Vision Research 133 (2017) 81–86

Contents lists available at ScienceDirect

Vision Research

journal homepage: www.elsevier.com/locate/visres

Peripheral target identification performance modulates eye movements

Min-Suk Kang [a,b,*], Sori Kim [b], Kyoung-Min Lee [c]

[a] Center for Neuroscience Imaging Research (CNIR), Institute for Basic Science (IBS), Suwon, Republic of Korea
[b] Department of Psychology, Sungkyunkwan University, Seoul, Republic of Korea
[c] Department of Neurology, Seoul National University Hospital, Seoul, Republic of Korea

ARTICLE INFO

Article history:
Received 9 March 2016
Received in revised form 26 December 2016
Accepted 27 December 2016

Keywords:
Eye movement
Inhibition

ABSTRACT

We often shift our eyes to an interesting stimulus, but it is important to inhibit that eye movement in some environments (e.g., a no-look pass in basketball). Here, we investigated participants' ability to inhibit eye movements when they had to process a peripheral target with a requirement to maintain strict fixation. An array of eight letters composed of four characters was briefly presented and a directional cue was centrally presented to indicate the target location. The stimulus onset asynchrony (SOA) between the cue and the stimulus array was chosen from six values, consisting of pre-cue conditions (−400 and −200 ms), a simultaneous cue condition (0 ms), and post-cue conditions (200, 400, and 800 ms). We found the following: 1) participants shifted their eyes toward the cued location even though the stimulus array was absent at the onset of eye movements, but the eye movement amplitude was smaller than the actual location of the target; 2) eye movements occurred approximately 150 ms after the onset of stimulus array in the pre-cue conditions and 250 ms after cue onset in the simultaneous and post-cue conditions; and 3) eye movement onsets were delayed and their amplitudes were smaller in correct trials than incorrect trials. These results indicate that the inhibitory process controlling eye movements also compete for cognitive resources like other cognitive processes.

1. Introduction

Cognitive operations processing visual information are closely linked to eye movements. If an interesting object captures an individual's attention when walking along a street, the person tends to make an eye movement towards that object. However, it is important to inhibit such eye movements in some situations. For example, basketball players tend to inhibit their eye movements so that defenders cannot determine where the ball will be passed. Furthermore, it is common for volunteers in laboratory experiments to maintain fixation for an extended period of time while processing visual information in the periphery.

Nevertheless, the ability to inhibit eye movements interacts with cognitive processes. First, the mere presence of a fixation point influences saccadic eye movements, such that simply removing the fixation point (the gap condition) decreases saccadic latency substantially (Fischer & Ramsperger, 1984). The influence of fixation in controlling eye movements is more dramatically portrayed in anti-saccade tasks (Hallett, 1978; Munoz & Everling, 2004). In the anti-saccade tasks, participants have to inhibit their eye movements and shift their eyes to the opposite side of the target position. Yet, participants occasionally shift their eyes erroneously to the target location and these erroneous saccades to the target location increase in frequency and decrease in latency with the extinction of the fixation point (Dorris & Munoz, 1995; Fischer & Weber, 1997). Second, microsaccades refer to very small saccadic eye movements that we are not even aware of (Steinman, Haddad, Skavenski, & Wyman, 1973). Recent studies have provided evidence that microsaccades reflect cognitive processes and even serve our vision (Rolfs, 2009). For example, microsaccades modulate perceptual processing (Martinez-Conde, Macknik, Troncoso, & Dyar, 2006; Poletti, Listorti, & Rucci, 2013) and reflect shifts in covert attention (Engbert & Kliegl, 2003; Hafed & Clark, 2002; Yuval-Greenberg, Merriam, & Heeger, 2014) and task load (Kang & Woodman, 2014, Siegenthaler et al., 2014). In a related vein, eye movements including microsaccades are inhibited following external visual or auditory stimulation (Engbert & Kliegl, 2003; Hafed & Clark, 2002; Hafed & Ignashchenkova, 2013; Pastukhov & Braun, 2010; Rolfs, 2009). Third, eye movements to a particular location are inhibited when inhibiting visual or memory representations occurring at that location (Belopolsky & Theeuwes, 2011; Theeuwes, Olivers, & Chizk, 2005). Taken together, these studies provide reasons to analyze the ability to inhibit eye movements

* Corresponding author at: Department of Psychology, Sungkyunkwan University, Seoul, Republic of Korea.
E-mail address: kangminsuk@skku.edu (M.-S. Kang).

http://dx.doi.org/10.1016/j.visres.2016.12.020
0042-6989/

in relation to cognitive operations involved in processing visual information.

One particular aspect of the interaction is that the inhibitory control of eye movements is weakened with task demand. Increasing working memory load leads to higher errors in anti-saccade tasks due to reduced inhibitory control for reflexive eye movements (Mitchell, Macrae, & Gilchrist, 2002; Roberts, Hager, & Heron, 1994) and so do other dual-tasks (e.g., perceptual judgment tasks) for unpracticed participants (Evens & Ludwig, 2010). Halliday and Carpenter (2010) also concluded that inhibitory control is weakened with task demand. In their study, participants had to move their eyes to a green, peripheral stimulus (go-trial) but maintain fixation for a red, peripheral stimulus (no-go trial). With an additional task to perform, the error rate as well as saccades with very short latency in the no-go trials increased. Theoretically, these results indicate that the inhibition of eye movements compete for the same cognitive resources like other cognitive processes (e.g. attention); however, its implication is limited because overt eye movements were required to perform the task and the inhibition of eye movements was evaluated when eye movements were made erroneously.

