

Analysis of Pupil Dynamics during Cued and Self-Initiated Saccades

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Driven to DiscoverSM

Background: Saccadic Eye Movements

- A “saccade” is a quick movement of the eyes toward a target, while an “anti-saccade” is the equal and opposite movement away from a target (i.e. box appears on a screen, participant looks at it or away).
- Pupil size, a relevant measure for cognitive processing, follows a specific pattern of constriction and subsequent dilation leading up to a saccadic eye movement (Figure 1).

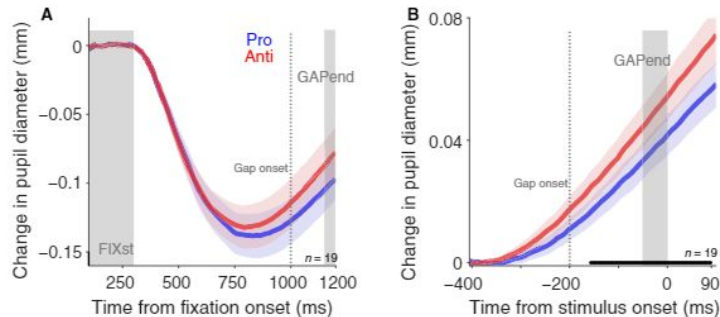


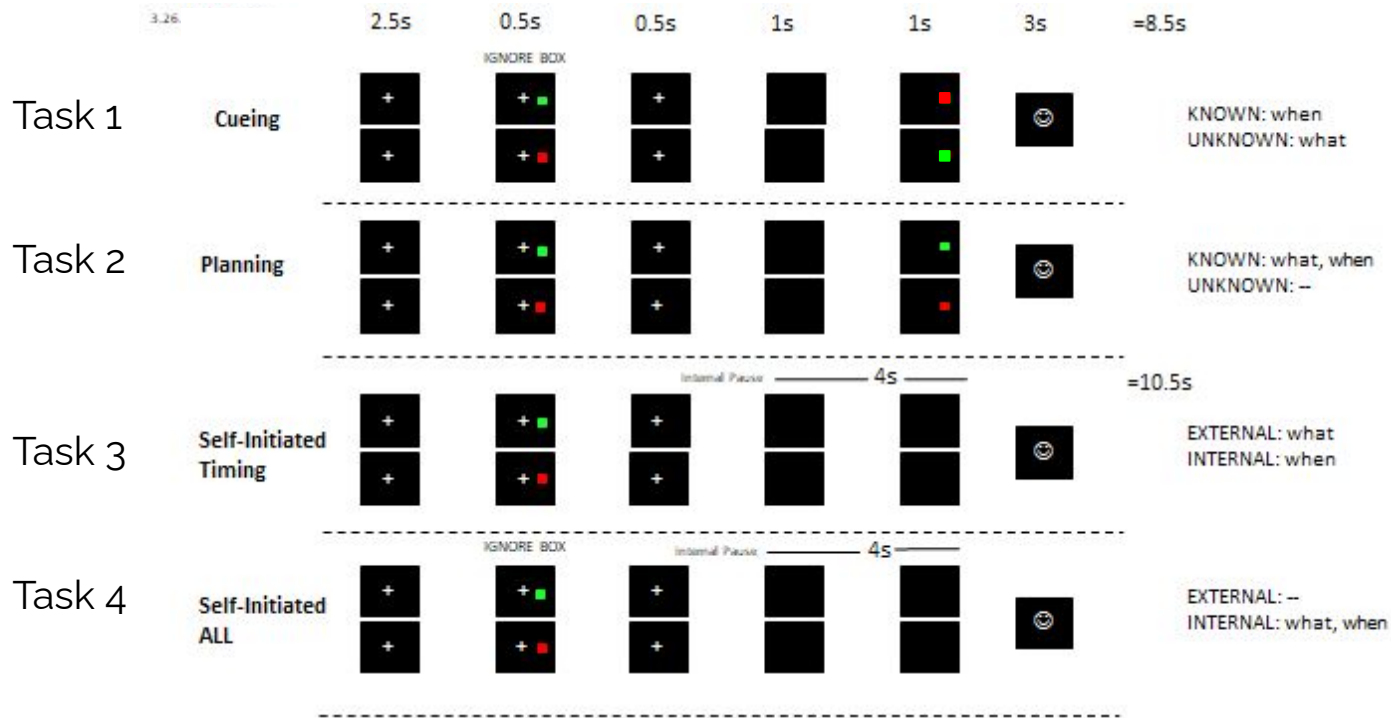
Figure 1: (A) pupil constriction leading up to saccade; (B) pupil dilation up to and past the movement. *Anti-saccades, shown in red, tend to have more shallow maximum constrictions.

