Can smooth pursuit performance in adults be positively influenced by task requirements?

Purpose and aims:

The purpose of the study is to find out whether the gain[1] (ratio between eye velocity and target velocity) in smooth pursuit can be positively influenced by adding a mock-task which requires following the target at exactly the same velocity and its exact position. When the eye velocity and target velocity are identical, the value of gain is 1. Thus, the aim of the study is to determine whether the gain value for smooth pursuit including the additional mock-task is significantly closer to 1 than the gain value for smooth pursuit without the additional mock-task.

Survey of the field:

According to Lencer & Trillenberg (2008), smooth pursuit movements “occur to compensate for the dislocation of the retinal image from the centre of the fovea” (Lencer & Trillenberg, 2008, p.219) and thus differ from the saccades, which bring the eye towards a new object. Smooth pursuit appears to be a stable oculomotor function: Ettinger et al. (2003) found no major improvement in smooth pursuit gain when they tested and retested participants within the interval of circa 58 days, while; for example, there were considerable improvements in the anti-saccade tasks observed between the testing sessions. The findings of Ettinger et al. (2003) also replicated the high stability of anticipatory saccade frequency during smooth pursuit. Since anticipatory saccades seem to be stable, reporting their amount would not bring any additional information regarding the smooth pursuit performance in healthy population, so they will not be analyzed and reported in this study. In addition, Lencer & Trillenberg (2008), say that “saccades have to be excluded from the analysis [of smooth pursuit]” or “an analysis has to be chosen that is not influenced by data points with large velocity” (Lencer & Trillenberg, 2008, p.221). Since the purpose of the study is to calculate the value of gain which is sensitive to velocity values, it seems plausible to discard the saccades from the analysis. Since the detection algorithm needs to know which parts of the signal to discard, a saccade for the purpose of this study will have the minimum amplitude of 1.5° and velocity of 30°/s, as defined in Ettinger et al., 2003 (p.622). A very important piece of information, however, is conveyed by the first catch-up saccade, which indicates the onset of smooth pursuit (Lencer & Trillenberg, 2008, p.221). The smooth pursuit onset appears after a delay of approximately 150ms (Bahill & Donald, 1983, p. 1573).

Since Lencer & Trillenberg (2008, p.219) claim that “smooth pursuit performance is optimal for target speeds ranging between 15°/s and 30°/s“ (as in Ettinger et al., 2003; and Meyer, Lasker, & Robinson, 1985), I decided to focus on these speeds. Even though the smooth pursuit system seems to be stable, a study by Sharpe & Sylvester (1978) reports that “smooth pursuit is an age-dependent motor system” (Sharpe & Sylvester, 1978, p.465). With respect to the critical target speeds I am focusing on, they found that smooth pursuit gain for targets moving in the above mentioned range was significantly better for young participants (aged between 19 to 32 years) than for elderly participants (aged between 65 to 77). At the target velocity of 30°/s, for example, the gain value for young participants was between 0.9 and 1, while for elderly participants it was between 0.5 and 0.6 (Sharpe & Sylvester, 1978, p.465). Following their findings, I decided to invite participants aged 18 to 30 for

[1] Gain is the measure of “pursuit performance in sinusoidal stimuli“(Lencer & Trillenberg, 2008, p.222).

my study, as the smooth pursuit performance of that particular age group seems to be the best possible.

Keeping a similar attitude, I decided to choose a predictable sinusoidal motion of the target since abrupt changes elicit “a mixture of the reaction to the now target movement and the prediction of the previous movement” (Lencer & Trillenberg, 2008, p.221) so it is easy to deduce that performance of smooth pursuit would be negatively impacted by such changes, while the purpose of the study is to find the best performance and attempt its improvement through additional task manipulation.

The reason for trying to achieve the gain value of 1 while pursuing a target following a sine wave is to help answer issues raised by Steinman et al. (1969), who in their article *Voluntary Control of Smooth Pursuit Velocity* posed these two questions:

> “(1) why is the operation of the low velocity control system confined to smooth pursuits below target velocity and (2) under what conditions, if any, does the velocity of the eye accurately match the velocity of constant velocity target motions?” (Steinman et al., 1969, p.1170)

<u>Project description</u>:

Experiment procedure

After participants enter the lab, they are introduced to the eye-tracker and told how it works. Then they are explained what will follow: the camera setup, mechanics of calibration and calibration validation, and the experiment itself, which will have instructions written on the screen in English. At the beginning of the experiment, the participant is randomly assigned to a control or experimental group by the software. Participants in both groups will be pressing a key on the keyboard during the experiment, and participants in experimental group will also do mouseclicks – both mouse and the keyboard will not be located at the same desk with the eye-tracker. After the experiment, the participant is debriefed and signs a written consensus that they agree with their data being used in the study.

