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An Attempt to Speed-up the Examination of Saccadic Reaction Time

DAGMARA WITKOWSKA*, JAN OBER

Laboratory for Oculomotor Research, Department for Biophysical Measurements and Imaging, Nałęcz Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Sciences, Warsaw, Poland

One of possible ways to speed-up the prosaccadic latency examination is applying the target walk paradigm. The authors describe the physiological phenomena involved in carrying such paradigms, which may affect latency time and which should be balanced in this kind of task. Thirteen subjects were examined applying the newly designed target-walk paradigm and for comparison the standard prosaccade task. A significant reduction of the saccadic latency ($p < 0.01$) was found on average by 21 ms, which probably resulted from an increased saccadic decision urgency forced by the new test design. Another reason can be different ways of capturing of the subject's attention achieved in this task.

K e y w o r d s: saccadic latency, standard prosaccade task, inhibition of saccadic return, directional asymmetry

1. Introduction

Every second our eyes make in average three saccadic movements. These are closely linked with attention processes, working memory, long-term memory, learning and decision making [1]. Studying different aspects of saccades control not only widens our knowledge about the underlying cognitive processes [1], but has proved to be useful in diagnosing some neurodegenerative diseases [1–3]. The fact that neither the observer nor the person being examined can influence dynamics of the saccadic responses, provides objectivity of the saccadic examination. Due to increasing interest of applying saccadic latency monitoring in clinical research and diagnosis, develop-

* Correspondence to: Dagmara Witkowska, Laboratory for Oculomotor Research, Department for Biophysical Measurements and Imaging, Nałęcz Institute of Biocybernetics and Biomedical Engineering, Polish Academy of Sciences, ul. Szeherezady 132, 60-195 Poznań, Poland, e-mail: dwitkowska@ibib.waw.pl
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ing a short and attention-catching examination procedure become very important. An example of its application in the field of medical diagnosis can be Huntington's disease (HD), which progression is accompanied by changes in saccadic latency distribution [3]. The increase of saccadic latency also occurs in patients with Alzheimer's disease and can be used as a reliable indicator of its progression [2]. Regular monitoring of saccadic latency can also help to define whether subject's ageing follows in the physiological course [4].

Due to natural high variability of the latency time, the reliable monitoring of its parameters requires analysis of high number of saccadic responses [5]. Programming of saccadic response involves the superior colliculus and other subcortical structures, which are responsible for target localization and saccade generation. The superior colliculus possesses its connection with the cortical area (the parietal cortex, the frontal regions) which receives impulses from V1 and other areas of the visual cortex [1]. Saccade generation is connected with processing of signals that carry information about position, luminance, size etc, and also the signals that depend on fulfilling current goals and the subject's intentions [1].

Signal conduction from the retina to the superior colliculus lasts about 40 ms. Conductions of muscles contraction command from the superior colliculus itself needs another 20 ms to reach the eye muscles [1, 6]. Meanwhile, the typical saccadic latency is around 200 ms and it changes from trial to trial. Carpenter claims that such additional delaying of the saccade is caused by the higher level response procrastination which reflects the necessity to evaluate if it is the target worth shifting the gaze to [7]. Duration of 10° saccade oscillates around 50 ms and increases with the saccade amplitude (2.2 ms per degree). During this time the vision mechanisms are suspended preventing the visual slip from being noticed. It means that the more saccades are generated, the less time remains for seeing [7]. This is an enough good reason for evaluating the potential advantage of performing each of the saccades. The system also takes into account constraints of attention resources available for reaching its current goals. Carpenter suggests the existence of an over-riding mechanism of attention directing that decides between competitive targets and prevents occurrence of the less important saccades [7]. He proposes a model of saccadic decision making (LATER- Linear Approach to Threshold with Ergodic Rate). It is associated with an increment of information available for particular responses. In the moment of target onset decision signal S starts from initial level S_0 and increases linearly with rate *"r"* until it reaches the decision threshold S_t. Reaching the threshold S_t causes the initiation of saccade to a target. The rate *"r"* varies from sample to sample about the average *"μ"* with variance *"σ^2"*. Variability of this rate exhibits characteristics of a normal distribution [6–11]. Saccadic latency, like other responses, is characterized by a skewness of distribution towards the responses with longer latencies. However, reciprocal values of saccadic latency are characterized by the normal distribution. After transformation the distribution to the cumulative and by proper axis scaling, the distribution of latency on the probability scale presented as the function of reciprocal latency takes the form of a straight line. Such diagram is called reciprobit plot [10]. Modification in parameters of LATER model (*"μ"*, S_0 and S_t) causes either parallel shifting of the reciprobit plot with constant slope or its swiveling about the intercept with infinity- time axis [7–11] (Fig. 1).

