Saccade landing point does not affect transsaccadic integration

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Abstract

In transsaccadic integration visual information, obtained before and after an eye movement, is combined. Since saccade landing point is very variable, transsaccadic integration needs to be a robust system for it to work in facilitating visual perception. When two stimuli are present, saccade landing point usually lands somewhere intermediate of the two; a phenomenon called the global effect. However, attention does not seem to follow a similar path. Attention might be goal dependent, thereby able to withstand visual noise. To investigate the robustness of transsaccadic integration, a global effect paradigm was used; alongside a target a salient distracter was displayed. Results indicate that the presence of a distracter does not influence the sensitivity to visual information in transsaccadic integration trials. Saccade latency was also investigated; the presence of a distracter elicited a faster eye movement, as compared to eye movements in the absence of a distracter. In conclusion, transsaccadic integration seems to be a robust mechanism that is not affected by saccade landing point. Saccade latency on the other hand, is influenced by the prominence of a stimulus.

Introduction

When we move our eyes, we have the impression that the world is stable between fixations. In order to maintain this optimal visual acuity of the constantly changing world around us, eye movements need to be made to keep the focal point on the retina; these movements are called saccades (Collewijn & Tamminga, 1984). The visual information obtained before and after a saccade is processed and enhanced; this is called transsaccadic integration. In transsaccadic integration two sources of visual information are merged together over a saccadic eye movement, resulting in a steady representation of the stimulus. Before humans direct their gaze towards a stimulus, low-resolution peripheral information is already obtained. This information is then combined with high-resolution information from the fovea after the gaze is directed towards the stimulus (Ernst & Banks, 2002; Wolf & Schütz, 2015). Recent studies have proposed that transsaccadic integration might be responsible for the optimal visual acuity across saccades. However, to facilitate visual perception across the many saccades that are made in daily life, transsaccadic integration is required to be robust against regularly occurring motor variance. Currently, it is still unclear if and how motor variance could affect transsaccadic integration.

In a recent behavioral study, using human subjects, transsaccadic integration was investigated using orientation information. Subjects were asked to determine the line orientation in a grated stimulus. When this stimulus was presented both pre- and post-saccadic, the subjects' performance improved compared to a single sighting of the stimulus (Ganmor, Landy & Simoncelli, 2015). These findings suggest that humans integrate visual information across saccades; namely when no eye movement was registered neither was visual integration (Ganmor et al., 2015).

Though transsaccadic integration is a naturally occurring phenomenon, it is not a flawless mechanism. When we redirect our gaze towards a new location the landing point is very variable (Collins, Rolfs, Deubel & Cavanagh, 2009). It has been shown that a redirection of gaze towards two stimuli in the periphery usually lands somewhere intermediate of the stimuli; a phenomenon called the global effect (Findlay, 1982). The landing point of the saccade is dependent on the nearness and prominence of both stimuli (Findlay, 1982; Van der Stigchel & Nijboer, 2011).

In a recent study the effect of attention in transsaccadic integration was investigated. In order to influence the saccade landing point a global effect paradigm was used. A target could be accompanied by a salient distracter, resulting in an overshoot of the saccade made towards the target. The landing point was usually located between the target and the distracter; as shown in the study by Findlay (1982). In addition attentional shift was measured. However, this did not follow the same path as the saccade. In distracter present trials attention was mainly located on either the target or the distracter and not on the intermediate area. This suggest that the attentional shift is not dependant on the saccadic eye movement, but benefits from the ongoing oculomotor process (Van der Stigchel, & De Vries, 2015). The findings in this study are in agreeance with the selection hypothesis that suggests that in distracter present trials both the target and the distracter are possible goals for the saccadic eye movement. Because both area's are of interest the attentional shift will most likely land on one of these points and not on the intermediate area between the two stimuli. Seemingly two processes are at work in visual processing, one stimulus dependent and the other goal dependent (van Zoest, Donk & Theeuwes, 2004).

