Influence of bottom-up and top-down processing on eye movement parameters in horizontal scanning tasks

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Abstract

Horizontal gaze transfer in scanning tasks depends on cognitive and reflexive components of processing. Response to onset of peripheral stimulus is mostly reflexive. If stimulus consists of equally big stable dots arranged in horizontal lines, the importance of reflexive component in gaze transfer diminishes. Cognitive component can be increased by adding linguistic content to the stimulus and making the task similar to the scanning in reading.

Participants

Six graduate students (one male and five female participants), age 21-26 (average 23.8 years), from the department of Optometry and Vision Science, University of Latvia. All subjects had normal or near-normal vision. Participants were not informed about the aim and hypothesis of the research.

Design and stimuli

Seven tasks of horizontal scanning were designed (henceforth: N1-N7), Fig. 1. The general task was to execute horizontal gaze shifting (a) from dot to dot (in second and third set of stimuli flashing dots were used), (b) to read an artificially constructed text.
The instructions according to the research design and stimuli sets were as follows:
N1: to execute gaze shifting between two horizontally distributed dots.
N2: to execute gaze shifting between two horizontally distributed dots, whereby the right dot flashes and disappears after every 350 ms.

N3: to execute the scanning of horizontally distributed row of dots. Every next dot appears after 350 ms.
N4: to scan horizontal row of dots where all dots are visible. The speed of gaze shifting is freely chosen.
N5: to scan six horizontal rows of dots; each row has to be scanned sequentially as in stimuli set N4.
N6: to read a given text.
N7: to scan six horizontal rows of symbols sequentially as in stimuli set N4.

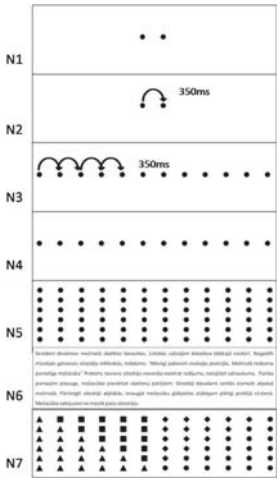

Fig. 1. Stimuli sets.

Distance from participants face to stimuli in experimental setting was 60 cm and distance between the beginnings of dots, figures, letters - 1.9^0. Text was constructed in the way that horizontal distance between the beginnings of words is approximately 1.9^0 (average length of a word was measured as 6-8 symbols). Vertical distance between dots and symbols corresponded to the vertical distance between the text rows. Stimuli were presented on a LCD (1280 x 1024 pixels) screen.
Eye movements were recorded with a video-oculograph *iViewH Hi-Speed 250 Hz*. Data analysis was conducted with the program *BeGaze*. Furthes statistical analysis was conducted with MS Excel and IBM SPSS software. The threshold level of saccadic speed was stated 35^0/s because according to previous research results (Lacis, Laicane, &Skilters, 2012) threshold level $25\text{-}35^0$/s was acceptable for the most of participants.

Results

Tasks N2 and N3 have been constructed to verify how "classical" stimuli of saccades (a gaze transfer follows flashing dots) are modifying gaze transfer parameters during horizontal scanning when stimuli are stabile in time. To check up how an external factors and experimental bias are influencing experimental results repeated studies are realized after 2 months.
In general there are almost no significant differences in mean measures of saccadic amplitudes of different tasks (Table 1.), but there are some interesting observations in the distribution of fixation times (Table 2.).

Table 1. Average saccade amplitudes (degrees) in horizontal scanning tasks. Results for the group of participants are shown for both: the first and the repeated experiment.

	Participant						Mean, repeated, degree	Mean, first, degree
	1.	2.	3.	4.	5.	6.		
N1	1.8	2.3	1.8	2.3	1.9	2.3	2.1±0.1	2.0±0.1
N2	1.8	1.9	1.7	1.8	1.8	2.1	1.9±0.1	1.8±0.1
N3	1.8	1.1	2.1	1.8	2.2	1.5	1.8±0.2	1.7±0.1
N4	1.1	1.1	2.0	2.2	1.9	1.6	1.7±0.2	
N5	1.2	1.3	2.5	2.2	1.6	1.7	1.7±0.2	1.7±0.2
N6	1.8	1.5	3.1	2.0	1.5	1.9	2.0±0.2	1.9±0.1
N7	1.1	1.1	1.9	2.0	1.8	1.5	1.6±0.2	1.6±0.2

Table 2. Average fixation times (ms). Results for the group of participants are shovn for both: the first and the repeated experiment.

	Participant						Mean, repeated, ms	Mean, first, ms
	1.	2.	3.	4.	5.	6.		
N1	933	615	557	359	759	471	616±84	672±103
N2	317	353	290	443	402	268	346±28	359±19
N3	310	255	436	389	414	290	349±30	311±24
N4	303	260	283	259	363	303	295±16	
N5	368	260	275	225	427	313	311±31	322±31
N6	214	292	257	231	371	210	262±25	274±31

We consider processing time as the most important aspect. The longest processing time is in case (N1) - two symmetricall dots without additional configurational effect -672±103ms). The shortest processing time 274±31ms is in case of scanning a meaningful text (N6).

