Covert Shifts of Attention Precede Involuntary Eye Movements

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ABSTRACT

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It is generally believed that covert attention and eye movements are inexorably linked, such that the planning of an eye movement automatically leads to a shift of covert attention to the saccade target. Previous research demonstrating this link has concentrated on voluntary eye movements. In two experiments, we examined whether covert attention precedes involuntary eye movements made to onsets. The task was to move the eyes to a small uniquely colored saccade target and to identify which of two letters were contained within. At the same time that the target changed color, an irrelevant onset appeared. To measure covert attention, we placed large response compatible or incompatible probes at the location of either the onset or the colored target. Probes were identifiable from central fixation and only visible between the presentation of the target and onset and the initiation of the first saccade. When the eyes moved to the intended color target, only probes at the location of the saccade target affected responses, and no trace of covert attention was found at the location of the onset. When the eyes made an involuntary saccade to the onset, probes at the onset affected response times, indicating that covert attention had preceded the eyes to the onset. However, probes at the color target also affected response times, but not when they were presented during the first 100 ms. This suggests that covert attention first made an involuntary shift to the onset and then made a corrective shift to the intended target, even though this was followed a short time later by an unintentional saccade to the onset. These results suggest that eye movements are a valid measure of the initial shift of covert attention. Consequently, this suggests that previous experiments showing only modest oculomotor capture by onsets are indicative of only modest covert attentional capture. Results are discussed in terms of a horse-race model between voluntary and involuntary signals.

INTRODUCTION

- Covert attention and eye movements are coupled: covert attention always precedes an eye movement to the saccade target (Deubel & Schneider, 1996; Hoffman & Subramaniam, 1995).
- Response time studies have suggested that abrupt onsets always capture attention (Yantis & Jonides, 1984).
- However, abrupt onsets capture the eyes at a lower rate (25-30%) than suggested by RT studies (Theeuwes et al., 1998).

Two possibilities:
1) The original RT studies overestimate onset capture
or
2) Covert attention does not necessarily precede involuntary eye movements.

PARADIGM

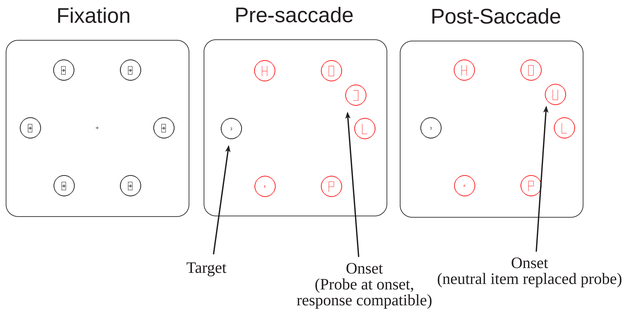
Task based on Theeuwes et al (1998).

Task: When the color change occurs move the eyes to the white circle and determine if a small C or reverse-C is present.

Probe: used to measure covert attention
- Probes were a C or reverse-C
- Response compatible or incompatible with the target
- Large enough to be identified from fixation
- Were only visible after the color changed.
- Replaced by a neutral letter when the eyes moved (Exp 1.)
- Probe occured at Target or Onset locations.

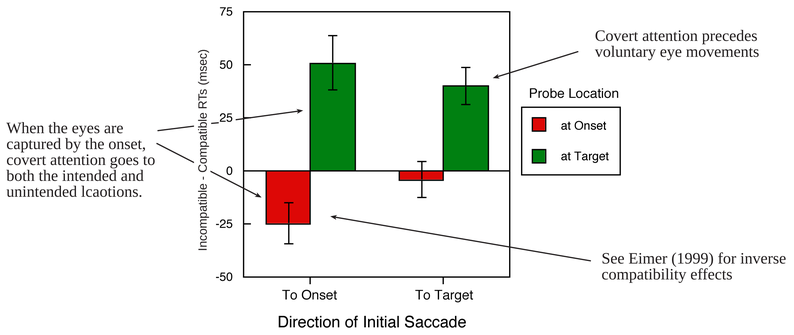
Covert Attention Measure: Response compatibility effect
- Incompatible RT - Compatible RT
- contingent on direction of initial saccade.

