Amplitude Changes in Response to Target Displacements During Human Eye-Head Movements

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Introduction

With the head restrained, changes in saccade amplitude can be produced by displacing a visual target during a saccade (McLaughlin, 1967). This form of saccadic adaptation has been described in both humans and monkeys (Hopps & Fuchs, 2004). We investigated the effects on gaze, eye, and head movement amplitudes when targets were displaced during large amplitude horizontal gaze shifts made by head-unrestrained human subjects during the McLaughlin paradigm.

Methods: *Centered Initial Eye Positions (IEPs)*

SUBJECTS: Seven human subjects (4 male, 3 female; range 21-28 years of age) participated in this study. All subjects, except the first author (Subject YA), were initially naïve to the behavioral relevance and specific tasks described below. All subjects were free of gross neurological or sensory impairment.

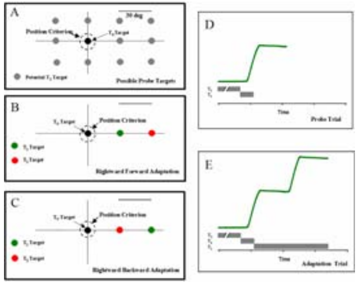
EXPERIMENTAL APPARATUS AND MEASURES:

- **Test Chamber**: darkened room, spherical presentation screen.
- **Subject Orientation:** Subjects sat upright in an orthopedic chair and were free to move their eyes and heads. Subjects were instructed to keep their torso as still as possible for the duration of the experiment, however the body was not physically restrained.
- **Visual Targets & Presentation:** Targets were 13 computer-controlled red lasers that were presented on a hemi field subtending ±80º horizontally and ±40º vertically.
- **Measurements**: Eye and head movements were monitored using search coils (Collewijn et al. 1975; Skalar Delt, The Netherlands). Subjects wore a lightweight head band with an imbedded search coil and a laser used for head calibration and head pointing.

TRIAL TYPES:

In each trial type (Figure 1) subjects were required to align the head laser and fixate a stationary target (T_0). Following this fixation period (250-1500ms) the T_0 was turned off and another target (T_1) was illuminated at another spatial location. In "probe" trials T_1 was turned off after the gaze signal had moved out of a computer defined window centered on the T_0 location (Figure1 A & D). After the same criterion was met in "adaptation" trials (Fig 1E), the T_1 target was extinguished a new target (T_2) was illuminated either further away ("Forward Adaptation" Fig. 1B) or closer to ("Backward Adaptation", Fig. 1C) the initial fixation point (T_0).

Figure 1: Trial Types & Target Positions



DATA ANALYSIS:

- During adaptation and probe trials, the beginning and end of each primary Gaze, Eye, and Head movement were marked using a velocity criterion.
- Average primary Gaze, Eye, Head Contribution, and Total Head movement amplitudes were calculated from the last five pre-adaptation probe, post-adaptation probe, and post-adaptation trials (Figure 3, 4 & 7).
- Statistical significance was determined using Bonferroni corrected t-tests (p<0.05) .

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Results: *Centered Initial Eye Positions*

Figure 2: Example Gaze Behavior (Adapt Trials)

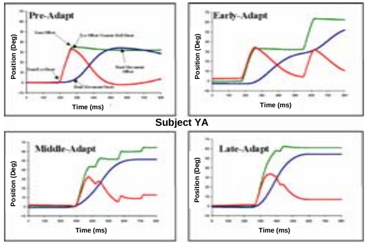


Figure 2. Gaze (green), eye (red), and head (blue) positions as functions of time during a rightward forward adaptation session (subject YA) in which the eyes were initially centered in the orbits (±5°). Each panel illustrates a gaze shift made a a different stage of the adaptation process.

Figure 3: Behavioral Change as a Function of Time

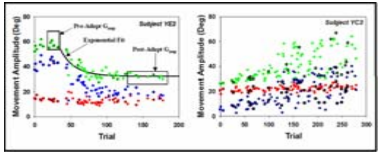


Figure 3. Gaze (green), eye (red), and head contribution (blue) amplitudes as a function of trial number for a backward (A) and forward adaptation experiment (B). Gaze, eye, and head contribution data from probe trials are signified by black dots surrounded by the appropriate color.