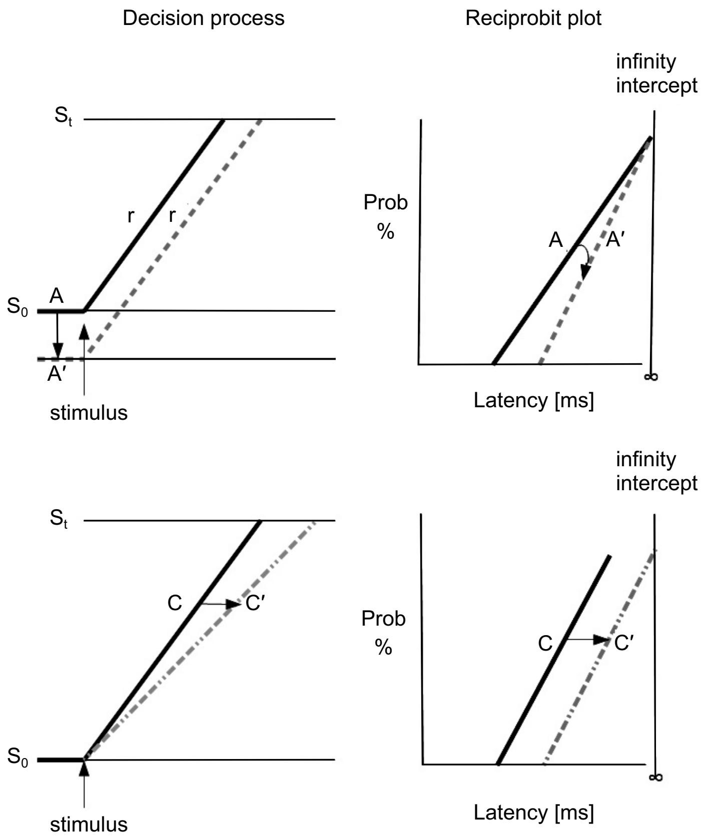


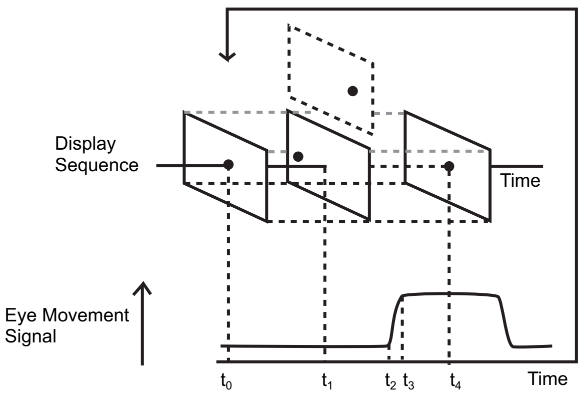
Fig. 1. Dependences between model LATER (left side) and reciprobit plot (right side). Alteration of the distance between initial level S_0 and threshold S_t (in presented example it results from lowering of initial thresholds S_0) causes swiveling of the reciprobit plot around infinity- time intercept (changes in the slope). Alterations in the mean of the rate of rise μ results as shifting of the reciprobit plot (changes in the intercept but not in the slope) *After Carpenter [7-11]*

In the second paragraph we describe the standard prosaccade latency task and discuss possibilities for its optimization. The task optimization means a reduction of time required for carrying the examination, as well as facilitating the subjects' attention to sustain on the same high level of engagement during whole duration of the experiment. The third paragraph presents several factors that should be taken into consideration when planning such optimized task. The research part of the article attempts to answer whether is it possible to speed-up the examination of the saccadic reaction time without affecting the latency distribution parameters. We compare the results of the new design task with those obtained using the standard prosaccade paradigm.

2. Standard Prosaccade Paradigm

The term "standard prosaccade paradigm" is used intentionally to point to importance of using the same experimental procedure and conditions when testing the saccadic latency in different clinical settings. The prosaccade paradigm described in this paragraph has already been used in the following studies: [12–19].

The refixation response involves the initial fixation, usually on a centrally located target, followed by the stepwise shift of the gaze toward a target appearing randomly either on the left or right side with eccentricity of ±10 degree. To prevent the predictive and anticipatory saccades, time between the onset of the initial fixation target and its lateral displacement varies randomly. The saccadic responses which are initiated within a physiologically impossible short latency or appear before the target displacement are considered predictive and anticipatory. These saccades belong to the group of the endogenously guided saccades, whose generation is based on an internal model of experimental situation that reflects the process of learning and expectations. Meanwhile, visually guided refixation saccades (prosaccades) belong to the category of exogenously guided saccades [1]. After the constant interval (for example 100 ms) from detection of the saccade landing on a new target position, the stimulus disappears and the central target is instantly displayed again (Fig. 2).



t_0 – presentation of the central fixation point
t_1 – presentation of one of two lateral targets simultaneously with central fixation point offset
t_2 – onset of saccade, lateral target continues to be displayed
t_3 – detection of saccade landing
t_4 – after 100 ms from detection of saccade landing target is replaced by central fixation point

Fig. 2. One trial of standard prosaccade task

This cycle allows to measure only one refixation response. The standard examination which requires to measure at least 100 saccadic responses lasts ca 4 minutes. Such a standard task is often perceived by the subjects as "boring". The participants often report weariness and difficulty with maintaining attention on the task. The authors consider that monotony of this paradigm may cause the redirection of subjects' attention to some internal distractions, such as health problems, causing wandering thoughts, or simply dozing off.