In the present study, we asked the same question without requiring eye movements to perform the task to establish the conclusion and its theoretical implications over settings that are more relevant to many laboratory experiments. Participants reported the target item among an array of eight letters indicated by a centrally presented arrow cue under the instruction of strict fixation (Fig. 1). We used a central cue to indicate the target location because such cues are less potent in eliciting eye movements in a particular direction than exogenous, peripheral cues. In addition, we varied the stimulus onset asynchrony (SOA) between the cue and the stimulus array to manipulate visual processing of the cued stimulus. The SOA was chosen from six values, consisting of pre-cue conditions (−400 and −200 ms), a simultaneous cue condition (0 ms), and post-cue conditions (200, 400, and 800 ms).

According to previous studies, despite instructing participants to maintain fixation throughout the trials, participants would shift their eyes toward the target location irrespective of whether the target was available in the pre-cue conditions (Engbert & Kliegl, 2003; Hafed & Clark, 2002) or in the post-cue conditions (Kang & Woodman, 2014). Post-cue conditions are particularly critical to the present study. If the inhibition of eye movements and other cognitive processes (e.g. attention) compete for the same cognitive resources, the shift toward the target should be larger in the incorrect trials than the correct trials. This is because attention or decision-making processes could have been involved for a longer period of time when the target representation was unavailable or ambiguous than when the target stimulus was available with confidence and, thus, the task demand should be higher in the incorrect trials than correct trials. Instead of directly manipulating task demand by increasing memory load or another task to perform, we decided to compare the correct and incorrect trials mainly because changing stimulus configuration can also modulate reflexive and microsaccadic eye movements (Hafed & Ignashchenkova, 2013; Kang & Woodman, 2014).

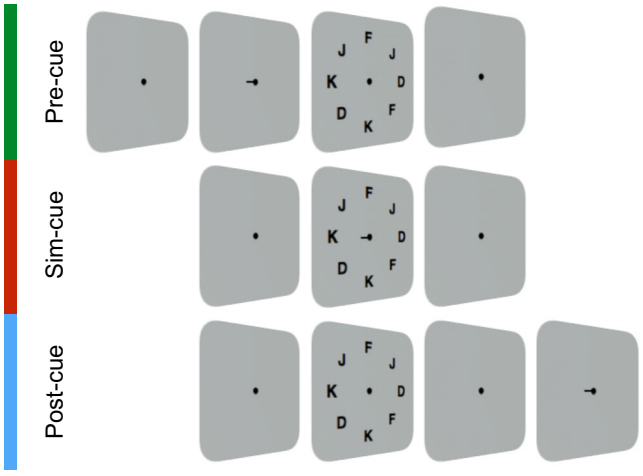

Fig. 1. Illustrations of the stimulus sequence of a pre-cue condition, simultaneous-cue condition, and post-cue condition.

2. Methods

2.1. Participants

The experiment was carried out in accordance with the Declaration of Helsinki. Seventeen volunteers (age: 19–28 years, average 23.3 years; 12 females) participated in the present study after providing informed consent in advance for procedures approved by Sungkyunkwan University's Institutional Review Board. The participants received monetary compensation (approximately 10 USD per hour). They declared that they had normal color vision, visual acuity, and no neurological history. Data from two participants were excluded from the analysis because too many trials were lost due to eye blinks (50%), and thus it was difficult to obtain meaningful data from each condition. As a result, 83.8% of trials were used for the analysis on an average (range 59.8–95.7%).

2.2. Apparatus

The participant was seated with his or her head positioned on a chin rest, 60 cm from a computer screen, in a dimly illuminated room. All stimuli were presented on a CRT monitor (1024 × 768 pixels resolution; 31 × 24 cm size; 85 Hz refresh rate; 70.69 cd/m^2 mean luminance) using the Psychophysics Toolbox-3 (Brainard, 1997; Pelli, 1997) running on a Mac Mini (Apple, Cupertino, CA, USA). The participants' eye movements were recorded using an Eyelink II (SR Research, Ontario, Canada) video-based eye tracker with the video camera attached to the chin-head rest. For all participants, the positions of both eyes were recorded at a 500 Hz sampling rate.

2.3. Stimuli and procedures

Fig. 1 illustrates three stimulus sequences. A stimulus array consisted of eight black capital letters, namely D, F, J, and K (subtending approximately 0.5° × 0.7° of visual angle), each of which appeared twice, in randomized positions (Lu, Neuse, Madigan, & Dosher, 2005). The eight letters were equally spaced, occupying four cardinal locations and four diagonal locations, and separated from the fixation point by 3.0°. The fixation point was a small dot (0.1° in diameter) and the cue was a short clock hand (0.3°) pointing to one of the eight locations.

The stimulus sequence consisted of a brief fixation (500 ms), cue (100 ms), and stimulus array (100 ms). SOA determining the interval between the cue and stimulus array was chosen from six values (−400, −200, 0, 200, 400, and 800 ms). In the pre-cue conditions, the cue preceded the stimulus array (−400 and −200 ms SOAs). In the simultaneous cue condition (0 ms), the cue and stimulus array were presented at the same time. In post-cue conditions (200, 400, and 800 ms SOAs), the cue was presented after the stimulus array. The fixation point was presented throughout the trial to facilitate the participant's fixation.