In using two-factor *ANOVA* we can observe minor differences between processing different stimuli sets that are lacking in individual analysis. There are statistically significant differences between scanning two symmetrical dots (N1) and dots flashing with a 350 ms interval (N2) – average fixation time 346±28ms in the initial experiment; also there is a statistically significant difference between scanning dots (N1) and reading a text (N6). However, there are no statistically significant differences between processing stimuli (fixation times) in sets N4 and N5 (according to two-factor *ANOVA* without replication).
Although there are differences in fixation times between initial and repeated experiments (after 2 months), they are not statistically significant according to *Mann-Whitney U* test (Table 3).There are casual exceptions in 3 from 6 participants; or in 4 from 24 experiments. Interesting is the fact, that for all of the participants reading (N6) has no differences in fixation times between initial and repeated experiment.

Table 4. Results of *Mann-Whitney U* test for fixation time in first and repeated experiment.

Set number	Values of Z and p	Participant					
		1.	2.	3.	4.	5.	6.
N3	Z	-1,859	-0,192	-1,837	-1,324	-0,638	-3,722
	p	0,063	0,848	0,066	0,185	0,524	<0,01
N5	Z	-0,284	-1,026	-2,145	-2,649	-1,147	-1,325
	p	0,776	0,305	0,032	0,008	0,251	0,185
N6	Z	-0,101	-0,675	-1,264	-0,904	1,066	-0,570
	p	0,919	0,500	0,206	0,366	0,286	0,954
N7	Z	-1,188	-0,993	-0,442	-2,741	-1,920	-0,272
	p	0,235	0,320	0,658	0,006	0,055	0,785

Table 5. Results of *Mann-Whitney U* test for saccades in first and repeated experiment.

Set number	Values of Z and p	Participant					
		1.	2.	3.	4.	5.	6.
N3	Z	-1.859	-0.192	-0.019	-2.273	-2.257	-2.882
	p	0.063	0.848	0.985	0.023	0.024	0.004
N5	Z	-0.284	-1.026	-2.533	-2.512	-0.246	-0.844
	p	0.776	0.305	0.011	0.120	0.805	0.399
N6	Z	-0.101	-0.675	-2.999	-1.922	-0.856	0.259
	p	0.919	0.500	0.003	0.055	0.392	0.796
N7	Z	-1.188	-0.993	-0.083	-0.046	-0.215	-2.159
	p	0.235	0.320	0.933	0.964	0.830	0.031

There are more differences in saccadic amplitudes between the initial and repeated experiment than fixations (red marks in Tables 3 and 4). There are, however, almost no other patterns in data as the high individual differences (e.g., participant 2 has no differences between the initial and the repeated experiments whereby participant 3 has significant differences between both experiments in majority of stimuli sets.)
Due to the fact that during instructing participants all stimuli sets were presented it might be the case that some initial perceptual learning has already taken place.
An interesting observation can be seen, if we compare the average saccade amplitude of every participant with the average amplitude of the group (Fig.2.). In scanning tasks the participants have individual tendency to make on average shorter or longer saccades, or saccades that are about the same as the average result in the group (the difference rarely exceeds 0.4 degrees). The same individual tendency is observed in both: the first and the repeated experiments.
The large individual differences in fixation times also can be observed in comparison of average fixation time of every participant with the average fixation time of the group (Fig.3.).

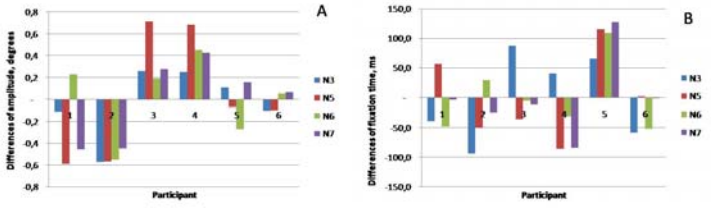

Fig.3. Differences between the average value of every participant and the mean result of the group. A-saccadic amplitudes, first experiment; B- fixation time, repeated experiment.

Discussion

There are almost no configurational effects in terms of increasing configurational complexity in fixations and saccadic amplitudes but there are some robust differences between scanning two dots without any configuration (N1) and dots in rows or columns , and text. Scanning meaningful text (N6) is stable and fast. Important that repeated experiment indicates no statistical differences in fixation times between the initial and repeated experiment in case of reading meaningful text (N6) (also in measuring saccadic amplitudes there is only one single difference between initial and repeated experiment in case of a single participant). This indicates that the gaze shifting is especially stable in case of a meaningful text. Granting that formal programming time of saccade to next, 1.9^0 spatially distant object to the right should not depend of task (N1-N7), observed differences in fixation times we can relate to decision making component in total fixation time.

Conclusion

Gaze shifting parameters in horizontal scanning tasks contain high dispersion of data of individuals. However there are no statistically significant differences in mean values of group parameters in first and repeated experiment.
There are crucial differences between scanning dots and letters of a meaningful text. In the latter case the anticipatory processes guide saccadic processing and thus decrease fixation times. Especially in case of reading meaningful text (N6) but also in other stimuli sets top-down effects are important.

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