Isachenko AV, Zhao DG, Melnichuk EV, Dubynin IA, Velichkovsky BM, Shishkin SL. The pursuing gaze beats mouse in non-po
target selection. 2018 IEEE International Conference on Systems, Man, and Cybernetics (SMC), 2018 Oct 7, pp. 3518-3523.
https://doi.org/10.1109/SMC.2018.00595

The Pursuing Gaze Beats Mouse in Non-Pop-Out Target Selection

Andrey V. Isachenko
Dept. for Neurocognitive Technology
NRC "Kurchatov Institute"
Inst. of NBCIS S&T
Moscow Institute of Physics and Technology
Moscow, Russia
andr_isachenko@mail.ru

Darisy G. Zhao
Dept. for Neurocognitive Technology
NRC "Kurchatov Institute"
Inst. of NBCIS S&T
Moscow Institute of Physics and Technology
Moscow, Russia

Eugeny V. Melnichuk
Dept. for Neurocognitive Technology
NRC "Kurchatov Institute"
Moscow, Russia

Ignat A. Dubynin
Dept. for Neurocognitive Technology
NRC "Kurchatov Institute"
Moscow, Russia

Boris M. Velichkovsky
NRC "Kurchatov Institute"
Moscow, Russia

Sergei L. Shishkin
Dept. for Neurocognitive Technology
NRC "Kurchatov Institute"
Moscow, Russia
sergshishkin@mail.ru

***Abstract*—Demonstration of faster target selection by gaze compared to computer mouse so far was limited to targets attracting attention due to their visual saliency. This task, however, can be performed much faster with modern computer vision systems. Can gaze be faster than mouse in a more "intentional" selection task: when targets and non-targets do not significantly differ by their visual features? We propose that this may be the case when targets are moving at speeds beneficial for smooth pursuit eye movements. 16 healthy participants were asked to select 20 balls numbered 1 to 20 in numerical order. Balls were moving linearly at a screen in different directions at 12°/s speed. We compared selection made using a consumer grade eye tracker and a simple smooth pursuit detection algorithm with selection made using a computer mouse, either with clicks or pursuit. Compared to both mouse selection techniques, gaze selection was significantly faster and was experienced as more convenient by all participants.**

Keywords—eye tracking, gaze interaction, intention, selection, smooth pursuit, computer mouse

I. INTRODUCTION

It is well known that eye gaze-based human-computer interaction (input based on the user's eye movements detected with an eye tracker) is faster in certain tasks than traditional computer mouse-based input [1-3]. However, specific for such demonstrations was visual saliency of the target objects. These objects could easily attract visual attention, which, in turn, drive gaze. Gaze tends to focus on salient targets even in the absence of the user's intention to interact with them. Such fast and effortless pre-decision, attention-driven gaze behavior was proposed to be used as an input to the non-command [4] human-machine interfaces [5-7].

With the development of computer vision, however, salient objects can be faster identified by the computers. While low-level functions in the future will likely be even further moved from a human to a machine, the human-machine interface should become more and more responsive to decisions and intentions of a user.

The case of *fast* translating an *intention* (in contrast to *attention*) to a machine seems to be especially difficult one for a gaze-based input system. This is exactly the case when the Midas touch problem, i.e. inability to avoid issuing false (unintended) commands, becomes most severe: an interface that is highly sensitive to user's intentions may also tend to become especially easily activated in the absence of a user's intention [8].

Measures against the Midas touch problem, such as setting a longer gaze dwell threshold or requiring confirmation of selection with additional gaze dwell or saccade, make interaction slower and/or less intuitive [7]. Moreover, while the visual feedback provided by a cursor is very effective in mouse input, an apparent gaze cursor can be distractive (e.g., [9]) (it is therefore not often used in gaze interaction). Mouse and other manual input devices have, of course, their own shortcomings, such as the need to locate their cursor (a rather distractive and therefore annoying additional visual search task) and move it to a target (a task that requires a rather complicated sensorimotor coordination!); both elements of their use contribute to time required to complete various tasks and claim additional cognitive resources. These limitations are not critical, however, as in a number of experimental studies where various types of human-computer interaction were examined gaze was not able to outperform mouse and other traditional manual input devices (e.g., [10-13]). To our knowledge, faster or more accurate selection with gaze compared to mouse has been never demonstrated for non-salient targets.