Figure 4: Average Changes in Gaze, Eye, and Head

Forward Adaptation | **Backward Adaptation**

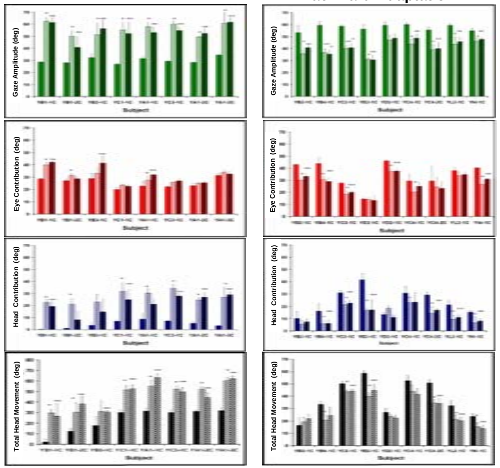


Figure 4. Pre-adaptation probe (solid), post-adaptation probe (diagonal stripe) and post adaptation trial (black boxes) mean ±SD for the primary gaze (green), eye (red) and head (black) movements. Head contribution to the gaze shift is shown in blue. (*) denotes a significant difference between Pre-Adaptation probes and Post Adaptation Probes; (**) denotes a difference between Pre-Adaptation Probes and Post Adaptation trials (Bonferonni corrected p<0.05).

Summary and Conclusions

- The "McLaughlin Task" can be used to produce large changes (~15 to 30°) in the amplitude of gaze shifts made by head-unrestrained human subjects (Gaze Adaptation).
- During both adaptation and probe trials when the eyes were initially ***centered*** in the orbits, changes in the amplitudes of primary gaze shifts generally resulted from changes in ***both*** eye and head contributions (forward & backward adaptation).
- During both adaptation and probe trials when the eyes were initially ***displaced in the orbits*** (in the direction of the ensuing gaze shift) changes in primary gaze amplitudes could be accomplished by changes only in the ***head*** contribution.
- We hypothesize that the changes in gaze shift amplitude, induced by surreptitious displacement of the visual target, occur at the level of a gaze shift command and not at the level of separate eye and head movement commands.

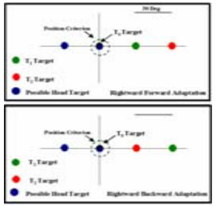
Citations

Collewiijn, H, van der Mark F, Jansen, TC. (1975). Precise recording of human eye movements. *Vis Res.* 15(3):447-50.

Hopp, JJ, Fuchs, AF (2004). The characteristics and neuronal substrate of saccadic eye movement plasticity. *Prog Neurobiol.* 72(1):27-53.

McLaughlin, S. (1967). Parametric adjustment in saccadic eye movements. *Percept. Psychophys.* **2**, pp. 359–362.

Figure 5: Methods For Multiple Initial Eye Positions



Results: *Positive Initial Eye Positions*

Figure 6: Example Gaze Behavior (Adapt Trials)

Figure 6. Gaze (green), eye (red), and head (blue) positions as functions of time (subject YA) during a rightward forward adaptation session. Eyes were initially deviated in the orbits (+28° to +32°).

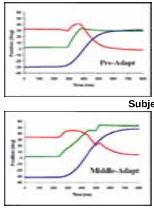


Figure 7: Behavioral Change as a function of Time

Figure 7. Gaze (green), eye (red), and head contribution (blue) plotted as functions of trial number for a forward adaptation experiment. Gaze, eye, and head contribution data from probe trials are indicated by black dots surrounded by the appropriate color.

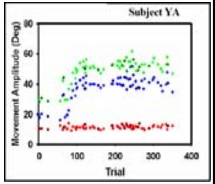


Figure 8: Average Changes in Gaze, Eye, and Head

Forward Adaptation (A)

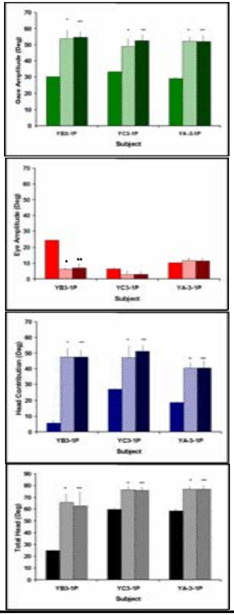
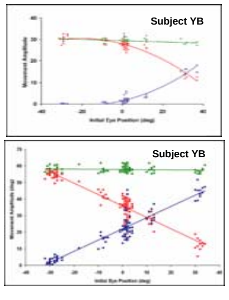


Figure 8. Pre-adaptation probe (solid), post-adaptation probe (diagonal stripe) and post adaptation trial (black boxes) mean ±SD for the primary gaze (green), eye (red) and head movements (gray) during forward (A) and backward (B) adaptation experiments. Head contribution to the gaze shift is shown in blue. (*) denotes a significant difference between Pre-Adaptation probes and Post Adaptation Probes; (**) a difference between Pre-Adaptation Probes and Post Adaptation trials (Bonferonni corrected p<0.05). Panel C represents the effects of IEP on the relative contribution of the eyes and head to gaze shifts during probe trials taken from a non-adaptation experiment

IEP Effects (C)



Backward Adaptation (B)