Source: Wang, C. A., Brien, D. C., & Munoz, D. P. (2015). Pupil size reveals preparatory processes in the generation of pro-saccades and anti-saccades. *European Journal of Neuroscience*, 41(8), 1102-1110.

Introduction to the Project

- Original hypothesis: As more information is given about the timing and direction of saccade, greater change in pupil dilations will occur
- **Research Question: How does the pupil size change in healthy young adults during saccades with differences in preparatory information and cueing?**
 - Specific Aims
 - Create protocol for testing pupil size changes
 - Measure pupil constriction and dilation in cued and self-initiated saccades
 - *Summer 2020: analyze data from 6 participants*

Experimental Conditions



Pro
Anti

Green boxes indicate pro-saccades (look toward), while red boxes indicate anti-saccades (look away).

Figure 2: Black boxes represent screens on the monitor. All tasks begin with fixation point, followed by a colored box. Task 1: Participant gets a second, different box, to which they respond. Task 2: Participant gets the same box as the initial box, to which they respond. Task 3: Participant self-initiates instructed movement by the first box. Task 4: Participant self-initiates movement time and chooses direction.

Methods

- Protocol: 2 tasks have cued/structured timing, 2 tasks have self-timed saccades
- Summer 2020 analysis:
 - a. Visually inspect all trials for errors
 - b. Manually correct movement onset timing
 - c. Normalize pupil size changes to baseline
 - d. Plot average pupil size change for pro vs. anti saccades by task
 - e. Plot behavioral data (velocity, reaction time for structured tasks)
 - f. Started running stats

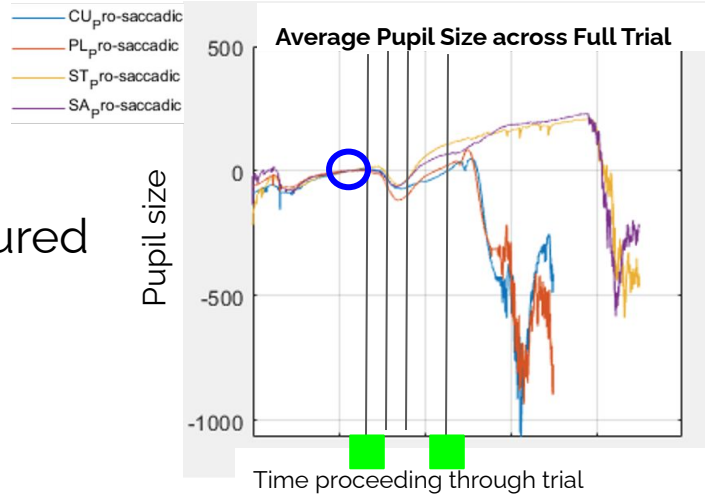


Figure 3: Pupil size averaged for pro-saccades, one participant, all conditions, corrected to baseline (taken at blue circle). Lines and boxes represent time structure within the task (second box is not present for self-initiated tasks).