In the recent years, a new gaze interaction technique has been developed, based on smooth pursuit eye movements rather than on fixations or saccades [14-19]. It was primarily

---

This work was partially supported by the Russian Science Foundation, grant 18-19-00593 (literature analysis, general approach development and elaboration of the selection algorithms) and Russian Foundation for Basic Research, grant 17-29-07083 (study design and data analysis).

XXX-X-XXXX-XXXX-X/XX/$XX.00 ©20XX IEEE

applied for interaction using small screens (e.g., smart watches) and calibration-free interaction, but may also have other possible application areas, such as games (especially in virtual reality), control of traffic, selection of robots from a swarm or other group of moving robots (e.g., robots working at a warehouse or drones used in a rescue operation; selection can be used to get information from one of the robots or to change its behavior), etc. Some of these tasks can be effectively and efficiently performed using touchscreens; however, they have a disadvantage of occlusion of important parts of the view field with a hand, finger and/or stylus.

Pursuit eye movements enable automatic and precise gaze fixation on a moving object. As they can be relatively easily suppressed, the Midas touch problem becomes less severe for interaction based on them [18]. However, when not only the target but also multiple non-target objects are moving, these non-targets may also attract attention. It seems not impossible that, because of such effects, gaze-based selection would be slower than selection with a mouse. While impressive results were demonstrated in the above cited studies of smooth pursuit-based interaction, they were not compared with selection with mechanical input devices in the same conditions. The current study is, to our knowledge, the first one that directly compared mouse and gaze-based selection of moving targets.

We hypothesized that, at least for certain target speeds and visual conditions, intentional selection of targets which do not differ by their visual features from non-targets can be made faster and easier with a gaze-based interface than with a computer mouse. To test this hypothesis, we designed a task where multiple potential target objects are moving on a computer screen. Since it is difficult (and often impossible) to get the ground truth if the operator of an interface is making free decisions, we asked our participants to select the objects according to an instruction. However, every object was both target and non-target (in different trials) without any difference in its appearance.

II. METHODS

A. Participants

16 healthy volunteers (8 male, 8 female) aged 19–31 years (mean 24.5) participated in the study after signing an informed consent. Eight of them had prior experience with gaze interaction. In most participants, vision was either normal (in eight participants) or corrected to normal (with glasses in 3 and with contact lenses in 2 participants). Three participants did not use their glasses, claiming that they perceive well the screen view. However, one of them reported, after the experiment, that he had to use intentionally only one eye for the gaze-based selection while using the two eyes all other time (his eye tracker selection time was much slower than in the rest of the participants), and we decided to exclude his data from the analysis. Data of one more participant (who wore glasses) were excluded from analysis because of excessive deviations from the correct order of selection (see the task description below).

B. Apparatus and Software

The task was presented at a 18.5" monitor with a resolution of 1440 × 900 px and 75 Hz refresh rate. A consumer grade eye tracker Tobii Eye Tracker 4C (*Tobii*, Sweden) with 90 Hz sampling rate was attached to the lower edge of the monitor. A wireless optical mouse Defender Berkeley C-925 with standard speed was used in the mouse input conditions.

Eye tracker calibration and estimation of gaze coordinates were performed by the eye tracker software. The visual task and selection algorithms were implemented in C++ and QML with the use of Qt framework.

C. Task

The participants were presented with 20 “balls” (circles), each 80 px in diameter (2.8°), which moved linearly on the screen at 344 px/s (~12°/s) speed, changing their movement direction in a natural way when hitting each other or the screen edges. The balls were numbered 1 to 20 (Fig. 1).

