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Temporal dynamics of neural adaptation effect in the human visual ventral stream

Yasuki Noguchi*, Koji Inui, Ryusuke Kakigi

Department of Integrative Physiology, National Institute for Physiological Sciences, 38 Nishigonaka, Myodaiji, Okazaki 444 8585, Japan

Abstract. When the same visual stimulus is repeatedly presented with a brief interval, the brain's responses to that stimulus are attenuated relative to those at first presentation (neural adaptation, NA). Although this effect has been widely observed in various regions of human brain, its temporal dynamics as a neuronal population has been mostly unclear. In the present study, we used a magnetoencephalography (MEG) and conducted a macrolevel investigation of the temporal profiles of the NA occurring in the human visual ventral stream. We dissociated three dimensions of the NA: activation strength, peak latency, and temporal duration of neural response. The results revealed that visual responses to the repeated as compared with novel stimulus showed a significant reduction in both activation strength and peak latency but not in the duration of neural processing. These results indicate that (i) the NA involves brain response changes in the temporal domain as well as the response attenuation reported previously, and (ii) this temporal change is mainly observed as a rapid rising of 'what' responses rather than a temporal shortening of neural response curves within the visual ventral stream as previously considered.

Keywords: Priming; Repetition suppression; Ventral pathway; Human; Magnetoencephalography

1. Introduction

One common finding in neurophysiological and neuroimaging studies is a reduced neural response to repeated as compared with unrepeated stimuli (neural adaptation, NA) [1]. Although this attenuation was first reported in inferior temporal neurons of monkeys, recent studies using positron emission tomography (PET) and functional magnetic

* Corresponding author. Tel.: +81 564 55 7715; fax: +81 564 52 7913.
E-mail address: noguchi@nips.ac.jp (Y. Noguchi).

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resonance imaging (fMRI) showed that the effect also occurs in various regions of the human brain, including the occipital, parietal, and inferior frontal cortices.

In spite of mounting evidence of the repetition attenuation, the temporal profiles of this effect as a neural network have been poorly understood probably due to the limited temporal resolution of hemodynamic imaging methods, such as PET and fMRI. In the present study, we used magnetoencephalography (MEG) and measured directly the neural response changes underlying the NA in higher visual area of the human brain. The original part of this article has been published previously [2], reproduced here with the permission from the publisher (Copyright 2004 by the Society for Neuroscience).

2. Material and methods

Ten healthy volunteers participated in the present study. Informed consent was received from each participant, and approval for these experiments was obtained from the Ethics Committee of the National Institute for Physiological Sciences, Okazaki, Japan.

One problem with MEG experiments on visual function is that the neuronal signals from the higher visual areas are difficult to be distinguished from those in early visual cortex (such as V1) in most cases. Since neural responses in the early visual areas are relatively insensitive to the repetition effect compared with those in the later visual areas [3], the confounding of early visual signals into MEG data in the present study would obscure the NA effect occurring in higher visual areas. We therefore presented visual stimuli based on our random dot blinking (RDB) technique developed previously [4]. With this method, characters are presented in the center of a black-and-white random dot field (6×6 degrees). Although all dots in the field flicker continuously (60 Hz) in the resting state, a subset of dots becomes static during the character presentation period while the other dots remain dynamic (Fig. 1). This static–dynamic contrast enables observers to perceive the shape of a letter. Since the ratio of white and black pixels is fixed throughout both periods (white:black=1:3), the mean luminance of the field is always the same. Our previous study has shown that this stimulation paradigm effectively inhibits the neural responses from the V1 area and elicits one simple component of magnetic response at a peak latency of ~300 ms, the signal source of which is estimated to lie in the occipito-temporal area around the fusiform gyrus.

Using the RDB method, two visual stimuli (letters) were sequentially presented in the present study. We used six capital letters (A, O, E, B, K, P) as letter stimuli. The display duration of S1 and S2 was 300 and 500 ms, respectively. The time interval between S1 and

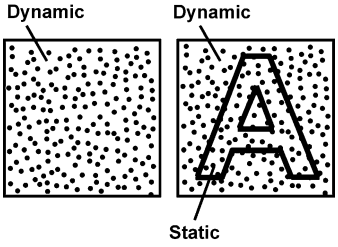

Fig. 1. Random dot blinking method. The resting period (left) and character presentation period (right).