METHOD



Covert Results (Exp 1)

- Compatibility Effects calculated by subtracting Compatible RT from Incompatible RT.
- Contingent on direction of initial saccade
- Probe occured at target or onset location



1) Covert attention precedes the eyes to the intended location

2) When an involuntary eye movement is made, covert attention precedes the eyes to the involuntary and the intended locations.

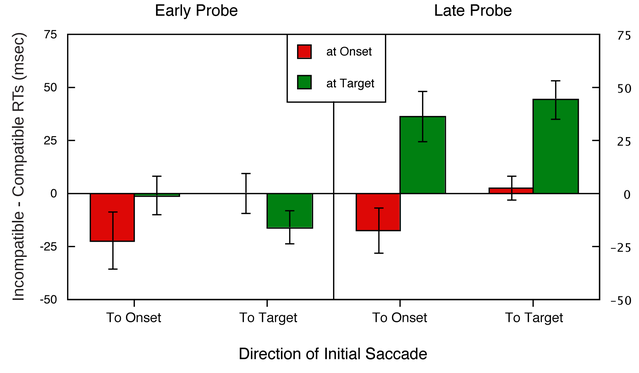
Experiment 2

Q: When the eyes make an involuntary saccade, does attention…

(a) Split between the intended and unattended locations?
(b) Go to the intended location on some trials and the unintended location on other trials.
OR
(c) Mirror the eventual eye movements, by first going to the intended location followed by a rapid shift to the intended saccade target.

METHODS & RESULTS

2 Probe times:
Early Probe: First 100 msec, then replaced by neutral item.
Late Probe: changes from neutral item to probe 100 msec after color change. Changes back to neutral items when saccade is made.



Suggests attention first moves to the unintended location followed by a switch to the intended saccade target, mimicing the eventual eye movements (option #3).

Conclusions

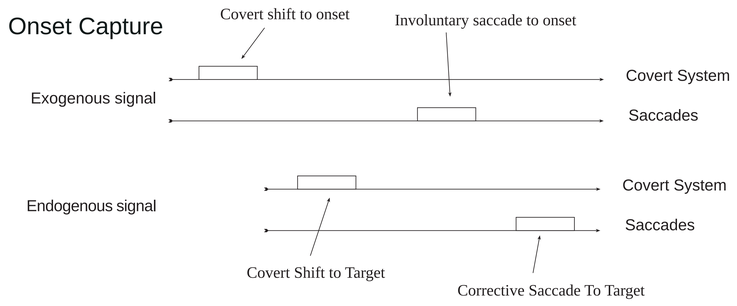
(1) Covert attention always precedes a saccade.

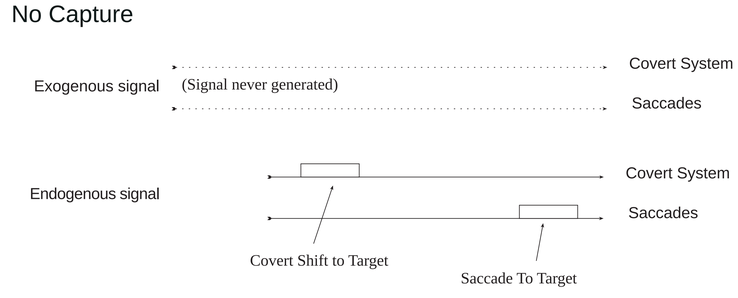
(2) Therefore, eye movements are a valid indicator of shifts of covert attention.

(3) Suggests that onsets do not automatically capture covert attention (Peterson & Kramer, in press).

Model of covert and overt attention

- A signal to move the eyes automatically leads to a signal to shift covert attention.
- Control of orienting is a horserace between endogenous and exogenous signals.
- Exogenous signals are faster than endogenous signals and always win the control for attention.
- An onset fails to capture attention when an exogenous signal fails to be generated. Note that subjects never made a "corrective" saccade to the onset on trials in which their eyes first went to the target.
- Additional transient noise (e.g. the color change) might lead to the failure of an exogenous signal to be generated (see Martin-Emerson & Kramer, 1997).
- Less time is needed to switch covert attention than to plan an eye movement. This allows covert attention to precede a saccade (or a saccade to lag a covert shift).





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