In a standard prosaccade task the latencies of saccades performed from the lateral target position back to the central fixation point were not evaluated for the reason of preventing from generation of the predictive and anticipatory saccades. It was supposed that the constant position of initial fixation point and the constant time of its reappearing would favor the endogenous saccades. Reduction of the examination time can be achieved by stimulating saccadic responses in such a way that all of them will contribute to the examination result. This requirement fulfills the target-walk paradigm, where the targets can appear randomly at one of several positions. When designing a new paradigm, one should take into account all phenomena which are known to influence the latency time like: the inhibition of saccadic return or the reduction of saccadic latency when the current saccade is made toward the same direction as the previous one. Obviously such influences cannot be eliminated, but by using the right proportion they can be balanced.

3. Factors Affecting Latency Time

The saccadic latency is sensitive to the external trial conditions but also depends on internal attention state of the subject (Fig. 3). Instead of concentrating on the task, the participant may focus his/her attention on personal problems, especially when he/she become tired or bored by the monotony of saccadic task. The subjects may intermittently disengage their attention from controlling the task, leading to changing of the saccadic latency and/or introducing an additional variability. Internal factors as the attention focusing are difficult to normalize by simple asking the subjects to continuously hold his/ her attention on the task. One can only attempt to design the diagnostic paradigm in such a way that it will attract and hold the subject's attention on the same high level, for at least some limited duration. It is known also that formulation of the instruction given to the subject may also affect the latency time. If we ask the participants to make the saccade as accurately as possible, but do not give due importance to the speediness of reaction time, then the saccadic latency will increase [9]. Manipulating the probability of target appearance on one of the lateral positions, causes the latency of saccades toward the more probable location to decrease [1, 20].

Some persons exhibit left/right asymmetries of the saccadic latency. In the 80's it was suggested that right-handers perform the rightward saccades significantly faster but left-handers perform the saccades without showing such asymmetry [21, 22]. Nowadays, it is accepted that handedness and oculomotor directional performance asymmetries are independent [23].

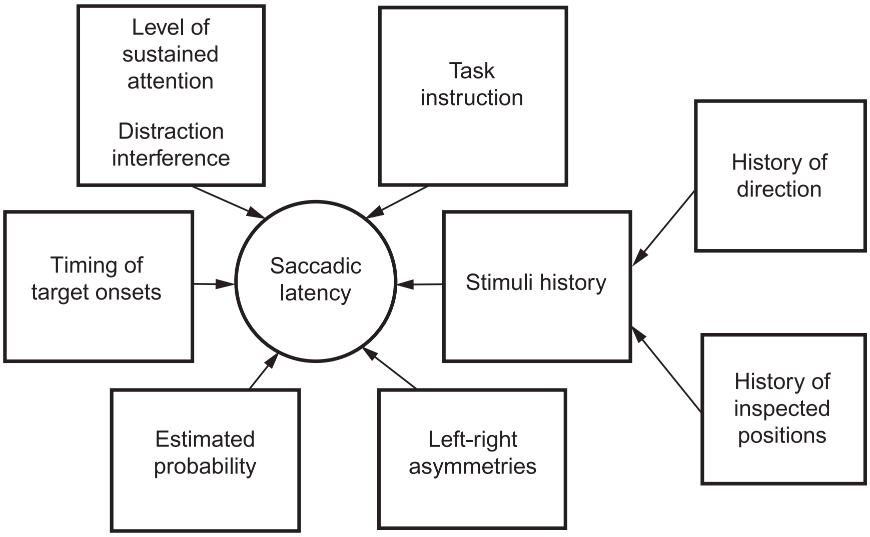


Fig. 3. Factors contributing to the latency of saccadic response

In 1995, Weber and Fischer investigated the directional asymmetries using the gap paradigm (the central fixation target disappears before the lateral target onset) [23]. They showed that subjects generate higher number of express saccades (saccades with latency about 120 ms or less) in either right or left direction. The directional asymmetry is canceled when the gap equals 0 ms or becomes longer than 400 ms [23]. In the gap paradigm, peripheral attention plays a significant role in distribution of the latency time. Disappearance of the fixation point, by itself initiates the process of attention disengagement, which results in a decrease of the saccadic latency [1]. It is likely that the process of attention releasing may affect to different extent the left and right hemisphere. The leftward and rightward saccades are independently controlled by the contralateral hemispheres. Attention disactivation, initiated at the instance of fixation point offset, increases to its maximal value along with the increase of the gap interval up to 200 ms, and above that time attention becomes completely disengaged. It would explain why such asymmetry is dependent on the duration of time interval in the gap paradigm [23].

The latency time may also depend on number of the possible target positions. Manual reaction time increases logarithmically with number of the possible stimulus alternatives [20, 24]. A lot of studies have shown that oculomotor reactions do not precisely demonstrate such dependence [20]. There is also an evidence of a saccadic latency decrease with increasing number of possible target location [24].