In the current study we will build on the work of Ganmor and his colleagues (2015) by further examining the effect of saccade landing point on transsaccadic integration using a global effect paradigm. As in the previous study, stimuli will be presented pre-saccadic, post-saccadic or both pre –and post-saccadic, thereby investigating if visual integration takes place. To investigate the influence of landing point a global effect paradigm will be used; adding a distracter stimulus next to the target. Since recent studies show that the global effect is a normal occurrence in daily life and represents the flexibility of the visual system, it is expected that a variance in landing point will not affect transsaccadic integration.

Methods

Participants

In this study twelve healthy participants (four male, eight female) with normal or corrected-to-normal vision, with ages ranging from eighteen to twenty-six years old (M = 22.17, SD = 3.21), were tested. The experiment was carried out at Utrecht University, where students had the opportunity to participate. All twelve subjects were tested for a two hour period and signed an informed consent beforehand. The study has been approved by the faculty ethics committee (FETC).

Stimuli

<u>Stimuli:</u> The stimulus used in this experiment was a Gabor plaid stimulus with different line orientations. Both the horizontal and the vertical grating had a spatial frequency of 2 c/° overlaid by a Gaussian window with a standard deviation of 0.4° of visual angle. The contrast of the overall stimulus remained 0.4 throughout the experiment, but was variable between the horizontal and the vertical grating. A possible presentation may be a horizontal contrast of 0.3 with a vertical contrast of 0.1. The lines of the horizontal grating remained fixed at the same angle for the duration of the experiment. The lines of the vertical grating however were presented clockwise or counterclockwise from the vertical position. The possible orientations were [8, 4, 2, 1, 0.5] degrees clockwise or counterclockwise from the vertical position [0°]. The participants task was to determine if the vertical grating was orientated clockwise or counterclockwise. To serve as a mask in the experiment a grey stimulus without any grating was used. This stimulus was a Gaussian blob; it had the same size and contrast as the Gabor plaid stimulus, but without any kind of grating.
<u>Trials:</u> Every trial began with a grey background, with a fixation point in the middle. After this fixation point disappeared a stimulus was presented (15° Euclidian distance from fixation). The stimulus could appear on eight different locations on the screen, four on either side. Beforehand a drift check was performed. After this check the fixation point would vanish and the target was presented on one of the eight positions, eliciting a redirection of gaze. The pre-saccadic target remained on the screen for the same duration as it took the participant to direct their gaze from the fixation point to the pre-saccadic target (this duration was between 50ms and 500ms). Then the post-saccadic target appeared on the same location

for the same duration as the pre-saccadic target was presented. The response, namely clockwise or counterclockwise orientation, was registered by a key press on the ‘up’ or ‘down’ arrow key on the keyboard.

<u>Conditions:</u> Three different conditions were randomly distributed over the total of 864 trials. The first condition was the ‘post-saccadic’ condition; the Gabor target was presented after the saccadic eye movement was made towards a patch without any grating (the Gaussian blob), presented at the same contrast as the target. In the ‘pre-saccadic’ condition this was the other way around; the Gabor target was presented before the eye movement and the grey patch appeared after the saccade was made. In the last condition, the ‘pre –and post saccadic’ condition, named ‘both’ condition, the Gabor target was presented both before and after the saccade. Over these three conditions, there were ‘distracter present’ and ‘distracter not present’ trials; this will be elaborated on later. See figure 1.

