NeuroImage 81 (2013) 158–163

Contents lists available at SciVerse ScienceDirect

NeuroImage

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

The impact of distractor congruency on stimulus processing in retinotopic visual cortex

Todd A. Kelley, Geraint Rees, Nilli Lavie *

Institute of Cognitive Neuroscience, University College London, UK

ARTICLE INFO

Article history:
Accepted 22 April 2013
Available online 3 May 2013

Keywords:
fMRI
Attention
Response competition
Flanker
V1
Retinotopic cortex

ABSTRACT

The brain is frequently confronted with sensory information that elicits conflicting response choices. While much research has addressed the top down control mechanisms associated with detection and resolution of response competition, the effects of response competition on sensory processing in the primary visual cortex remain unclear. To address this question we modified a typical 'flanker task' (Eriksen and Eriksen, 1974) so that the effects of response competition on human early retinotopic visual cortex could be assessed. Healthy human participants were scanned using fMRI while making a speeded choice response that classified a target object image into one of two categories (e.g. fruits, animals). An irrelevant distractor image that was either congruent (same image as target), incongruent (image from opposite category as target), or neutral (image from task-irrelevant category, e.g. household items) was also present on each trial, but in a different quadrant of the visual field relative to the target. Retinotopic V1 areas responding to the target stimuli showed increased response to targets in the presence of response-incongruent (compared to response-neutral) distractors. A negative correlation with behavioral response competition effects indicated that an increased primary visual cortical response to targets in the incongruent (vs. neutral) trials is associated with a reduced response competition effect on behavior. These results suggest a novel conflict resolution mechanism in the primary visual cortex.

Introduction

Most stimuli encountered in the environment elicit some form of response, related either to previous direct experience or to an indirect association. Coherent goal-directed behavior requires the suppression of responses to stimuli that are irrelevant to the current task in order to prevent response conflicts. This is not always successful; people often fail to ignore irrelevant stimuli and the tendency to respond to them elicits response conflicts, which reduce the efficiency of task performance (e.g. by slowing down task responses).

The neural correlates of response conflict include a network of parietal and prefrontal regions responsible for identifying response conflict, resolving it in favor of the goal-relevant 'target' in accords with current task goals, and redeploying attention accordingly (e.g., Bunge et al., 2002; Carter et al., 1998; Fan et al., 2003; Hazeltine et al., 2000; Kerns et al., 2004; MacDonald et al., 2000; van Veen et al., 2001). However, typically this 'resolution' of conflict does not prevent perception of the distracting stimuli (exceptions are cases of high perceptual load in the task, see Lavie, 2005, 2010; or conflict adaptation through sequential repetition of incongruent stimuli, e.g. Egner, 2007). That task-irrelevant stimuli are perceived even in cases of correct response selection (following resolution of the conflict in response tendencies) is clearly evident from typical findings that response times are slower on incongruent compared to congruent or neutral trials. Thus while it is clear that the fronto-parietal network controls response selection, it remains unclear whether the identification of conflict and its resolution in terms of response selection has any effect on the sensory processing of target and of the distractor stimuli. Specifically, when people encounter a response conflicting distractor stimulus but successfully select the correct target response, are there any effects on sensory visual processing related to the target or distractor perception?

In the present study we used fMRI to elucidate the effects of response competition on the sensory processing of the target and distractor stimuli. To that purpose we modified a well-established response-competition task (Eriksen and Eriksen, 1974) for an experiment that allowed us to investigate the sensory visual correlates of response competition. Using images of common objects presented in separate visual quadrants, we were able to isolate the early visual cortical response to the target and distractor images under varying conditions of response congruency. We also further analyzed the response in retinotopic cortex relative to the magnitude of behavioral congruency effects.

* Corresponding author at: 17 Queen Square, London, WC1N 3AR, UK.
E-mail address: n.lavie@ucl.ac.uk (N. Lavie).

1053-8119
http://dx.doi.org/10.1016/j.neuroimage.2013.04.094

Material and methods

Participants

Seventeen people recruited from the University College London experiment pool participated in this study for monetary compensation. Two people were excluded from the final analysis: one because of excessive head motion during the scanning session, and one because the participant's mean RT and overall accuracy on the behavioral task were more than 2.5 standard deviations away from the group mean. This resulted in a final pool of 15 participants (six females, ages 18–35). All participants provided informed consent in accordance with the UCL ethics committee.

Stimuli

For the main task, the stimuli consisted of 12 gray scale images of objects spanning three different categories: fruits (strawberry, apple, pineapple, banana), household items (desk, sofa, fan, chair), and animals (cat, bird, bear, turtle). These images fit within a square that measured six degrees of visual angle on a side, and were positioned within the middle of each visual quadrant at a center-to-center distance of six degrees from the fixation point in the middle of the display. The stimuli were presented on a gray background; text and the fixation cross were presented in black.

For a functional localizer, the stimuli consisted of a disk with alternating black and white quarters, presented at the same size and location as the images in the main task. The contrast of the disks reversed at a rate of 5 Hz. The background, fixation cross and text color were the same as in the main task. For the retinotopic mapping runs, the stimuli consisted of pairs of wedges oriented along either the horizontal or vertical midlines and arranged in a "bow-tie" pattern. The interior of the wedges contained a black and white checkerboard pattern whose luminance oscillated at 8 Hz, and were presented on a gray background. Each wedge constituted an arc of 30 radial degrees.