Also the history of target shifts may affect the saccadic reaction time. Effects based on stimulus history include the inhibition of saccadic return (ISR) and the reduction of saccadic latency in situations where the current saccade is made in the same direction as the previous one. The ISR is connected with the history of already inspected locations when the second effect is related to the history of saccade directions performed earlier. The inhibition of saccadic return (ISR) slows down the saccadic reaction on the target that appears at the same location as the previously fixated [25, 26]. Our behavioral goals are relatively static, and aiming of attention at the previously visited or attended position wouldn't enrich our knowledge. More adaptive behavior would be fixating or attending toward new locations that may provide us with new information [25, 26].

In the target-walk paradigm the target returns to the previously fixated positions can not be avoided. It is also impossible to avoid the movement of stimuli in the same as previous direction. Shortening of the latency for the subsequent saccades made in the same direction and its increasing for movements in the opposite direction is another kind of effect based on the stimulus history. It was first noticed in the random-walk paradigm [27]. In this paradigm the target appears either on the left or right of the previously fixated position and there is no return to the central fixation point. In the standard prosaccade paradigm, after each lateral target presentation, the gaze needs to return to the central fixation point and the phenomena of directional prediction are not taking place [27].

The neuronal structures responsible for the direction of gaze shifting reflect the patterns which occur in the real world. The prediction of target position can play a significant role when the target movement is partially hidden. The decisions based on the prediction can be described as a "race to the threshold" between several competitive alternatives [27]. This effect of the stimulus history may result from residual neuronal activation left behind the previous saccade [27].

4. Description of Experiment – Subjects and Method

The objective of this study was to design a new type of the balanced rapid target walk paradigm (RTW) that would allow to acquire a relatively large number of the prosaccadic responses in the shortest possible time and simultaneously providing constant level of attracting the subject's attention as well as to evaluate it by comparing its results with the data acquired with the standard prosaccade paradigm.

We studied 13 volunteers (5 persons aged 25–32 and 7 persons aged 59–76). The study was approved by the Ethics Committee of the University of Medical Sciences in Poznań. Each subject ran both the standard and the RTW paradigms. Saccadometer

Research (produced by Ober Consulting) was used to control the target displacement and to measure eye movements (Fig. 4).

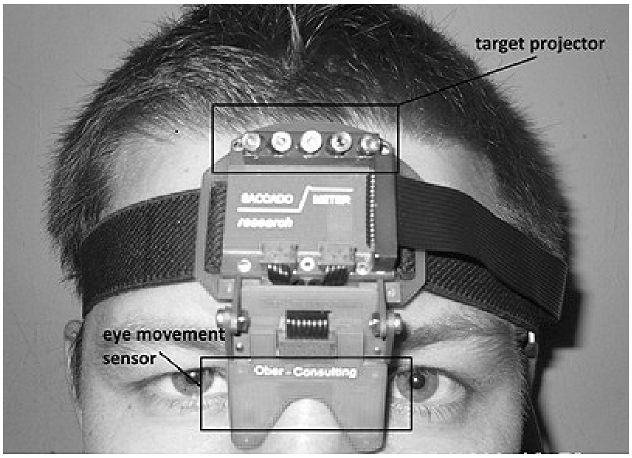


Fig. 4. Saccadometer Research, Cyklops sensor assembly frontal view. Eye movement uses direct infrared reflectometry, targets are displayed by miniature laser spot projectors

4.1. Standard Prosaccade Paradigm

The subject sat at distance 1.5 m away from a blank wall and fixated his gaze on the central fixation point. After a random interval the central fixation point disappeared and simultaneously the peripheral target appeared randomly at 10 deg to the left or right of the fixation point. The time between the onset of the initial fixation point and its lateral reappearance was varied randomly between 1100 to 2143 ms. After the detection of saccade landing, the target was allowed to stay there for only 100 ms. After that the target disappeared and the central fixation point was displayed again (Fig. 2). During the experiment 100 saccadic responses were collected and the experiment lasted around four minutes.

4.2. Rapid Target-Walk Paradigm (RTW)

Due to the previously discussed factors which affect the saccadic latency, the target movements can not be simply random. They require to be equally represented to allow their balancing. Such condition was achieved by designing the predefined target dislocation sequences which contained equal proportions of the particular factors. The experiment design comprises four sequences each containing 28 target dislocations, organized in a form of four bursts of the saccadic stimulation. The bursts were separated by three seconds pauses allowing the subjects to rest from the attention arresting task and blink to restore wetting of the eye surface. There were five possible target positions (Fig. 5) so the stimuli could shift either by 10 or 20 degree. Some of target direction changes could go without necessity of the returning to the previously attended position. Therefore designing the experiment we had to take into account three possible cases of the stimuli history: target dislocation in the same direction as the previous one, return to the previously attended position and change of the direction associated with visiting a new position. As a result the bursts of target dislocations became balanced with respect to those factors: 1/3 of all target dislocations constituted returns to their previous positions (ISR), next 1/3- target movements were made in the same direction as the previous one ("Directional Prediction") and the rest of target dislocations included shifts in the opposite direction but not to the same location as the previously attended (Other). Half of the target dislocations were performed in the right direction (Table 1). The target-walk paradigm required increased number of target positions, therefore the possible impact of the number of alternative target locations on saccadic latency could not be excluded.

