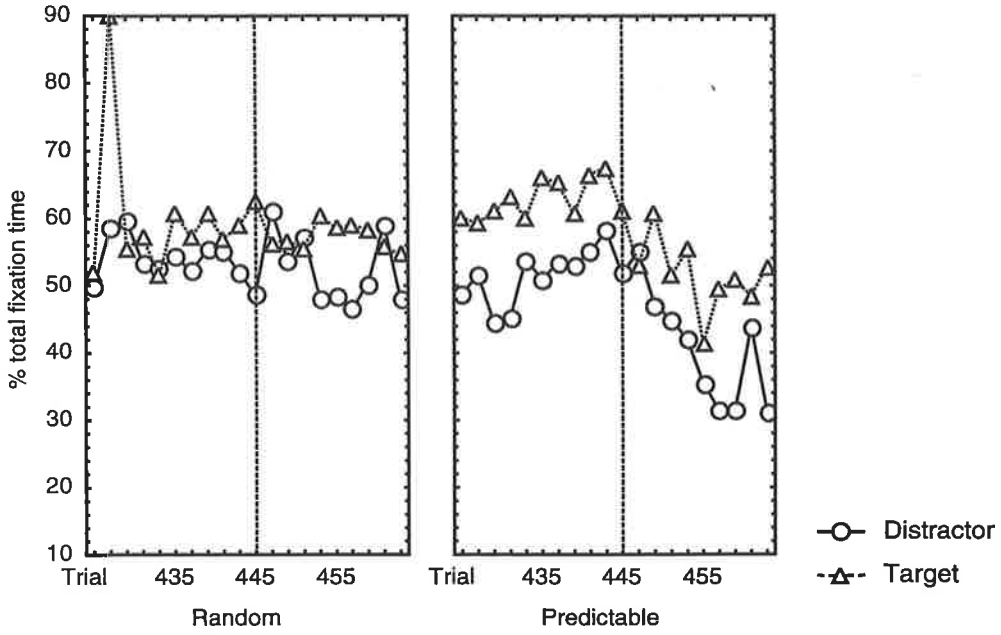
90
80
70
60
50
40
30
20
10
% total fixation time
Trial
435
445
455
Random
Trial
435
445
455
Predictable
Distractor
Target

Figure 4

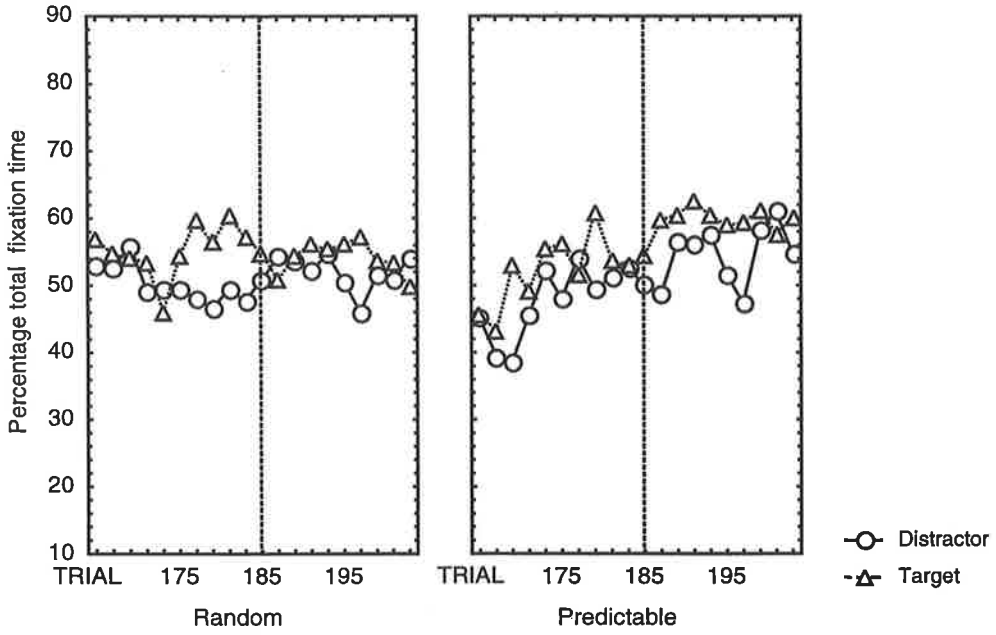
Percentage total fixation time
90
80
70
60
50
40
30
20
10
TRIAL
175
185
195
Random
TRIAL
175
185
195
Predictable
Distractor
Target

