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Do precise hand movements rely on accurate smooth pursuit eye movements? An exploratory analysis project using existing visualization tools.

Domain Description

In ball sports, athletes are taught to keep their eyes on the ball to catch or hit it successfully. This intuitive field experience has already been studied in the laboratory, showing that tracking a moving object with smooth pursuit eye movements enhances our ability to predict the object's trajectory in time [5] and space [11]. Smooth pursuit eye movements describe a continuous movement that slowly rotates the eyes to keep up with the motion of the observed object, such as a flying ball [6]. In order to compensate for high speeds of the moving object, observers also make fast discrete eye movements called saccades [7]. This combination of smooth pursuit and saccadic eye movement has been observed in athletes in various ball sports, such as baseball [3], cricket [8], or basketball [10]. Indeed, manually intercepting the moving object critically relies on precise motion prediction [4] [9]. These previous studies suggest that smooth pursuit eye movements play an important role in interception tasks. However, the relationship between the quality of smooth pursuit eye movements and hand movement accuracy has not yet been studied systematically.

Task Description

Does accurately tracking a briefly presented target with smooth pursuit eye movements improves the ability to intercept its trajectory? Which characteristics of athletes' eye and hand movements are the highest predictor for a successful hit? I am studying the correlation between eye and hand movements based on several quantities recorded in a manual interception task (described below). For hand movements, the Euclidean distance between the finger's and the target's end position holds as a first measure of the interception quality. This will later be extended to a spatio-time error that takes trajectory shape and interception timing into account. In addition to this, hand movement latency with respect to target motion onset as well as peak and mean hand velocity is determined. The smooth pursuit eye movement quality is assessed by measures such as initial eye velocity and acceleration, position error, velocity error, steady-state velocity gain and catch-up saccade characteristics.

Dataset

We developed a paradigm in which 32 players of the UBC baseball team were asked to track a small moving dot, back-projected onto a translucent screen, and to intercept it as fast and accurately as possible (see supplementary video for demo). Observers were instructed to hit the target with their index finger as soon as it entered a designated 'hit zone', a darker gray zone of half the display width. During training, the target was shown for the entire trajectory. In experimental trials, the target trajectory was only shown briefly (100, 200 or 300 ms). Thus, observers had to extrapolate the target's trajectory after the dot disappeared from the screen and subsequently intercept the target at its assumed current position anywhere within the hit zone. Stimulus speed (25, 30 or 35 deg/s), trajectory shape (curved or linear), and handedness (right or left) were also varied. Figure 1 shows the basic structure of the experiment. Eye and hand movements were recorded throughout each trial using an Eyelink 1000 (SR Research Osgoode, Ontario, Canada) and a 3D Guidance trakSTAR (Ascension Technology Corporation, Vermont, USA), respectively. In addition to the data from the interception experiment, we measured visual accuracy, stereo-vision, contrast sensitivity and color vision to cross reference overall visual performance.