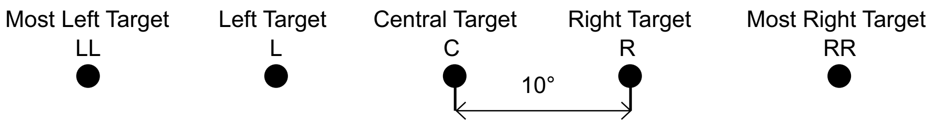
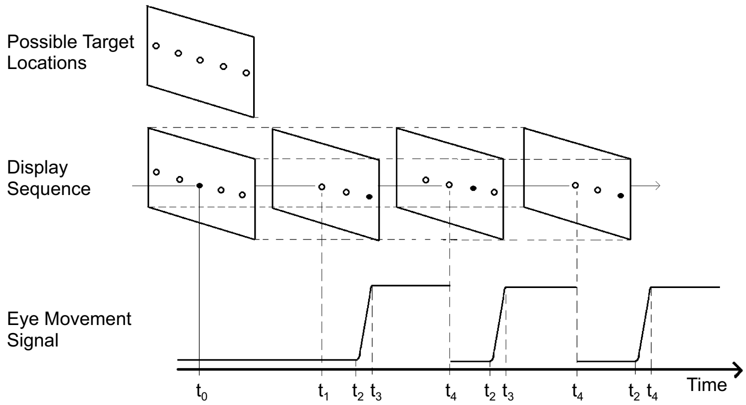


Fig. 5. Targets in the rapid target-walk tasks are equally separated by 10 degrees

Table 1. Particular sequences of the rapid target-walk task

Seq. nr	Target positions	Right direction	Directional Prediction	ISR	Other
1	C, RR, R, RR, C, LL, C, L, R, L, LL, L, C, R, C, RR, R, RR, C, L, LL, L, R, L, C, LL, C, R, C	14	8	10	9
2	C, LL, C, L, R, RR, R, RR, C, R, L, LL, L, C, RR, R, C, R, L, LL, L, C, RR, C, LL, C, L, R, C	14	9	8	10
3	C, R, C, LL, L, LL, C, L, R, RR, R, L, R, C, L, C, RR, C, LL, L, LL, C, RR, C, R, RR, R, L, C	14	9	9	9
4	C, L, C, LL, L, R, RR, R, L, R, C. RR, C, R, L, LL, C, LL, C, R, RR, R, C, RR, C, L, LL, L, C	14	10	9	8
total		56	36	36	36
%		50%	33.33%	33.33%	33.33%

According to the balance requirements there were 14 predefined target displacements from C to R, C RR, C L, C LL, L LL, L C, L R, LL L, LL C, R L, R C, R RR, RR R, RR C. In every sequence each of the listed target dislocations occurred two times. The sequences appeared in the random order and every sequence was started by displaying the centrally located target. After the detection of saccade landing on the new target position and passing the target "ON" time, the stimuli was moved to a next predefined location. The target "ON" time varied randomly between 250–370 ms and changed in 15 ms steps (Fig. 6). This paradigm allowed the measurement of 112 saccades, in most cases in around one minute and forty seconds.



t_0 – presentation of the central fixation point
t_1 – presentation of one of four lateral targets simultaneously with central fixation point offset
t_2 – onset of saccade; lateral target continues to be displayed
t_3 – detection of saccade landing
t_4 – random time (250-370 ms) after detection of saccade landing present target is replaced by another one
o – possible locations of upcoming target (symbol not displayed during the task)

Fig. 6. Schema of the rapid target-walk paradigm. There were two possible amplitude of saccades: 10 and 20°. To simplify the scheme symbol saccade was used without indicating its amplitude

5. Statistics

Error responses and blinks were removed from the analysis. The latencies shorter than 80 ms and longer than 800 ms were not analyzed and the latencies longer than 2.5 SD from the mean result were treated as outsiders and were not taken into the analysis [28]. Proportion of the removed saccades was about 3.4% of all trials greater for the rapid target-walk paradigm. Types of error responses excluded from the analysis are shown in Table 2.

The saccadic latency distributions were analyzed using the *SPIC* application [29] *(Carpenter, open access program* downloaded from http://www.cudos.ac.uk/spic.html) that processes the acquired data according to the LATER model, construct the reciprobit plot and allows the calculation of one-sample and two-sample Kolmogorov-Smirnov tests. The one-sample Kolmogorov-Smirnov test was used to determine the agreement between the observed distributions and the theoretical distributions predicted by LATER. The two-sample Kolmogorov-Smirnov test allows comparison

Table 2. Improper saccadic responses removed from the analysis (% of all gathered responses)

	RTW	STANDARD
wrong direction	2.4%	0.3%
prediction (correct and incorrect)	12.2%	4.8%
blinks	0.5%	3.0%
lack of reaction	1.0%	0.7%
too late	0.2%	0.6%
outsider	1.8%	1.8%
others	1.7%	5.2%
total	19.8%	16.4%

of the observed distributions one with the other. To calculate a line of best fit to the main part of distribution (ignoring the population of the fast response saccades) Kolmogorov- Smirnov test was used. SPIC calculated the best fit LATER parameters (*"μ"*, *"σ"*) and also the slope and the intercept with infinite-time axis of the best fit line. To determine whether a pair of distributions were characterized by the alteration of the slope (swiveling of the reciprobit plot about the intercept with infinity-time axis) or by the change of the intercept position (lateral shift of the reciprobit plot with a constant slope) both were simultaneously fitted by maximization of likelihood (performed in the SPIC application) with the alternative identical intercept or identical slope. The log likelihood ratio between hypothesis was measured [13].