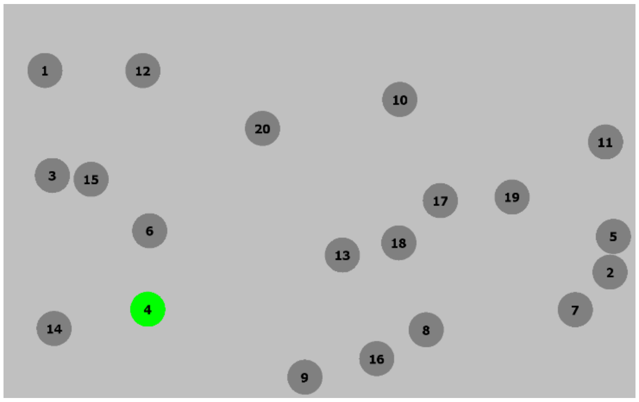

Fig. 1. A screenshot from the gaze pursuit (GP) condition. Ball #4 has been selected.

The participants were asked to select all 20 balls according to their numbers, in ascending order. There were three experiment conditions, differed by the selection method:

- **Mouse clicks (MC)** – hover the mouse cursor over the ball, approximately over its center, and make a click with the left mouse button
- **Mouse pursuit (MP)** – hover the mouse cursor over the ball, approximately over its center, and try to keep it over the ball until the ball is selected
- **Gaze pursuit (GP)** – look at the ball’s number, approximately at the ball’s center, and try to steadily pursue it with the gaze until it is selected.

In the MC and MP conditions, a mouse cursor was shown as a blue dot of 10 px (0.35°) diameter. In the GP condition, no cursor was displayed.

In the beginning of a run, all balls were dark grey. When a ball was selected, it changed its color to green. Ball color returned to dark grey when another ball was selected.

Participants were asked to select the 20 balls as soon as possible. They were told that they should try to avoid selection of wrong balls (with a number different from what was the current target), but if such selection happened, they should continue an attempt to select the ball with the number next to the previous correct selection. They were also told not to hurry with selecting the first ball in each run, to provide them with an opportunity to better customize themselves with the layout and to become more focused on the task.

D. Selection Algorithms

Parameters of the gaze and mouse selection algorithms were adjusted in pilot experiments to increase selection speed and to make the procedure more comfortable to the participants.

In the **MC condition**, a left mouse click led to the selection of the ball closest to the click position if the distance between it and the ball's center did not exceed 68 px (2.4°).

In the **MP condition**, distance from the mouse cursor to each ball was estimated in a sliding window of 867 ms length as median of the corresponding distances computed for each data sample within the window. A ball was selected if the median distance between its center and the cursor did not exceed 50 px (1.7°) and was smallest among all balls.

In the **GP condition**, the same algorithm as in the MP condition was used, again with the distance threshold of 50 px (2.4°), but some samples from the eye tracker (which worked at 90 Hz sampling rate) were discarded from time to time to approach the monitor refresh rate (75 Hz). Using an accelerometer for mouse movement and a photodiode attached to the screen for cursor movement monitoring, we found that the delay between the movements rarely exceeded 50 ms. However, for the GP condition a test based on additional simultaneous video registration of eye movements indicated that our software received the data samples from the eye tracker with approximately 140 ms delay. To improve synchronization between the gaze and ball coordinate streams, the latter was deliberately delayed by the same value. The eye tracker's built-in alignment filter was not applied.

Selection time of the median-based algorithm used in the MP and GP conditions may significantly depend on gaze or mouse cursor trajectory. We could not analyze gaze trajectory and selection time itself in the GP condition due to limitations of the eye tracker license. However, as the 50 px was quite a moderate threshold (a ball could be chosen even with a cursor or gaze kept all time outside the ball), and typically gaze and cursor were not close to the ball before the start of an attempt to select it, we expected to have distances above the threshold most time before the attempt to select and below it after the attempt started. Thus, with the median criterion selection time could be almost equal or just slightly above half of the sliding window, i.e., ~435 ms, plus the software delay (in total, about 575 ms in the GP condition). In another pilot study [20] employing the same algorithm and window length we observed, in synchronously recorded electroencephalogram (EEG), a clear positive peak in the occipital brain area about 450 ms prior to selection. The peak highly resembled the so-called lambda that is typically found about 100 ms after the onset of gaze fixations on stable objects (in case of pursuit, longer peak latency may be expected due to complexity of the visual task). This observation confirmed that selection time variability was low (otherwise this sharp peak could not be seen in averaged EEG waveforms) and, indeed, selection time value was likely about half of the sliding window.