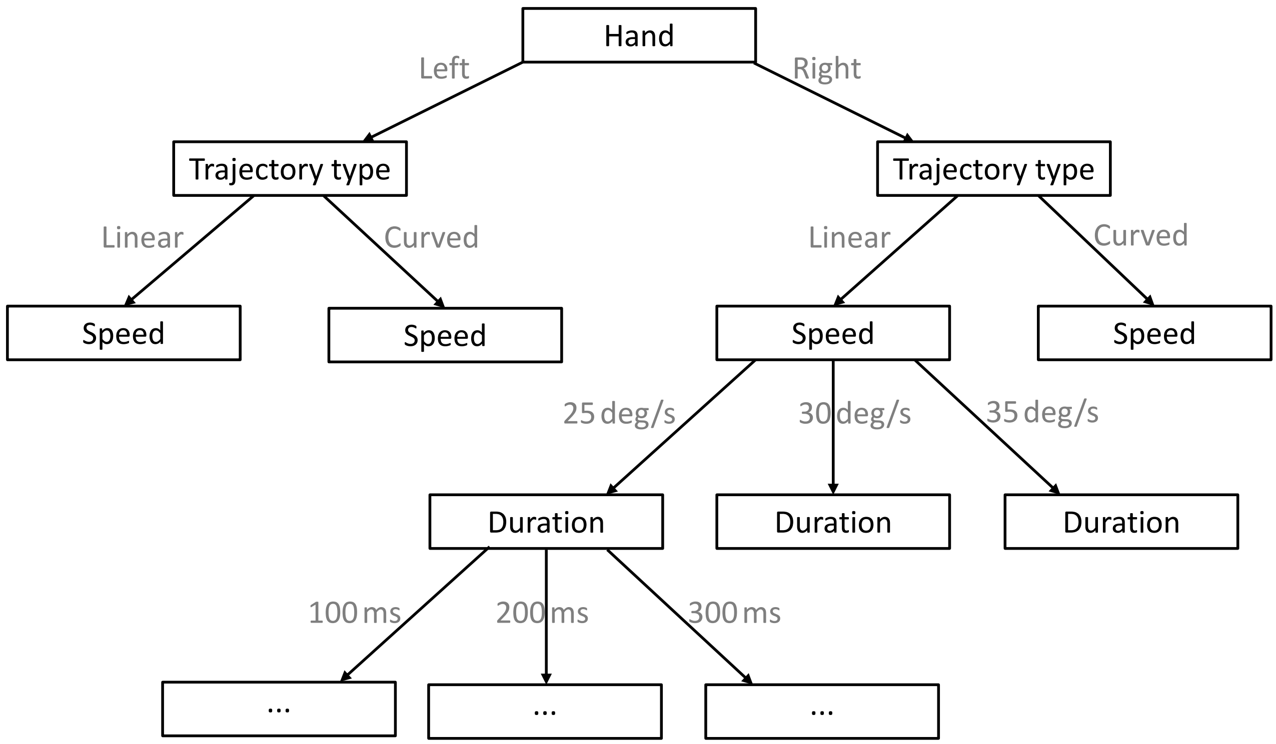

Figure 1 Basic experimental structure.

Personal Expertise

This class project ties into a research project that I have been working on for about a year through my RAship. I was involved in designing the paradigm, carried out the player testing (which included the standard vision tests) and performed all previous data analysis. The data have gone through several processing steps that are commonly done in smooth pursuit eye movement analysis such as filtering, flagging, analyzing, and removing saccades as well as finding the eye movement onset. For these analysis steps I used `Matlab`. About two weeks ago I have also started using R for statistical analysis.

Proposed infovis solution

I am interested in visualizing two different aspects of the above described dataset:

1. Effects across all players
2. Intra-player effects

The main part of the project will focus on visualizing the overall effect of eye movements on manual interception accuracy. In addition to this, I would like to visualize individual players differences based on a not yet determined ranking scheme. I am planning to compare the use of R [2] (including packages such as *ggplot2* or *shiny*) and Tableau [1] as software programs for the proposed analysis.

Effects across all players: The dataset described above has approximately 20 attributes that we are interested in. Relating eye or finger attributes to the interception accuracy can be done through scatterplots. However, we tested 32 players with 750 trials each, yielding a total of about 24 000 trials. Plotting attributes trial by trial could therefore lead to occlusions. Thus, it will be important to aggregate the data in a meaningful way. A first step would be to separate into right and left handed players and then to further separate into the two different trajectory types (compare figure 1). Furthermore, we have concluded from preliminary analysis that speed and presentation duration of the stimulus have an effect on interception accuracy. Accordingly, data could be categorized into 9 conditions:

Condition	Speed	Duration	Symbol
1	35 [deg]	100 ms	green ◆
2	35 [deg]	200 ms	red ◆
3	35 [deg]	300 ms	blue ◆
4	30 [deg]	100 ms	green ●
5	30 [deg]	200 ms	red ●
6	30 [deg]	300 ms	blue ●
7	25 [deg]	100 ms	green ■
8	25 [deg]	200 ms	red ■
9	25 [deg]	300 ms	blue ■

A sketch of a possible visualization is shown in figure 2. In this example the results of all right handed players are averaged over each condition. This could be optional.