Data was analyzed using appropriate statistical methods. Shapiro–Wilk test was used to determine whether the distributions depart from normality. The differences between the parametric variables were evaluated by paired-samples *T* test. In case of non-parametric ones Wilcoxon signed-rank test was performed. Dependencies between variables were measured using Pearson's correlation.

6. Results

The analysis of the population of all results revealed significant differences between the distributions of latencies obtained by using the rapid target walk (RTW) and the standard paradigms. A lack of significant differences was revealed in the case of six out of 13 subjects. There were significant differences between means ($p < 0.01$, $t = -3.553$), medians ($p < 0.01$, $Z = -3.059$) of the latencies obtained in both paradigms (standard deviations did not differ: $p = 0.726$, $Z = -0.350$). The analysis revealed significant correlation for means ($p < 0.01$, Pearson's $r = 0.727$), medians ($p < 0.05$, Pearson's $r = 0.678$) and standard deviations ($p < 0.05$, Pearson's $r = 0.644$). Results of the RTW task were characterized by the reduced mean and median latencies compared to results of the standard paradigm (Table 3).

Table 3. Mean, standard error of mean (SEM), standard deviation (SD) and median of latency time [ms] obtained in RTW and standard task. By " * " it has marked the significant differences between latency distribution for these two kinds of tasks

		THE RAPID TARGET-WALK				THE STANDARD			
Subject nr.	age	mean	SEM	SD	median	mean	SEM	SD	median
1	25	113	2	19	109	116	2	17	114
*2	26	135	3	25	137	159	3	27	156
*3	27	135	2	24	136	158	3	29	153
4	27	181	8	81	159	161	3	29	159
*5	32	145	4	33	140	194	6	60	187
6	59	168	4	39	166	172	4	34	167
7	59	178	6	54	169	188	5	50	178
*8	60	162	4	42	156	219	7	56	210
*9	61	153	5	44	148	187	4	41	181
10	62	177	6	52	165	182	4	38	168
11	71	190	7	69	187	209	8	73	189
*12	73	194	11	87	176	246	13	98	247
*13	76	170	6	55	153	194	7	59	174
average		162	5	48	154	183	5	47	176
***population of results**		160	2	56	148	181	2	58	168

To determine whether the pair of distributions (for the standard and rapid target-walk tasks) were characterized by alternation in the slope or in the intercept, we carried out a maximum-likelihood fit of both distributions at once, constrained either by an equal intercept or identical slope. The log-likelihood ratio (LLR) between hypotheses was estimated for each subject. Swivel was favoured over then shift in case of twelve subjects (significant for four of them) and only one person (subject number 5) show not significant difference in the opposite direction. The LLR for all populations of results was –30.360 ($p < 0.001$) in favor of swivel (alternation in the slope) rather than shift (alternation in the intercept). Figure 7 presents the reciprobit plots for a population of all results acquired in both paradigms.

The best fit model parameters were also analyzed. Analysis of dependent variables revealed significant differences between the standard and the RTW tasks due to the variables: "μ" ($p < 0.001$, $t = 4.773$), "σ" ($p < 0.001$, $t = 7.347$), slope ($p < 0.001$, $t = -5.947$) and intercept ($p < 0.01$, $t = -3.283$). Results of the RTW task were characterized by greater value of the mean and standard deviation of the rate of rise ("μ" and "σ"). The contrary was in the case of the slope and intercept.

7. Discussion

The rapid target-walk paradigm has allowed the reduction of the duration of the prosaccadic latency examination by more than 58%. Number of the rejected responses was higher in the RTW paradigm only by 3.4% of all trials. The new design of the target-walk task generated about 7.4% more predicted and about 2.1% wrong directed saccades than the standard paradigm. However, the standard prosaccade paradigm has encouraged the formation of blinks (about 2.5% of trials more than in the case of the RTW task) and other improper saccadic responses (inter alia too large or too small saccades). It's important to notice that the decreased duration of the refixation examination was not associated with a large increase of the number of excluded responses. Beside the shortening of examination duration the rapid target-walk task was characterized by a significant decrease of the reaction time (unfortunately, there was no reduction in standard deviation of latency). Anyhow almost half (46%) of the subjects performed without significant differences between the latency distribution for the standard and the RTW tasks.