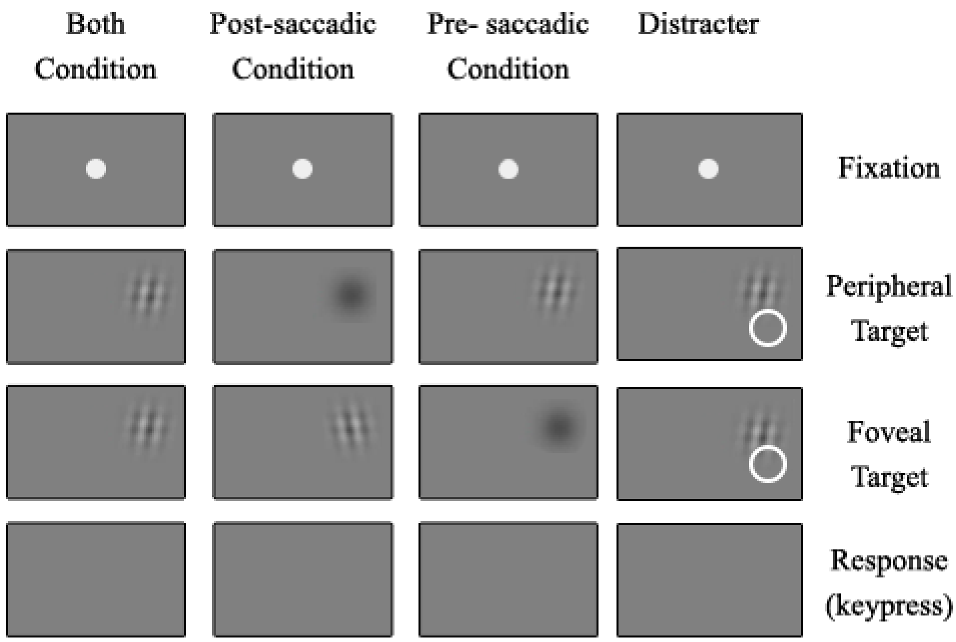

Figure 1. Representation of the procession of trials in the three different conditions; both, post-saccadic and pre-saccadic condition.

Task: The task started with 100 balancing trials. In these trials a QUEST staircase method was applied to determine the contrast targets needed to be for the participant to successfully discriminate the orientation in 75% of the cases. This strength in contrast was measured for the location for foveal input as well as for peripheral information (This distinction was made because pre-saccadic targets were presented in the periphery and post-saccadic targets were presented in the foveal area). When participants obtained a correct score of 75% the corresponding contrast was determined and used in the rest of the experiment. Before applying the staircase method a number of practice balancing trials were conducted, for participants to become familiar with the task.

The rest of the experiment consisted of twelve blocks containing seventy-two trials over which the three conditions as described above were randomly distributed . Another factor was taken into account; the presence of a distracter. Each trial was either a ‘distracter not present’ trial or a ‘distracter present’ trial. In the ‘distracter not present’ condition, trials were administered as described above. In the ‘distracter present’ trials a distracter stimulus (a white ring) was presented alongside the actual target. The presentation of the target and the distracter altered the gaze and made it land somewhere intermediate of the target and the distracter. Distracter present and distracter not present trials were administered equally over the experiment. A series of practice trials preceded the twelve blocks and after every block the participant had the opportunity to take a short break.

Apparatus:

Eye movements were recorded with an Eyelink 1000 (SR Research Ltd., Canada), positioned at 65 cm in front of the participant. The right eye was recorded at 1000 Hz. Participants kept their heads supported in a desk-mounted chin-rest during the experiment with their eyes at 70 centimeter from the monitor, which had a refresh rate of 100 Hz. The software used in the experiment was programmed in Python 2.7 using the PyGaze toolbox (Dalmaijer, Mathôt & Van der Stigchel, 2014).

Procedure

At the beginning of the appointment the participant was asked to sign the informed consent form, thereby agreeing to partake in the experiment. The instructions were given, explaining the task of determining the orientation of the detected target and responding accordingly by pressing one of the assigned keys on the keyboard. After the instructions the participant was asked to set their chair and the chin rest (with a distance of 70 cm from the computer) in a comfortable position. When everything was set and the eye tracker was fixed on the participant’s right eye the calibration took place; participants were asked to follow the dots presented on the screen. Hereafter a short validation was performed and if everything was in order the participant could start on the experiment. They began with practice balancing trials, followed by the actual balancing trials. If their contrast values were within the limits of this experiment, they were permitted to start on the experiment. During the experiment, which took approximately an hour to finish, participants could take breaks after every block. During the experiment the eye-movements were checked online by the participant leaving a 2 degree region of interest around fixation and offline with the native Eyelink saccade detection algorithm. After finishing the whole experiment the participants was given a compensation for their effort. The participant were aware of receiving a compensation and the extent of the experiment beforehand.