Figure 5

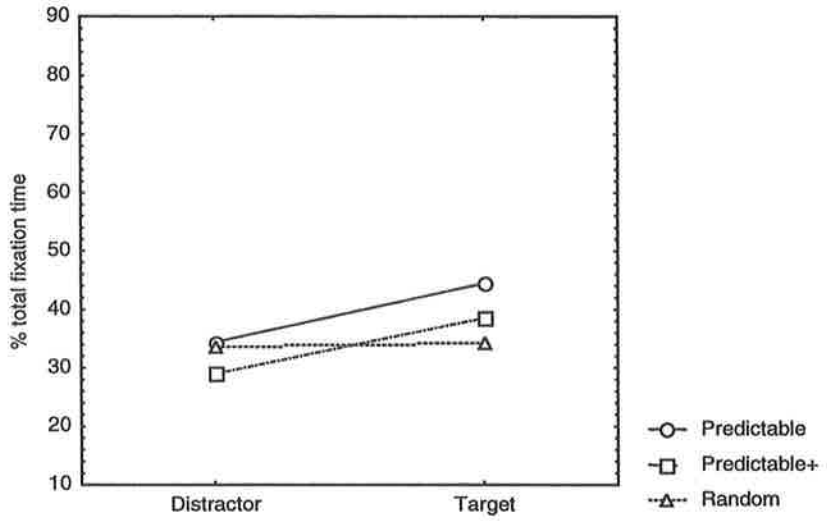
90
80
70
60
50
40
30
20
10
% total fixation time
Distractor
Target
Predictable
Predictable+
Random