For the analysis of the latency distribution the reciprobit plot was used (Fig. 7). The cumulative saccade latency on a reciprocal time axis for the rapid target-walk task was characterized mainly by different slope, when compared to the result of the standard prosaccade task. Interpreting the LATER model in the decision-making terms the level S_0 can represent the logarithm of the prior probability whilst *"μ"* (mean of the rate of rise) can be treated as the supply of information. The threshold S_t reflects the urgency of reaction [7, 9].

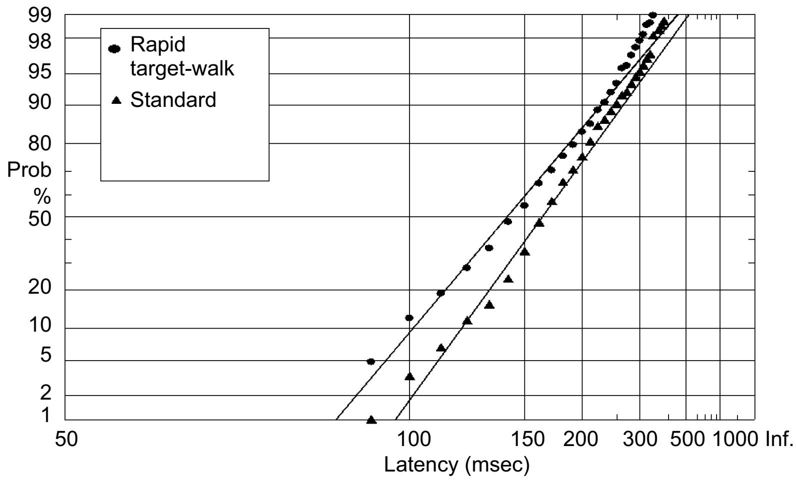


Fig. 7. Cumulative saccadic latency on a reciprocal time-axis (reciprobit plot) in RTW (circles) and standard (triangles) task. **Population of all results:** significant differences of latency distribution between both tasks

Alternation in S_t or S_0 will change the slope of the reciprobit plot without affecting the intercept position. Parameter S_t can be modified due to a different instruction given to the subjects ("react as fast as possible" or "react as accurate as possible") [7, 9]. Variation in S_0 can be caused by a different probability of the target dislocations. As a result changes of *"μ"* will alter the infinity intercept position on the reciprobit plot without affecting its slope, where the modification of *"σ"* (standard deviation of the rate of rise) will affect both the slope and the position of intercept of the reciprobit plot. The intercept may be treated as a representation of the probability of not making a saccade at all [7–11]. Analysis of the best fit LATER parameters revealed significant difference between the standard and the rapid target-walk task due to *"μ"* and *"σ"*. That suggests that swiveling of the reciprobit plot around the intercept with infinity time axis was dominated tendency but not the only reciprobit plot alteration. Regarding LATER it is suggested that fluctuations in the variation of rate *"r"* of the decision signal may be a result of changes in the attention level given to the different locations in the visual field [7]. In the case of a fast sequence of the target dislocations the previous one influences the level of attention associated with the following target displacement. According to it the alternation in the intercept and slope that is observed in the results of the rapid target-walk task, may be attributed to the effect based on the stimuli history (discussed in Paragraph 3.1). Another explanation may be that those differences may be also the result of different ways of capturing of the subject's attention achieved in the RTW as compared to the standard prosaccade task. Changes in the slope of reciprobit plot may also reflect greater urgency caused by the target dislocations rapidity.

8. Conclusion

Due to the differences observed in the latency distribution parameters that were revealed using the rapid target-walk paradigm, the question about possibility of speeding-up the examination of the saccadic reaction time without affecting the latency distribution parameters can not be clearly and definitely answered. It is possible that the initial expectation of the sustain capturing of attention, which is specific feature of the RTW paradigm, is causing the changes in the latency distribution parameters and reducing the mean latency time. Proposed paradigm is not without limitations-target dislocation from external position is characterized by predictable direction, and number of possible locations of upcoming target depends from a current target position. Perhaps alternative designs of such a paradigm will meet all requirements pointed to in the introduction (reduction of examination time and sustaining capture of the subject's attention) and give comparable results with those obtained in the standard paradigm. Searching for the ways of shortening the refixation examination duration seems very important due to the growing interest in saccadometry and its use in patient monitoring and research. It may be worth considering the reduction of latency time achieved in rapid target-walk paradigm, as its advantage, allowing the earlier detection of slowing of the brain.