Analyses

Data from all twelve participants was collected and analyzed. If the saccade landed farther than two degrees from the stimulus or distracter this trial was excluded. Furthermore, trials with a saccade latency shorter than 50 ms and greater than 500 ms were excluded from the analyses. It is impossible to make an eye movement in less than 50 ms, therefore these trials were not taken into account. Trials with a saccade latency greater than 500 ms were also excluded, these were most likely missed targets or due to a fault in the eye tracker.

When analyzing the remainder of the data, one participant was excluded from the data. This participant’s performance was equal to chance, most likely the task in the experiment was not understood.

Thereafter, the responses regarding the orientation of the Gabor plaid targets were analyzed using a Gaussian cumulative distribution function. The point of subjective equality was determined in order to register the correct and incorrect responses to the line orientation. With this information the standard deviation was estimated, which gave the sensitivity for the line orientation.

In order to investigate if the type of presentation and the presence of a distracter influenced sensitivity, a 2x3 Repeated Measures ANOVA was preformed. With a Levene's test the homogeneity of variance was tested. The dependent variable in this test was sensitivity. There were two independent variables with multiple levels; distracters and stimulus presentation. Distracters had two levels, namely distracter present and distracter not present. There were three levels in stimulus presentation; the pre-saccadic, the post-saccadic and the both condition, as described above.

A Paired Samples T Test was performed in order to investigate the effect of the presence of a distracter on transsaccadic integration alone. Sensitivity values from the two both conditions, with and without a distracter, were compared.

Lastly, a 2x3 Repeated Measures ANOVA was performed in order to investigate the influence of stimulus presentation and the presence of a distracter on saccade latency. The same variables where used as for the analysis on sensitivity and again a Levene's test was performed to investigate the homogeneity of variance.

Results

Sensitivity

In the current study pre-saccadic, post-saccadic and both pre-and post-saccadic stimuli were examined. Participant's sensitivity towards the different stimulus presentations was tested, using an orientation discrimination task. In order to investigate if transsaccadic integration took place, the three conditions were compared. It was expected that the pre-saccadic condition and post-saccadic condition would differ from the both condition. As well as stimulus presentation, the presence of a distracter was taken into account. The presence of a distracter should not influence sensitivity, since transsaccadic integration is thought to be a robust mechanism.

In order to investigate the effect of stimulus presentation and the presence of a distracter on sensitivity, a 2x3 Repeated Measures ANOVA was preformed. Mauchly's test for the assumption of sphericity showed that it was neither violated for the main effect Stimulus Presentation, nor for the interaction effect. Since Distracter had only two levels, sphericity could not be violated.

There was no significant effect for Stimulus Presentation. The pre-saccadic condition (M = 0.83, SD = 0.11), post-saccadic condition (M = 0.97, SD = 0.18) and the both condition (M = 1.04, SD = 0.08) did not differ significantly from one another, $F(2,20) = 0.85$, $p = .44$. These results indicate that participants performed similar over all three stimulus presentation conditions. This is in contradicting to what was expected. The descriptive statistics are shown in table 1 below.

Table 1

Descriptive statistics for the 2x3 Repeated Measures ANOVA for the three stimulus presentation conditions on sensitivity.

Condition	**N**	**M**	**SD**
Pre-Saccadic	11	0.83	0.11
Post-Saccadic	11	0.97	0.18
Both	11	1.04	0.08

There was a significant effect for Distracter; participants performed better on the distracter not present condition (M = 1.14, SD 0.11), as compared to the distracter present condition (M = 0.76, SD = 0.07), $F(1,10) = 32.72$, $p < .001$. These results indicate that participants were more accurate in the orientation discrimination task when no distracter was present than when a distracter was present; this is not in agreeance with our hypothesis. The descriptive statistics are shown in table 2 below.