The experiment was run on an Intel-based computer running Windows XP. The stimuli were generated and presented using MATLAB software (MathWorks, Natick, Massachusetts). This experiment was realized using Cogent 2000 developed by the Cogent 2000 team at the WTCN and the ICN and Cogent Graphics developed by John Romaya at the LON at the WTCN.

Task procedure

Participants were instructed to perform a category judgment task on one member of a pair of briefly presented images. Images were presented in two of the four possible locations (one location in each visual quadrant), both within the same hemifield (upper, lower, left, right). Two of the four possible locations were defined a priori as target locations during the participants' instruction period; these locations were always arranged along the diagonal (i.e. upper-left and lower-right, or lower-left and upper-right, counterbalanced across participants), such that one (and only one) image of each trial pair was presented in a target location. Participants judged which object category the target image belonged to in a 2AFC task; two of the three object categories (fruit, household item, animal) were defined as target categories at the beginning of the session (counterbalanced across subject, crossed with target locations).

Trials proceeded as follows. The fixation cross appeared in the middle of a blank display. 500 ms later, task images appeared in one of the configurations described above, and were present for 200 ms. Fig. 1 shows the stimuli from an example trial, where the upper-left and lower-right quadrants are defined as target locations. Participants then had 1.8 s to respond; the fixation cross remained visible during this time. Trials fell into one of three types, based on the identity of the non-target image: congruent (same image as the target), incongruent (image from opposite category as the target), or neutral (image from the task irrelevant category). Although our imaging comparisons involved only the incongruent and neutral conditions, the congruent condition was included to drive conflict in the incongruent condition (otherwise if the response-related distractors were always incongruent, the incongruent condition would become predictive of the (opposite) target). Identical images were used for the congruent condition, rather than different images from the same category, so as to avoid inducing conflict due to condition ambivalence (e.g. Santee and Egeth, 1982, Perception & Psychophysics).

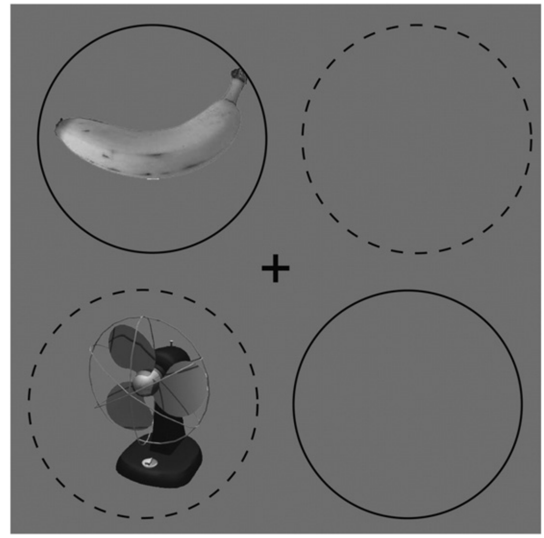

Fig. 1. Display example from a single trial. Solid circles indicate target locations; dashed circles indicate distractor locations. These locations were defined based on instructions to the participant. Circles were not present during the experiment. Target and distractor diagonals varied from participant to participant.

At the beginning of each experiment session, prior to the start of scanning, participants were given verbal and written instructions, followed by a practice block that was identical in all respects to block of trials during the main task. Participants completed four blocks of trials in the scanner. Each block consisted of 60 trials; trial type, target location and target category were all counterbalanced within each block. Blocks also contained 20 null trials, where the fixation cross appeared alone for 2.5 s and no response was required. Trials were separated by a variable interval (measured from the onset of fixation of one trial to the onset of fixation of the subsequent trial) of 3 to 7 s, to facilitate an event-related analysis. Each block began with a fixation period measuring 22.8 s (10 functional volumes) and ended with a fixation period measuring 11.4 s (5 functional volumes), and lasted ~428 s.

Scanning sessions also contained two blocks of retinotopic mapping and two blocks of a functional localizer. Retinotopic mapping scans lasted 296 s, and consisted of alternating periods of stimulation along the horizontal and vertical visual meridians, lasting 18 s each. Participants were instructed to maintain fixation, but given no other task. Functional localizer scans lasted 347 s, and consisted of alternating periods of stimulation in the target and non-target locations lasting 22.8 s. Blocks also contained 22.8 s of fixation at the beginning of the block, 11.4 s of fixation at the end of the block, and two 22.8 s of fixation occurring during the middle of the block. Participants were instructed to maintain fixation, and respond with a button press to a luminance increment in the fixation cross lasting 200 ms (this occurred once during each stimulation period).

The stimuli were presented on a projection screen mounted at the end of the scanner bore, and viewed using a mirror mounted on the head coil. Responses were made using MR compatible fiber-optic button boxes.

Imaging data collection and analysis

Imaging data were collected at the Wellcome Trust Centre for Neuroimaging using a 3-T Siemens Allegra Scanner with an 8-channel head