E. Procedure

Participants were seated in a chair in front of an office table where the monitor with the eye tracker and the mouse were placed. The distance from eyes to screen was about 65 cm. No chin or forehead rest were used.

The experiment consisted of five blocks. One block consisted of three conditions. The order of conditions was same over the blocks for a given participant but counterbalanced in the group of participants. Each condition in one block included one run, typically shorter than 1.5 min but not limited in time, when a participant had to select each of 20 balls at least once (the actual number of selections could be slightly higher due to additional selections of balls with "wrong" numbers).

Before the first block, the experimenter showed the moving balls and explained the task to a participant, demonstrating ball selection with the mouse (both as in MC and MP conditions). The first block was considered as practice, and the participant was allowed to ask any questions during the tasks. The second block was not announced as practice, but only data from the third, fourth and fifth blocks were used for analysis.

7-point calibration of the eye tracker using *Tobii* routine was run before its first use in the GP condition. In the subsequent blocks, GP condition was preceded by calibration check using another *Tobii* routine, and the eye tracker was re-calibrated only if significant deterioration of calibration was found (this happened in about one of four runs in the GP conditions). A run in any condition was terminated and re-run if 6 or more wrong selections within it were made (this was the case only 5 times in total in all experiments).

To increase motivation of the participants, they were told that in every run they may make a record selecting 20 balls for a given condition comparing to other participants, and that they will be notified in this case. They also were encouraged to ask about time spent for selecting 20 balls after any run.

F. Measures

For each selection, its time and the corresponding ball number were recorded. **Selection time** was computed as the time difference between two adjacent selections, but only for the cases when both balls' number followed correct order (#1, #2, … #19, #20). Given that the last correct selection was for the ball *k*, a selection was considered correct only if it was for the ball *k*+1 and counted as a **false selection** otherwise. For the MC condition, mouse clicks which did not led to new selections were counted as a different type of errors **(misses)**. We also computed **task completion time**, as the difference between time of selecting correctly ball #20 and ball #1 (note that, unlike selection time, this index included time spent for false selections). Time for selecting ball #1 was not included in any measure, because of the instruction not to hurry with this ball.

For selection time, **lower** and **upper quartiles** and **median** were computed for data collapsed over the three runs per participant and condition. The use of the quartiles was motivated by the specific nature that we expected for short and long selection times: the short ones could be almost free from time for the searching and mainly characterize selection, while the longest could characterize more the difficulty of search associated with a given selection method than the speed of selection itself. The median characterized typical performance in individual trials. For task completion time (an integrated performance estimator), the number of false selections and mouse misses we averaged the data from the three runs to characterize performance of a participant in each condition.

In the end of the experiment, the participants filled in a **questionnaire**, estimating their experience with each selection method (condition) using 10-point Likert scale and comparing their experience with different conditions.

III. RESULTS

In every run of the analyzed data, each of the 20 targets was once correctly selected. Maximal number of **false selections** per run, four, were found only in one run recorded in one participant (MC condition), and three false selections were found in 9 runs in total (5 in MC, 3 in MP, 1 in GP). In all other runs the number of false selections per run did not exceed 2. In some MC runs excessive **misses** (up to 17 in one run) were found (note that misses only spared additional efforts of the participant and could increase task completion time but were not crucial for the task). It appeared that mouse-based selection was generally associated with more errors than gaze-based selection, but the difference was low, and we focused on the analysis of time measures.

Task completion time was lowest for the GP condition, 42.4±6.3 s (M±SD). It was much higher for the MP condition, 74.1±13.1 s, while for the MC condition it was 54.8±12.3 s. The difference between the least different conditions, GP and MC, was significant (Student's paired sample *t*-test, $t(13) = -4.31$, $p = 0.0008$).