Figure 6

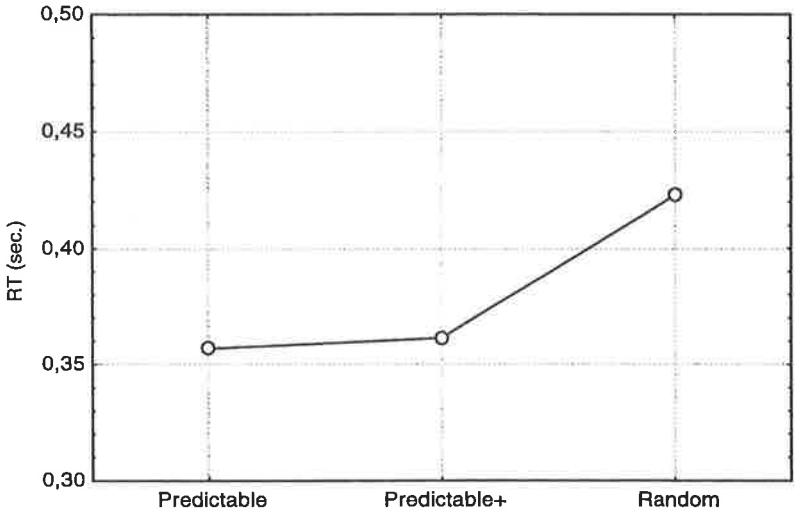

Figure 7

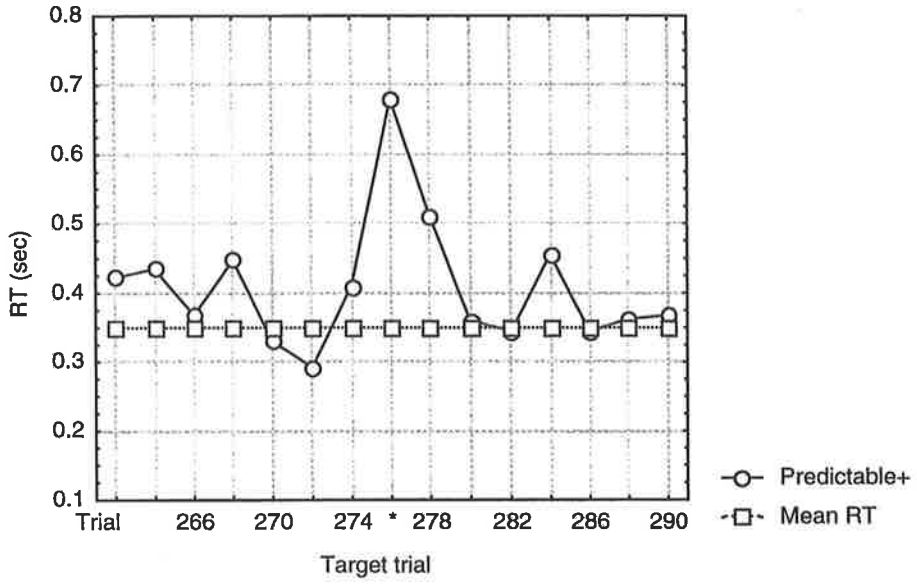
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
RT (sec)
Trial
266
270
274
*
278
282
286
290
Target trial
Predictable+
Mean RT

Figure 8

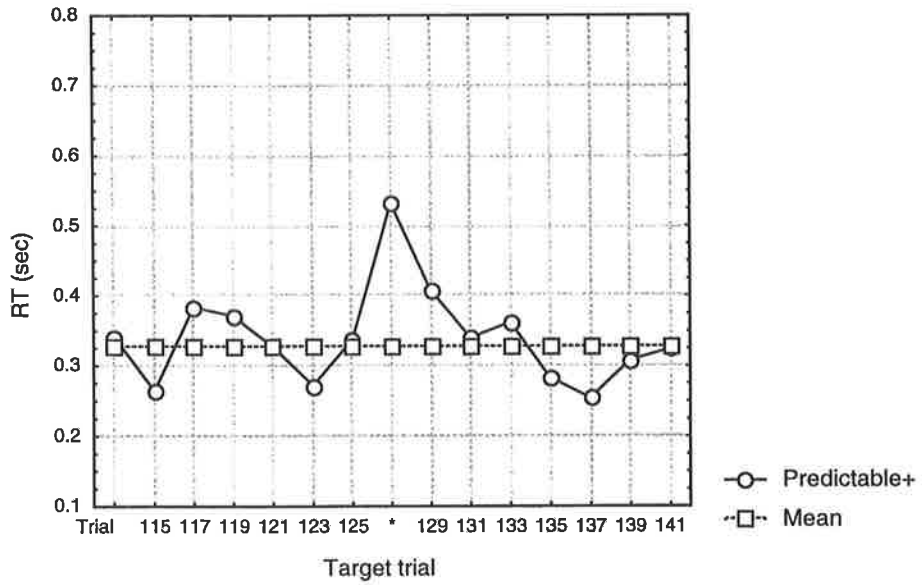
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
RT (sec)
Trial
115 117 119 121 123 125 * 129 131 133 135 137 139 141
Target trial
Predictable+
Mean

Figure 9

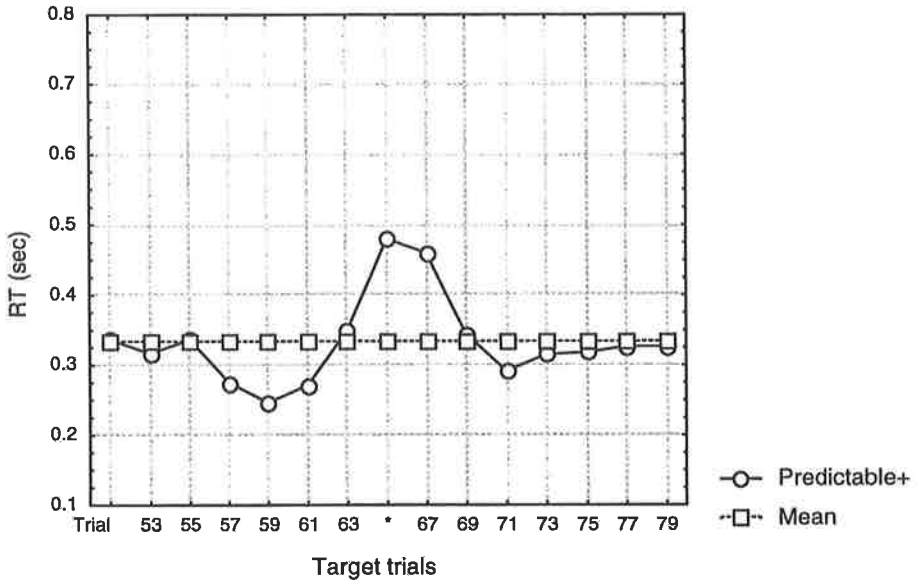
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
RT (sec)
Trial
53
55
57
59
61
63
*
67
69
71
73
75
77
79
Target trials
Predictable+
Mean