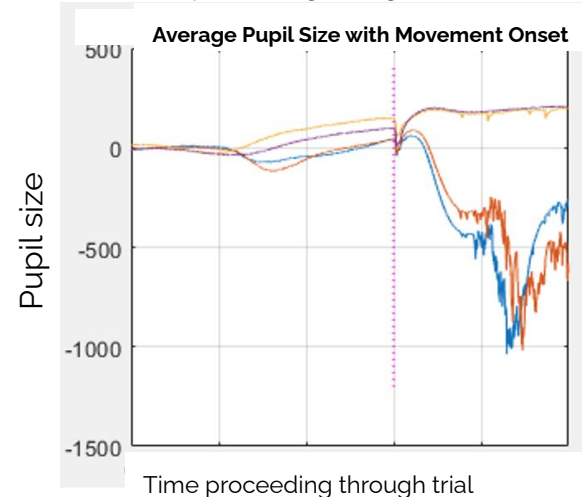


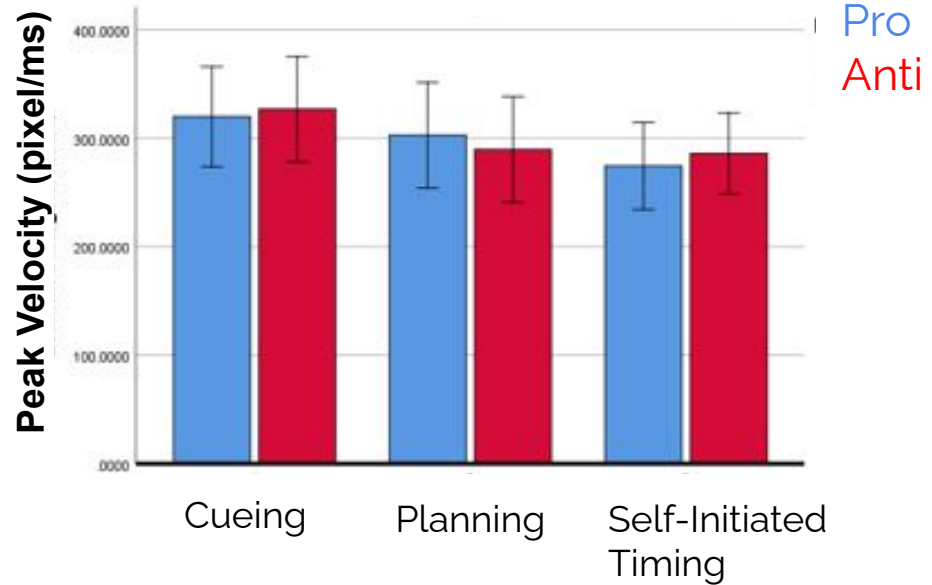
Figure 4: Pupil size averaged for pro-saccades, one participant, all trials aligned to eye movement onsets (pink line). Analyzing by movement onset is important for comparing cued vs. self-initiated tasks.

Data Analysis

- Statistical analysis: 3x2 repeated measures ANOVA
 - Cannot do all 4 because Self-Initiated All task has only Pro and no Anti
 - Currently, only Cueing, Planning, and Self-Initiated Timing are compared
- Behavioral data: peak velocity, reaction time
- Pupil size data: time to max constriction, max constriction magnitude
- Data shown here: 3 or 5 participants

Peak Velocity

- Peak velocity of the eye movement with Cueing was faster than Self-Initiated Timing ($P < 0.05$, $n=3$).
- There is an interaction effect between task and Pro/Anti condition ($P < 0.05$, $n=3$).
- Peak velocity measured by monitor pixels moved per millisecond during the eye movement.

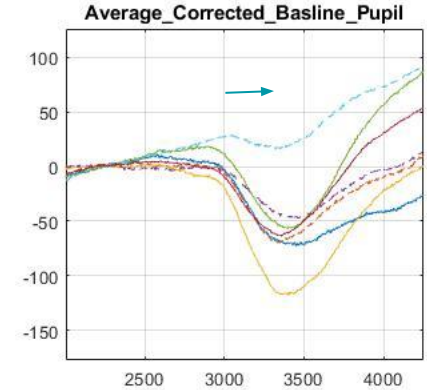
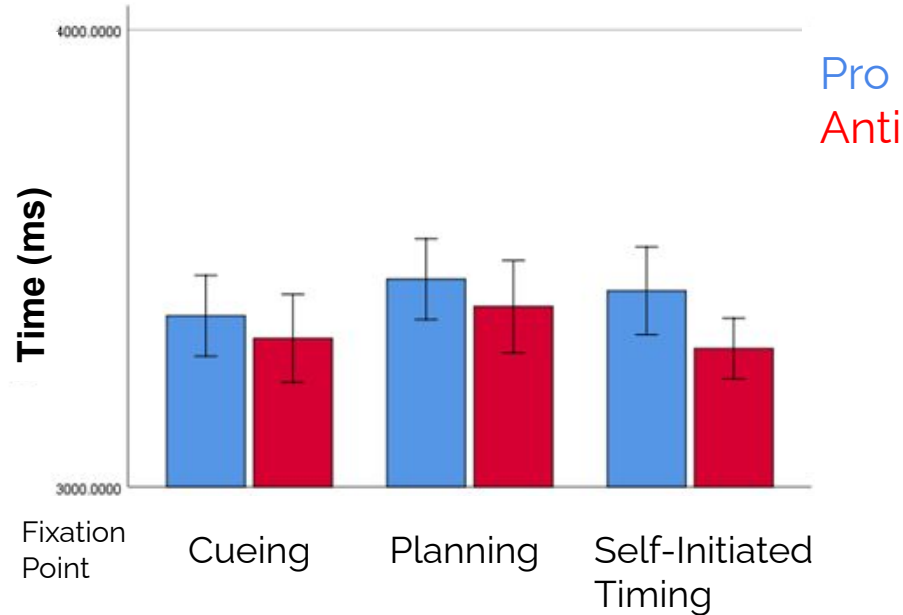