Statistics of **selection time** also clearly differed between conditions, in favor of gaze selection where it was shortest (Table I). All differences between conditions were statistically significant. The lowest difference was observed between the GP and MC conditions, where Student's paired sample t-test results were $t(13) = -4.97$, $p = 0.0003$ for low quartile, $t(13) = -3.66$, $p = 0.003$ for median and $t(13) = -3.32$, $p = 0.006$ for upper quartile.

Interestingly, individual values of selection time statistics for gaze selection were not only the lowest in clear majority of the participants compared to other conditions but also varied across the group much less than in other conditions (Fig. 2 and SD values in Table I).

In their responses to the **questionnaire**, all 14 participants indicated gaze input as the "more convenient" in the experiment task compared to mouse-based input. Comparing the two mouse modes, only one participant chose MP, while the other 13 preferred MC. Eight participants rated "convenience" in GP with score 10, five with score 9, and only one with score 6 (this participant had the worst visual acuity in the group (–7, corrected with lenses) and reported eye fatigue). M±SD for "convenience" in GP were 9.4±1.1. In contrast, scores for the MP mode ranged 2 to 8 (M±SD 4.1±2.0; four participants estimated this mode as low as with 2) and for the MC mode, 3 to 9 (M±SD 6.4±2.0).

Three participants experienced some misses when they were sure that a cursor was over a ball. A subsequent test showed that our software indeed misses clicks, with unpredictable frequency. However, such missed clicks were evidently not recorded in the experiment.

TABLE I. SELECTION TIME INDIVIDUAL STATISTICS IN DIFFERENT SELECTION CONDITIONS, IN SECONDS, M±SD FOR THE GROUP (N=14)

Statistics	**Selection Conditions**		
	MP	***MC***	***GP***
Low quartile	2.29±0.41	1.60±0.39	1.13±0.16
Median	3.89±0.56	2.26±0.53	1.78±0.24
Upper quartile	4.73±0.97	3.39±0.76	2.65±0.39

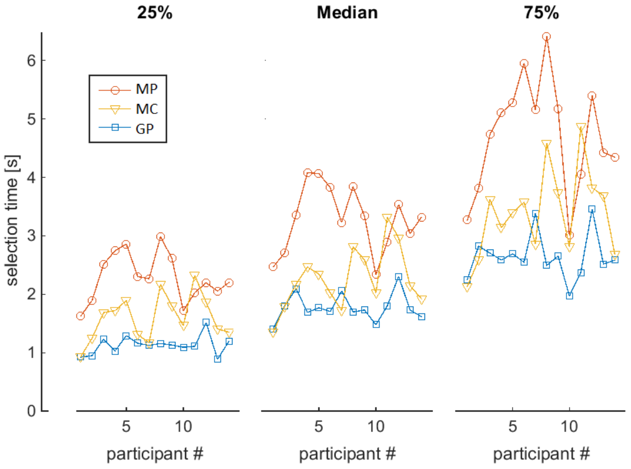

Fig. 2. Individual values of the selection time indices (lower quartile (25%), median and upper quartile (75%)) in the mouse pursuit (MP), mouse click (MC) and gaze pursuit (GP) conditions.

IV. DISCUSSION

Although we used a very simple selection algorithm and a very inexpensive eye tracker, gaze interaction in this study was effective for selecting non-salient moving targets and clearly outperformed each of two mouse selection methods. Gaze interaction was faster (on group average and in most of the participants) and more convenient (for all participants) than manual interaction.

Note that selection time estimated in the study consisted of several components, including not only the pursuit itself but also search time, time to bring gaze position sufficiently close to the target ball's center and to start the pursuit, and a 150 ms delay between an eye movement and receiving the related data by the selection algorithm. The selection algorithm was relatively slow, based on median computed over values obtained in a sliding window of 867 ms length. Surprisingly, the lower quartile of gaze selection time (time spent for 25% fastest selections) was, on group average, as low as 1128 ms (it was 1518 ms in the slowest participant and only 885 ms in the fastest one). For example, if selection was made after pursuing a target half the length of the window (about 430 ms), only 550 ms was left to perceive the visual feedback (it seems unlikely that the participants often suspended the pursuit before making sure that the ball is highlighted), locate the next target and to start the pursuit (305 ms in the fastest participant!).