Experiment description

- Participants

Recruited participants would be young adults (18 to 30 years), with normal or corrected-to-normal vision, and with no psychiatric diagnosis[2].

- Groups

Participants would be randomly assigned to one of two groups: control group (C) and experiment group (E).

[2] Impairments in smooth pursuit, for example, have been observed in patients with schizoprenia (Ettinger et al., 2003, p.622).

- Stimuli description

  Calibration and calibration validation – a 9-point calibration with automatically accepted positions, except for the first position which has to be accepted by pressing spacebar. The values above 0.5° will not be accepted since the data are very sensitive to wrong calibration.

  Key-response delay – an estimate of how long it takes for a person to notice a letter or number centered in the middle of target point after its random onset and press a key (spacebar), a measure that will be used for analysis of the experimental phase. At the center of the screen there will be a white circular target with black outline, of the same size that will be used in the experimental phase for smooth pursuit. Participants will be instructed to look at the target, and after a random delay (between 0-6s) after the initial 300ms target onset, a random letter or number will be shown inside the target (written in capital letters, English A-Z alphabet, numbers 0,1,2,…, 9; each of them in different fonts, an example can be seen at Figure 1). Immediately after the letter is seen, the participant hits the spacebar and is asked to type the letter / number in a dialog box that opens, and after entering the value another trial starts by showing the empty target in the center of the screen. This procedure will be repeated 10 times in order to obtain an average of key-response delay to a familiar stimulus, which is more closely described in the measures.

  Even though the experimental group will not be discriminating from letters and numbers but unrelated symbols[3], so one could argue that numbers and letters are not the best to use (participants may react to them faster than they will to the symbols), it is an easy warm-up exercise that measures the best performance. It adds additional freedom as the value of the delay will be deduced from the time when the person in an experimental group pushes spacebar. This measure will enable the researcher to more accurately estimate the time when the person noticed the symbol and take the value of gain from that point for the analysis of smooth pursuit performance. As each of the letters or numbers will be in a different font, it reduces the possibility of faster recognition due to the font type, and 10 trials will provide enough data about the response delay while minimizing the learning effects.

[3] Closely explained in *Experimental phase* below.

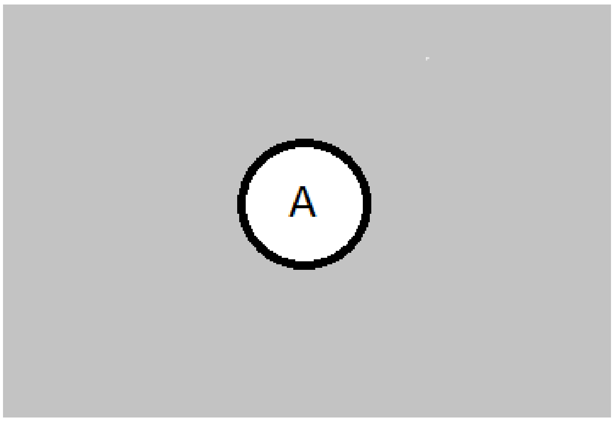

Figure 1 Example stimulus for measuring key-response delay

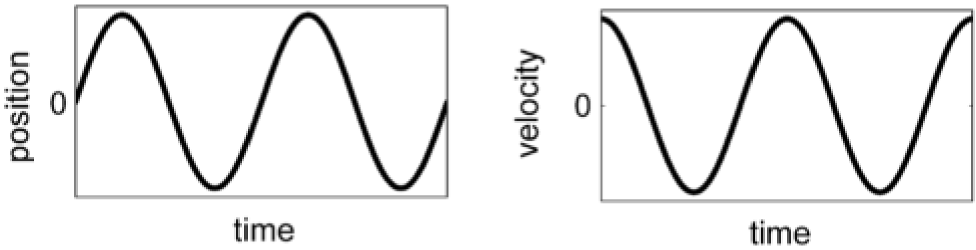

Figure 2 Sinusoidal path of the movement, the graph on the left depicts the changes in position of the target through time, while the graph on the right illustrates the velocity of the target

Experimental phase

For both the C and E group, the targets will be moving with the speeds between 15°-30°/s[4], following a sinusoidal path as shown in Figure 2 (modified from Lencer et al., 2008,p.221).