References

1. Hutton S.B.: Cognitive control of saccadic eye movements. Brain Cogn. 2008, 68, 327–340.
2. Przedpelska-Ober E.: Eye movements dysfunctions in Alzheimer's disease. Neurol. Neurochir. Pol. 2006 , 1, 34–41.
3. Ali F.R., Michelle A.W., Barker R.A., Carpenter R.H.S.: The use of quantitative oculometry in the assessment of Huntington's disease. Exp. Brain Res. 2006, 2, 237–245.
4. Hotson J.R., Steinke G.W.: Vertical and horizontal saccades in aging and dementia. Neuroophthalmol. 1988, 8, 267–273.
5. Ober J, Dylak J., Grycewicz W., Przedpelska-Ober E.: Saccadometry – new possibility for monitoring brain functional status. Nauka 2009, 4, 109–135.
6. Carpenter R.H.S.: A neural mechanism that randomises behaviour. J. Consciousness Studies 1999, 6, 13–22.
7. Carpenter R.H.S.: Oculomotor procrastination. In: D.F. Fisher, R.A. Monty, J.W. Senders (Eds.), Eye Movements: Cognition and Visual Perception, Hillsdale: Lawrence Erlbaum 1981, 237–246.
8. Carpenter R.H.S., Williams M.L.L.: Neural computation of log likelihood in the control of saccadic eye movements. Nature 1995, 37, 59–62.
9. Reddi B.A.J., Carpenter R.H.S.: The influence of urgency on decision time. Nature Neuroscience. Inc. 2000, 3, 827–830.
10. Oswal A., Ogden M., Carpenter R.H.S.: The time course of stimulus expectation in a saccadic decision task. J. Neurophysiol. 2007, 97, 2722–2730.
11. Reddi B.A.J., Asrress K. N., Carpenter R.H.S.: Accuracy, Information, and Response Time in a Saccadic Decision Task. J. Neurophysiol. 2003, 90, 3538–3546.
12. Michell A.W., Xu Z., Fritz D., Lewis S.J.G., Foltynie T., Williams-Gray C.H. et al.: Saccadic latency distributions in Parkinson's disease and the effects of L-dopa. Exp. Brain Res. 2006, 169, 237–245.
13. Temel Y., Visser-Vandewalle V., Carpenter R.H.S.: Saccadometry: a novel clinical tool for quantification of the motor effects of subthalamic nucleus stimulation in Parkinson's disease. Exp. Neurol. 2009, 216, 481–489.
14. Temel Y., Visser-Vandewalle V., Carpenter R.H.S.: Saccadic latency during electrical stimulation of the human subthalamic nucleus. Current Biol. 2008, 18, R412–4.
15. Ali F.R. Michell A.W., Barker R.A., Carpenter R.H.S.: The use of quantitative oculometry in the assessment of Huntington's disease. Exp. Brain Res. 2006, 169, 237–245.
16. Antoniades C.A., Zheyu X., Mason S.L., Carpenter R.H.S., Barker R.A..: Huntington's disease: changes in saccades and hand-tapping over three years. J. Neurol. 2010, 257, 1890–1898.
17. Pearson B.C., Armitage K.R., Horner C.W.M., Carpenter R.H.S.: Saccadometry: the possible application of latency distribution measurement for monitoring concussion. Br. J. Sports Med. 2007, 41, 610–612.
18. Robert M.P., Nachev P.C., Hicks S.L., Golding C.V., Tabrizi S.J., Kennard C.: Saccadometry of Conditional Rules in Presymptomatic Huntington's Disease. Ann N Y Acad. Sci. 2009, 1164, 444–450.
19. Wilson R.: The use of the Saccadometer to assess levels of Cognitive Control in patients with Tourette Syndrome. Essay submitted for The Professor Mary Robertson Prizes 2009.
20. Klower E.: The role of visual and cognitive processes in the control of eye movement, In: Kowler E.(Eds), Eye Movements and Their Role in Visual and Cognitive Processes, Elsevier Publishing Company, New York 1990, 1–70.

21. Pirozzolo F.J., Rayner K.: Handedness, hemispheric specialization and saccadic eye movement latencies. purchase Neuropsychol. 1980, 18, 225–229.
22. Hutton J.T., Palet J.: Lateral saccadic latencies and handedness. purchase Neuropsychol. 1986, 24, 449–451.
23. Weber H., Fischer B.: Gap Duration and Location of Attention Focus Modulate The Occurence of Left/Right Asymetries in Saccadic Reaction Times of Human Subjects. Vision Res. 1995, 7, 987–998.
24. Lawrence B.M., St. John A., Abrams R.A., Synder L.H.: An anti-Hick's effect in monkey and human saccade reaction Times. J. Vis. 2008, 8(3), 26, 1–7.
25. Farrell S., Ludwig C.J.H, Ellis L.A., Gilchrist I. D.: Influence of environmental statistics on inhibition of saccadic return. Proc. Natl. Acad. Sci. U S A. 2010, 107, 929–934.
26. Ludwig .J.H, Farrell S., Ellis L.A., Gilchrist I.D.: The mechanism underlying inhibition of saccadic return. Cog. Psychol. 2009, 59, 180–202.
27. Anderson A.J., Yadav H., Carpenter R.H.S.: Directional Prediction by the Saccadic System. Current Biol. 2008, 8, 614–618.
28. Van der Stigchel S., Mills M., Dodd M.D.: Shift and deviate: Saccades reveal that shifts of covert attention evoked by trained spatial stimuli are obligatory. Atten. Percept. Psychophys. 2010, 72 (5), 1244–1250.
29. Carpenter R.H.S.: SPIC: a PC-based system for rapid measurement of saccadic responses. J. Physiol. 1994, 4P, 480.