The mouse input algorithms used in the study are unlikely the best possible; moreover, we cannot be sure that the misses of some clicks caused by software misfunctioning were rare enough during the experiment to prevent significant negative effects on performance. The mouse used in the study was not a state-of-the art one, and other manual input tools (touchscreens, touchpads, trackpads, trackballs, joysticks) should be also considered as manual alternatives with a potential of good performance in non-salient moving target selection.

On the other hand, none of the participants had substantial experience with gaze-based input, while all of them used manual computer input, and especially a mouse, in everyday activities for many years; 6 of 14 participants reported significant experience in computer games requiring fast reactions.

To our knowledge, our results can be considered as the first substantial evidence in favor of gaze interaction in the case of non-salient moving target selection task. While it is possible that superiority of gaze performance can be observed only in a relatively narrow range of critical factors (movement speed and direction, size and number of moving targets, etc.), the results suggest more intensive exploration of the opportunities provided by gaze pursuit-based interaction.

V. FUTURE PLANS

In this study, participants were engaged in a selection task all time along the tests. We did not check what may happen if they were in a more passive mode, e.g. just viewing the screen, but it is evidently possible that false selections could be frequent in this case. Recently, it was proposed to use passive brain-computer interfaces (BCIs) based on feedback expectation for filtering off spontaneous dwells in gaze dwell-based interaction [21-23]. In another pilot study [20], we recorded the electroencephalogram (EEG) in six participants when they performed the selection task as in the GP conditions. Inspection of the averaged EEG waveforms showed that selection of a ball was preceded by the development of a negative potential, which was similar to one described in the detailed study of the dwell-related EEG [23]. If reliable detection of this EEG marker in single trials using a statistical classifier will be possible, selection based on pursuit could be executed only when it is detected. In this case, the user could watch moving objects without selecting them unintendedly in case of spontaneous pursuit, because in this case the EEG marker will not be found. We plan to go further in this direction in attempt to develop an intuitive and fast hybrid human-machine interface.

ACKNOWLEDGMENT

The authors thank Andrey R. Nikolaev for useful comments and suggestions.

REFERENCES

[1] C. Ware and H. H. Mikaelian, "An evaluation of an eye tracker as a device for computer input", ACM SIGCHI Bulletin, vol. 18, pp. 183–188, 1986.

[2] L. E. Sibert and R. J. K. Jacob, "Evaluation of eye gaze interaction", ACM CHI '00, pp. 281–288, 2000.

[3] M. Dorr, M. Böhme, T. Martinetz, and E. Barth, "Gaze beats mouse: a case study", Conf. on Communication by Gaze Interaction (COGAIN), pp. 16–19, 2007.

[4] J. Nielsen, "Noncommand user interfaces", Communications of the ACM, vol. 36, pp. 83-99, 1993.

[5] R. J. Jacob, "Eye movement-based human-computer interaction techniques: Toward non-command interfaces", Advances in Human-Computer Interaction, vol. 4, pp. 151-190, 1993.

[6] B. M. Velichkovsky and J. P. Hansen, "New technological windows into mind: there is more in eyes and brains for human-computer interaction", CM SIGCHI Conf. on Human Factors in Computing Systems (CHI '96), pp. 496-503, 1996.

[7] B. Velichkovsky, A. Sprenger, and P. Unema, "Towards gaze-mediated interaction: Collecting solutions of the "Midas touch problem"", Human-Computer Interaction INTERACT '97, pp. 509-516, 1997.

[8] R. J. K. Jacob, "The use of eye movements in human-computer interaction techniques: what you look at is what you get", ACM Trans. Inf. Syst., vol. 9, pp. 152-169, April 1991.