Figure 10

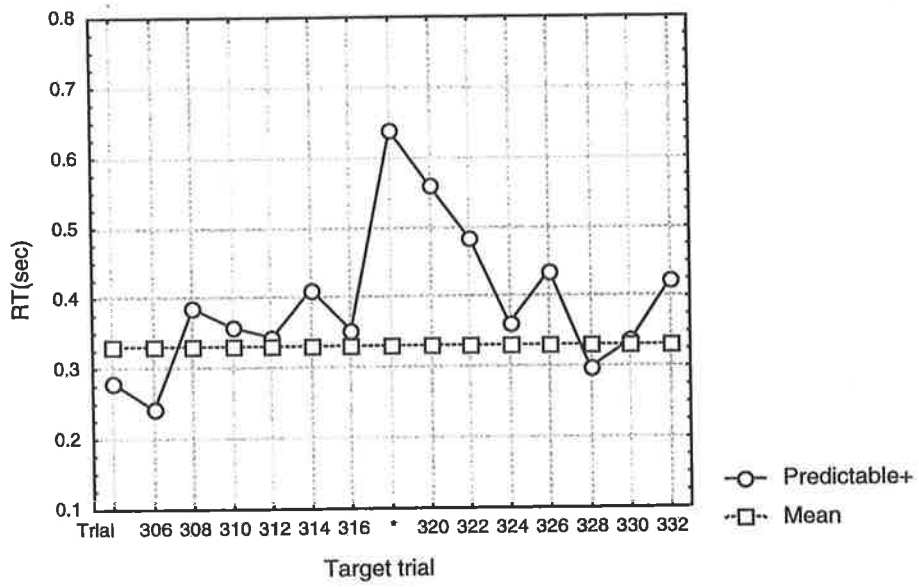
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
RT(sec)
Trial
306 308 310 312 314 316 * 320 322 324 326 328 330 332
Target trial
Predictable+
Mean

Figure 11

Figure 1: The task environment of experiment 1, with (a) showing a distractor (circle) and (b) showing a stimulus that has just turned into a target (oval)

Figure 2: The interaction effect between condition and stimulus, with shorter fixation times for the distractors in the predictable condition.

Figure 3: The course of percentage total fixation time over sequential trials for the two conditions (random and predictable) and for the two types of stimuli (distractors and targets).

Figure 4: The fixation times of the two experimental conditions with 10 stimuli before the irregularity and 10 stimuli after. Here data are not averaged, so every point on the x-axis is one fixation time to one stimulus.

Figure 5: First irregularity in the third trial, with one data point representing the percentage total fixation time for one stimulus.

Figure 6: The interaction between Condition and Stimulus for the three experimental conditions.

Figure 7: The RTs in seconds for responding to the targets in the three experimental conditions.

Figure 8: The RTs of the predictable+ condition around the time of the irregularity, with trial 276 being the irregularity in comparison to the mean RT in that condition.

Figure 9: The RTs of the predictable+ condition around the time of the irregularity, with trial 127 being the irregularity in comparison to the mean RT in that condition.

Figure 10: The RTs of the predictable+ condition around the time of the irregularity, with trial 65 being the irregularity in comparison to the mean RT in that condition.

Figure 11: The RTs of the predictable+ condition around the time of the irregularity, with trial 318 being the irregularity in comparison to the mean RT in that condition.

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