There will be 16 different speeds of the targets (15°/s,16°/s, …, 30°/s), and each of the speeds will be repeated 3times to verify the consistency, making the total of 48 trials. Thus, the speed on each trial will be assigned quasi-randomly; if, for example, the speed on Trial 1 is randomly assigned as 18°/s, in the Trials 2 to 48 it can only be assigned twice more for that participant. The trials will be divided into three blocks; each block will contain 16 trials. After the first and the second block, there will be a possibility to take a break – look around, and press a key when the participant is ready to continue. After the key is pressed, instructions will inform the participant about calibration validation process ("Before we start, it is necessary to check if our system is still tracking your eye properly. After you press the spacebar, four validation points will appear. Please look at the center of each of the points for the

[4] The rationale behind using this range of speeds is that if it is possible to improve the smooth pursuit performance, the effect should be visible and significant even for speed ranges which were determined as those when the smooth pursuit performance is the best.

whole time they will be on the screen. Press spacebar when ready.”). If the validation values will be lower than 0.5°, the experiment will continue, else there will be a new 9-point calibration (without validation).

Participants in the C group will be asked to follow the targets as best as they can for the whole trial. The value of gain will be calculated from the mean value of

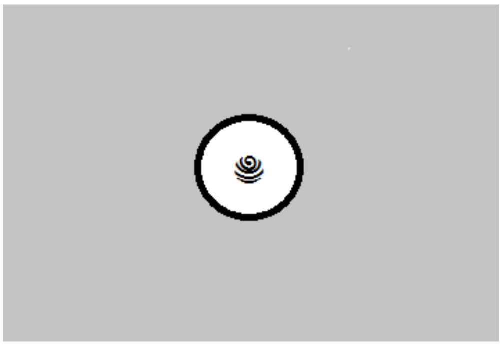

Figure 3 Example of the symbol stimulus

eye velocity at the peaks, measured at all peaks after the eye begins the pursuit (emergence of first catch up saccade). For participants in the E group, the center of the target will display a symbol (similarly like in the key-response delay, an example of the symbol-stimulus can be seen in Figure 3), the onset of the symbol will be set randomly 300ms after the trial begins, but at the latest when the target crosses to the second half of the monitor. The target with the symbol will keep moving like the target without any symbol would. As soon as the participant feels comfortable with recognizing the symbol, they will press the spacebar and a dialogue with multiple choices will appear. In the multiple choices, the participant will have to make a forced decision from 4 symbols, out of which one was in the middle of the target during the trial. If the participant does not press spacebar during the trial at all, they will be shown multiple choices with 5 possible answers after the end of the trial: 4 symbols out of which one was shown on the trial, and 5th answer saying “I did not see the symbol at all”. Example of multiple choices with 5 possible answers is shown in Figure 4.

Use of symbols rather than letters or numbers is introduced for two main reasons: first, it minimalizes learning possibilities as there will be different symbols used every time; second, since the symbol cannot be guessed and is not familiar like letters and numbers, it increases the necessity for the participant to foveate it and thus more accurately follow the target. Even when the participant is unable to tell the symbol after they have noticed its onset, I believe it will still make them follow the target movement with a better gain value than in the control condition, simply for the fact that they will be aware of how to “see” the symbol properly (by bringing it to the fovea). For this reason, all trials in E condition in which the participant will be unable to discriminate the symbol will be included in the analysis as well.

The value of gain in such cases will be calculated from the mean eye peak velocity after the onset of symbol in the target until the end of the trial since it

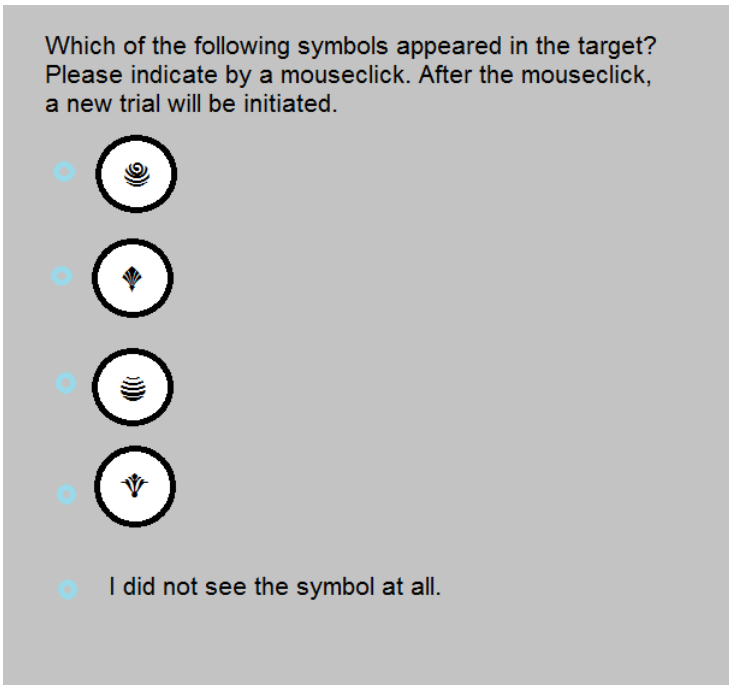

Figure 4 Example of multiple choices

presupposes that when the participant cannot see the symbol, they will keep trying to foveate it until the end of the trial, and thus give their best performance. The value of gain in cases where the participant pressed the spacebar during the trial will be calculated from the value of eye velocity at the time when the participant pressed the spacebar minus the time of key-response delay. The rationale behind this is that the participant would press the spacebar in the moment when they are most sure about being able to remember and recognize the symbol, which should coincide with the symbol being foveated and thus the prediction of the movement should be the most accurate at that moment, and eye velocity as close as possible.