[9] B. M. Velichkovsky, "Communicating attention: Gaze position transfer in cooperative problem solving", Pragmatics and Cognition, vol. 3, 199-223, 1995.

[10] J. P. Hansen, A. S. Johansen, D. W. Hansen, K. Itoh, and S. Mashino, "Command Without a Click : Dwell Time Typing by Mouse and Gaze Selections", Human-Computer Interaction – INTERACT′03, pp. 121–128, 2003.

[11] J. D. Smith and T. C. N. Graham, "Use of eye movements for video game control", ACM SIGCHI international conference on Advances in Computer Entertainment Technology - ACE '06, p. 20, 2006.

[12] S. Vickers, H. Istance, A. Hyrskykari, N. Ali, and R. Bates, "Keeping an eye on the game: Eye gaze interaction with massively multiplayer online games and virtual communities for motor impaired users", 7th ICDVRAT with ArtAbilitation, pp. 159–166, 2008.

[13] P. Kasprowski, K. Harezlak, and M. Niezabitowski, "Eye movement tracking as a new promising modality for human computer interaction", 17th Internat. Carpathian Control Conf., pp. 314–318, 2016.

[14] M. Vidal, A. Bulling, and H. Gellersen, "Pursuits: spontaneous interaction with displays based on smooth pursuit eye movement and moving targets", ACM Int. Joint Conf. on Pervasive and Ubiquitous Computing (UbiComp '13), pp. 439–448, 2013.

[15] A. Esteves, E. Velloso, A. Bulling and H. Gellersen, "Orbits: Gaze interaction for smart watches using smooth pursuit eye movements", ACM Symposium on User Interface Software and Technology (UIST '15), pp. 457–466, 2015.

[16] O. H. M. Lutz, A. C. Venjakob, and S. Ruff, "SMOOVS: Towards calibration-free text entry by gaze using smooth pursuit movements", J. of Eye Movement Research, vol. 8, pp. 1–11, 2015.

[17] M. Khamis, O. Saltuk, A. Hang, K. Stolz, A. Bulling, and F. Alt, "TextPursuits: using text for pursuits-based interaction and calibration

on public displays", ACM Int. Joint Conf. on Pervasive and Ubiquitous Computing (UbiComp '16), pp. 274-285, 2016.

[18] S. Schenk, P. Tiefenbacher, G. Rigoll, and M. Dorr, "SPOCK: A smooth pursuit oculomotor control kit", CHI Conf. Extended Abstracts on Human Factors in Computing Systems (CHI EA '16), pp. 2681-2687, 2016.

[19] D. J. Lohr and O. V. Komogortsev, "A comparison of smooth pursuit- and dwell-based selection at multiple levels of spatial accuracy", CHI Conf. Extended Abstracts on Human Factors in Computing Systems (CHI EA '17), pp. 2760-2766, 2017.

[20] D. G. Zhao, A. V. Isachenko, E. V. Melnichuk, B. L. Kozyrskiy, and S. L. Shishkin, "EEG potentials related to moving object selection with gaze: A possible basis for more flexible eye-brain-computer interfaces", Opera Medica et Physiologica, 2018 (Proc. Volga Neuroscience Meeting 2018), in press.

[21] K. Ihme and T. O. Zander, "What you expect is what you get? Potential use of contingent negative variation for passive BCI systems in gaze-based HCI", Affective Computing and Intelligent Interaction, pp. 447-456, 2011.

[22] J. Protzak, K. Ihme, and T. O. Zander, "A passive brain-computer interface for supporting gaze-based human-machine interaction", Int. Conf. on Universal Access in Human-Computer Interaction, pp. 662-671, July 2013.

[23] S. L. Shishkin, Y. O. Nuzhdin, E. P. Svirin, A. G. Trofimov, A. A. Fedorova, B. L. Kozyrskiy, and B. M. Velichkovsky, "EEG negativity in fixations used for gaze-based control: Toward converting intentions into actions with an eye-brain-computer interface", Frontiers in Neuroscience, vol. 10, article 528, 2016.