Table 2

Descriptive statistics for the 2x3 Repeated Measures ANOVA for the two distracter conditions on sensitivity.

Condition	**N**	**M**	**SD**
Distracter Not Present	11	1.14	0.11
Distracter Present	11	0.76	0.07

Because an effect was found for the presence of a distracter in the previous analyses, another test was performed in order to correct for any influence from the other conditions. Sensitivity was examined, using a line orientation task with targets containing a pre-saccadic presentation, as well as a post-saccadic presentation (the both condition). We tested if the presence of a salient distracter alongside the target would influence the sensitivity towards the discrimination task. Since transsaccadic integration is thought to be a robust mechanism, it was expected that the presence of a distracter would not influence sensitivity.

A Paired Samples T Test was performed in order to investigate the influence of the presence of a distracter on sensitivity. There was no significant difference between the distracter present condition (M = 0.91, SD = 0.28), and the distracter not present condition (M = 1.18, SD = 0.56), $t(10) = 1.25$, $p = .241$, $d = 0.386$ .These results indicate that the presence of a distracter does not influence sensitivity in the condition with a pre- and post-saccadic presentation of the target. This is in agreeance with what was expected.

Saccade Latency

In the experiment stimuli were shown in three different presentation conditions; pre-saccadic, post saccadic or both pre-and post-saccadic. The first stimulus was shown in the periphery, thereby eliciting an eye movement. The peripheral stimulus in the pre-saccadic and both condition was a Gabor plaid. However, in the post-saccadic condition this was a Gaussian blob. Since these stimuli differed, it was expected that the conditions with a Gabor plaid and a Gaussian blob would elicit a different eye movement, in respect to saccade latency. Furthermore, in half of the trials a distracter was present. Since this distracter was a prominent stimulus, it was expected that this would influence saccade latency; namely that a more prominent stimulus would elicit a faster eye movement.

In order to investigate the effect of stimulus presentation and the presence of a distracter on saccade latency, a 2x3 Repeated Measures ANOVA was preformed. Mauchly's test for the assumption of sphericity showed that it was neither violated for the main effect Stimulus Presentation, nor for the interaction effect. Since Distracter had only two levels, sphericity could not be violated.

There was no significant effect for Stimulus Presentation. The pre-saccadic condition (M = 155 ms, SD = 5 ms), post-saccadic condition (M = 155 ms, SD = 6 ms) and the both condition (M = 155 ms, SD = 6 ms) did not differ significantly from one another, $F(2,20) = 0.16$, $p = .857$. These results indicate that participants made eye movements similar in latency in all three stimulus presentation conditions. This is in contradicting to what was expected. The descriptive statistics are shown in table 3 below.

Table 3

Descriptive statistics for the 2x3 Repeated Measures ANOVA for the three stimulus presentation conditions on saccade latency, displayed in milliseconds.

Condition	**N**	**M**	**SD**
Pre-Saccadic	11	155.14	5.29
Post-Saccadic	11	155.50	6.19
Both	11	154.52	5.60

There was a significant effect for Distracter; participants were faster in the distracter present condition (M = 152 ms, SD 6 ms), as compared to the distracter not present condition (M = 158 ms, SD = 5 ms), $F(1,10) = 17.39$, $p = .002$. These results indicate that participants made faster saccades when a distracter was present than when there was no distracter present; this is in agreeance with our hypothesis. The descriptive statistics are shown in table 4 below.

Table 4

Descriptive statistics for the 2x3 Repeated Measures ANOVA for the two distracter conditions on saccade latency, displayed in milliseconds.