- Description of relevant measures and definitions of relevant oculomotor events
  Key-response delay – time in ms it takes a participant to notice the letter or number in the target and hit spacebar. In E group, the value of trimmed mean (discarding the fastest and the slowest response) of this delay will be subtracted from the time of the symbol onset until the participant hits the spacebar (e.g. the trimmed mean of response delay of Participant 1 will be subtracted from the response time of Participant 1 to the symbol in order to estimate the value of the velocity of the eye at that specific time when Participant 1 noticed the symbol). For C group, this measure will not be used in analyzing the gain of smooth pursuit.
  Gain – ratio between eye velocity and the target velocity. Usually, target velocity is bigger than eye velocity, so the ratio has values below 1. Supposing that the target velocity is 40°/s and eye velocity 20°/s, the value of gain is 0.5. Value of eye velocity, needed for calculating the gain, is taken differently from the C and the E group. In C group, the value of eye velocity is taken as a mean of the velocity peaks after the pursuit onset. In E group, the value of eye velocity can be obtained in two ways. For

cases when participants will not press the spacebar as the mean of the peak values after the symbol onset. For cases when participants will press the spacebar, the eye velocity will be taken at the time of pressing the spacebar, minus the key-response delay for respective participant. Subtracting the personal delay ensures the comparability of the results.

Smooth pursuit onset – the eye is believed to have started smooth pursuit of the target after the first occurrence of a catch up saccade.

Catch-up saccades (CUS)– "saccades in the target direction that serve to reduce position error, that is, to bring the eye closer to the target" (Ettinger et al., p.622) and "if more than half of the amplitude was spent behind the target, that is, reducing position error, the saccade was considered a CUS" (Ross, Olincy, Harris, Radant, Adler, et al., 1999).

- Expected outcomes

The average value of key-response delay is expected not to significantly differ in C and in E group. The velocity values are expected to look similarly to those in Figure 5. The differences between blue and red line with respect to the black line are expected to yield a significant result at all velocities, α = 0.05.

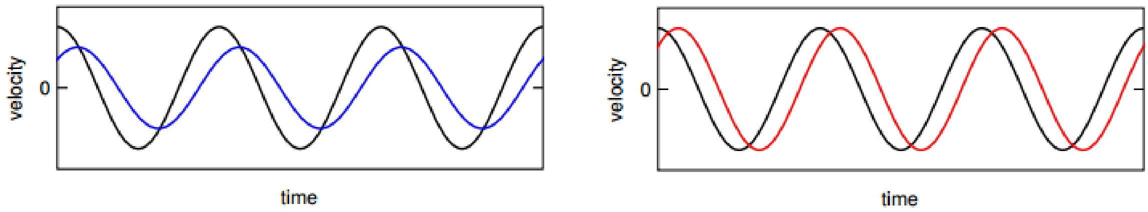

Figure 5 Expected graphs of velocities. The black line represents target velocity. The blue line on left represents expected eye velocities for condition C, showing lower velocities. Red line represents expected graph of condition E, showing same eye velocity values as target velocity.

Proposed eye-tracker

SR EyeLink 1000 for its gaze-contingency support, recording monocularly with chin- and headrest at the speed of 2000Hz.

Significance:

Finding a significant effect of gain improvement in the experimental condition in comparison to smooth pursuit gain without the additional mock-task would show that the common phenomenon of undershooting the target velocity during smooth pursuit is not a manifestation of physical limitations of smooth pursuit system, but rather an accommodation of the eye-movement to the task, and can be further improved. Apart from that, it could also improve the models of smooth pursuit control by adding the element of task requirement, which is currently missing in all the models of smooth pursuit dynamics listed in Lencer & Trillenberg (2008, p.223). Finding an insignificant result would show that smooth pursuit movement is not susceptible by a task that requires direct foveation.

Other tools and software:

PsychoPy will be used for creating the stimuli, R will be used as a tool for conducting the statistical analysis.

The symbols for symbol stimulus were downloaded from

http://www.fontspace.com/category/symbols and are free for personal and non-commercial use.

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