Reaction Time

- Reaction time of the participant was significantly faster in Planning than in Cueing ($P = 0.001$, $n=5$).
- Reaction time was significantly faster in Pro condition than in Anti ($P < 0.05$, $n=5$).
- Taller bar = longer, slower reaction time



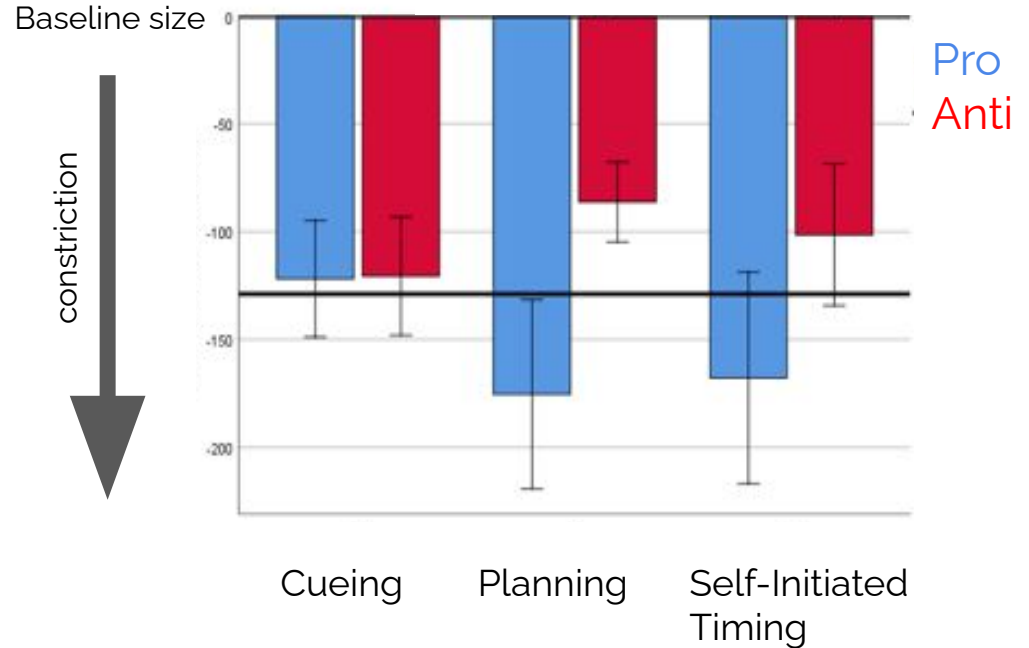
Time to Peak Constriction of Pupil



- Time to peak constriction of the pupil size in Pro condition (indicated on example graph above) was slower than Anti condition, but not statistically significant ($P = 0.072$, $n=5$).
- Taller bar = longer, slower time to peak constriction

Max Constriction

- Maximum constriction of pupil size was significantly larger in Pro condition than Anti condition ($P < 0.05$, $n=5$).
- Bars extending downward compare the depth of maximum constriction.



Summary of Findings

- Pro condition had faster peak velocities than Anti condition
- Reaction time in Planning was faster than in Cueing; reaction time was also faster in Pro condition than Anti condition
- Maximum constriction was larger in Pro condition than Anti condition for Planning and Self-Initiated Timing

Discussion

- Maximum constriction difference in Pro and Anti conditions replicate literature findings
- Planning task (with prior movement information) changes the pupil constriction prior to the movement in Pro and Anti saccades, while Cueing task (without this information) does not show these differences. This may be evidence of how prior information about the movement affects the eye's pupil size changes.
- Although young healthy controls have similar characteristics for the maximum constriction between Pro and Anti conditions in Planning and Self-Initiated Timing tasks, we expect that people with Parkinson's disease will have impaired Self-Initiated saccades and differences between these tasks.
- We anticipate that people with Parkinson's disease will have slower reaction times and slower peak velocities compared to young, healthy controls because of documented movement impairment in PD.

Future Directions

- Run correlation between behavior data and pupil size
- Next steps: run more statistics to look for differences in structured tasks vs. self-initiated, finish collecting data when possible
- Eventually adapt protocol to PD