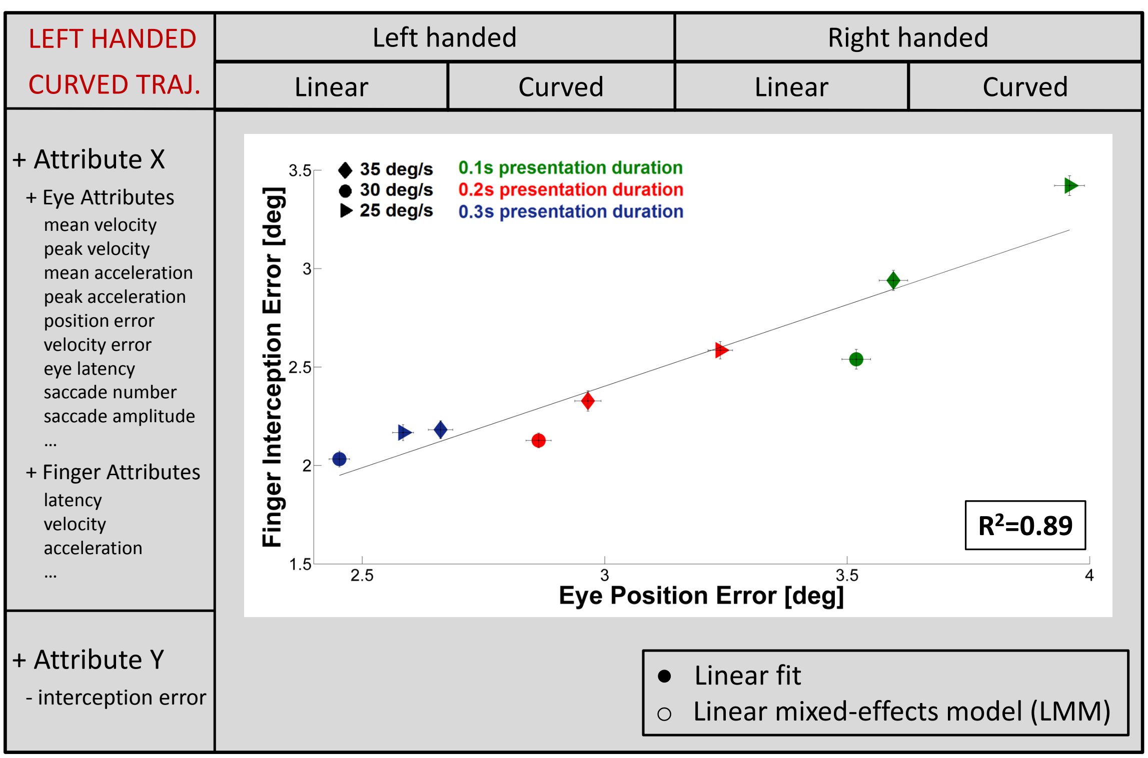

Figure 2 Sketch of possible visualization for correlation effects across all players.

Inter-player effects: In addition to the interception task described above, we carried out a set of basic vision tests for each player. I would like visualize player's performances individually as well as with respect to others. The individual player visualization should also include information about the players career such as the player's position, years played, or batting average. One idea would be to rank the players based on their performance in the basic vision tests, the interception accuracy and eye movement accuracy. These results could be plotted in e.g. a stacked bar plot comparing all players. Individual player information could be visualized in a kind of 'player card' with positions, year, and rank in each category recorded.