Condition	**N**	**M**	**SD**
Distracter Not Present	11	158.36	5.00
Distracter Present	11	151.74	6.27

Discussion

To obtain a, subjectively, stable visual representation of the world around us, a neurological mechanism is used to combine separate pieces of information to a whole; transsaccadic integration (Ernst et al., 2002). The recent study further examined this mechanism and it's possible limitations. To investigate the robustness of transsaccadic integration, a global effect paradigm was used; alongside a target a salient distracter was displayed. For visual information to be correctly obtained, transsaccadic integration needs to be a robust system. It was therefore thought that transsaccadic integration would not be affected by saccade landing point.

In the current study the presence of transsaccadic integration was not confirmed. Though transsaccadic integration has been studied over many years, results are not consisted (Wolf et al., 2015). A number of studies found little to no sign of visual integration between two fixation points over a saccade (Bridgeman, Hendry & Stark, 1975; Irwin, Zacks, & Brown, 1990; Rayner & Pollatsek, 1983). The absence of transsaccadic integration is usually explained by an inability to preserve peripheral, pre-saccadic, information across a saccade (Bridgeman et al., 1975). Other research has purposed that visual stability may not be due to transsaccadic integration, but due to memory (Irwin et al., 1990). A last factor that should be taken into account in the current study, is the presence of a distracter. Since the distracter was very prominent, this might have influenced the performance over the whole orientation discrimination task. A very prominent stimulus, in this case the distracter, could have distracted participants from the actual target (Findlay, 1982; Van der Stigchel et al., 2011). This is in agreeance with the results that indicate that the presence of a distracter seemed to negatively influence participant's performance on the orientation discrimination task. However, these results could have been effected by other factors; namely the effect of a distracter on other stimulus presentation conditions. When further investigating the effect of the presence of a distracter on the pre-and post-saccadic stimuli (both condition) alone, the analyses showed no difference in the performance. These results indicate that transsaccadic integration can withstand some visual noise and is not influenced by saccade landing point.

Since saccade landing points are very variable in day to the day life, it was thought that another mechanism might be in place to correct for this. The findings in the current research are in agreeance with previous studies, showing that saccadic eye movements and attention might be two different mechanism working alongside. Whilst the saccade landing point might land in an intermediate area of two stimuli, this is not the same for attention. It is thought that attention is goal dependent, therefore is will land on an area of interest, in this case the target (Van der Stigchel et al., 2015; van Zoest et al., 2004). In the current study this was shown when sensitivity to visual information remained similar when adding a distracter stimulus next to the actual target.

When investigating the effect of stimulus presentation on saccade latency, it was found that the three stimulus presentation conditions elicited a similarly fast eye movement. These results indicate that participants made equal latency eye movements and therefore were not affected by the difference in presentation of the post-saccadic condition, as compared to the pre- saccadic and both condition. The pre-saccadic and both condition showed a Gabor plaid as peripheral stimulus, whilst the post-saccadic condition used a Gaussian blob as initial stimulus to elicit the eye movement. The fact that the blob and the Gabor plaid elicited a similar saccade latency could be due to the equality in contrast of the stimuli, presented on the same background. Since the contrast, as well as size, of the stimuli was equal they most likely did not differ in prominence. This similarity in prominence could explain why equally fast eye movements were made towards different stimulus presentations (Findlay, 1982; Van der Stigchel et al., 2011).

However, an effect was found for the presence of a distracter. Namely, when a distracter was present, the saccade latency was shorter than when no distracter was present. This may have to do with the prominence of the stimuli; the distracter was a white ring on a grey screen. This could be very noticeable, thereby attracting attention and eliciting a faster eye movement (Findlay, 1982; Van der Stigchel et al., 2011).

In conclusion, the current study showed that transsaccadic integration is a robust mechanism that can withstand some visual noise. It supports the theory that states that landing point, which can be variable, and attention might be to different mechanism working alongside. Thus, landing point does not affect transsaccadic integration. Furthermore, results indicate that saccade latency is influenced by the prominence of a stimulus. When a stimulus is very noticeable, this elicits a faster eye movement.

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