Milestones

Figure 3 shows a drafted timeline including goals for each time period. The first *milestone* will be the status update on November 14. Until then, I want to focus on literature research and familiarization with the vis tools. I am planning to have completed this phase by the time I am back from a conference. Immediately after, I plan to fine-tune the data set visualization. The analysis part of the project will really be worked on throughout the entire time course of the project. A *milestone* here will be on November 23, when I will have determined which tool serves best for the proposed data visualization.

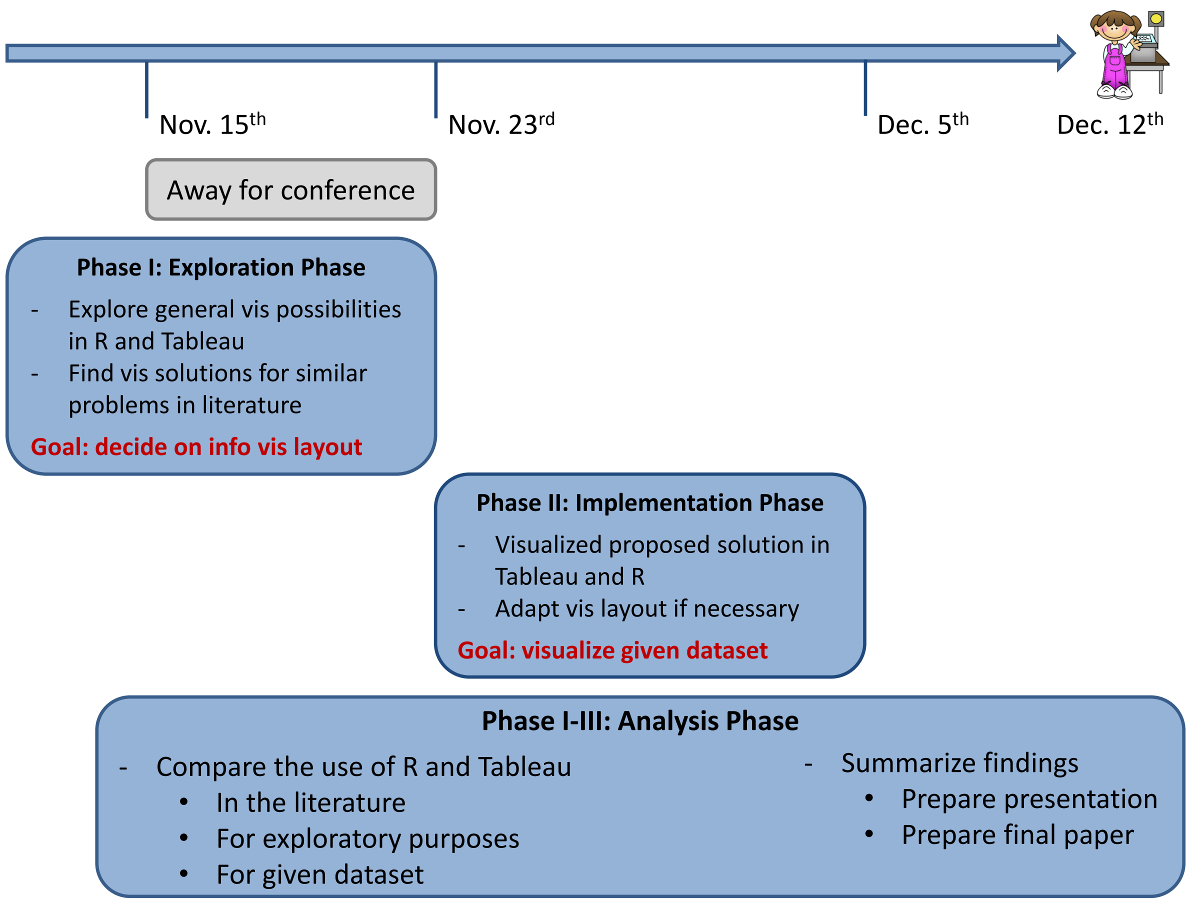

Figure 3 Drafted timeline for vis class project.

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