

GROUPING OF TARGET SEQUENCES FOR CONSCIOUS REPORT

Chie Nakatani and Cees van Leeuwen
Laboratory for Perceptual Dynamics
RIKEN Brain Science Institute
cnakatani@brain.riken.jp, ceesvl@brain.riken.jp

Abstract

A single target presented in a sequence of non-target items (distracters) is detected easily, even when each item is presented less than 100 ms. However, when the number of targets is increased to two, the second one becomes hard to detect. In particular, the second target (T2) is often missed when it is followed by a distracter and the lag from the first target (T1) is 200-500 ms (i.e., attentional blink). However, paradoxically, when T2 is presented just after T1, T2 is often successfully reported (i.e., Lag-1 sparing). A possible explanation of Lag-1 sparing is that T1 and T2 are grouped due to their adjacency in time. We considered this explanationo against the alternative hypothesis that both targets are separately encoded and submitted to working memory. As a neural measure of such processes, we took cross-lag EEG phase synchronization. The results suggest that Lag 1 sparing involves grouping at the item level, while attentional blink is caused by lack of consolidation at the individual item level.

Perception emerges through interaction of information processing and environment. This interaction takes place, primarily, in the brain. The brain, however, is not a static medium; it has its own dynamics of activity. Brain activity in various spatio-temporal scales takes the form of oscillation. Large-scale oscillations can be measured at the scalp using electroencephalography (EEG). In the current study we intend to demonstrate a close correlation between oscillatory EEG activity as characterized by its phase and the efficiency of perception.

To determine the efficiency of perception, we used target detection in a distracter sequence. A target presented in a rapid stimulus sequence (~10 items/sec) usually is detected easily. However, when two targets (T1 and T2) are presented in sequence, T2 is often missed when the two are 200-500 ms apart. This phenomenon is called attentional blink (Broadbent et al., 1987; Raymond et al., 1992). However, a second target presented just after the first is often detected (i.e., Lag-1 sparing). It has been considered that AB indicates a psychological 'refractory period', while Lag-1 sparing suggests a mechanism to circumvent the capacity limitation of visual working memory. The mechanism is thought of as a kind of integration of the target items due to their adjacency in time.

In a previous study, we hypothesized that the phase of whole-head gamma synchrony can reveal the underlying mechanism for the AB and Lag-1 sparing. We studied these effects using cross-lag EEG phase synchronization measurement. The results showed that synchrony in the gamma band (around 40 Hz) of activity increased between different brain regions when targets in AB conditions were reported successfully (Nakatani et al., 2005). The synchrony covered the whole head, and appeared even before T1 presentation. The frequency of whole-head synchrony on and offset was about 4 Hz, i.e. the Gamma activity of a given pair of sites went from synchronized to desynchronized approx. every 125 ms. In the current study, we extended the phase-synchrony analysis to a wider range of frequency bands, including, besides gamma, beta, alpha, theta, and delta bands.

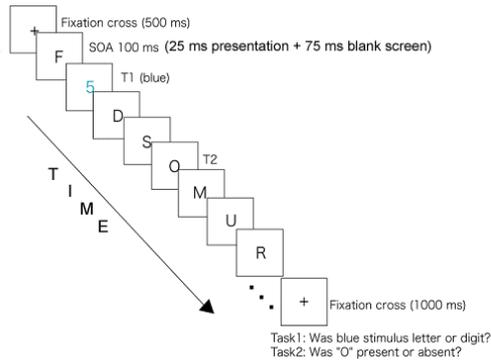


Figure 1. RSVP stream and tasks.

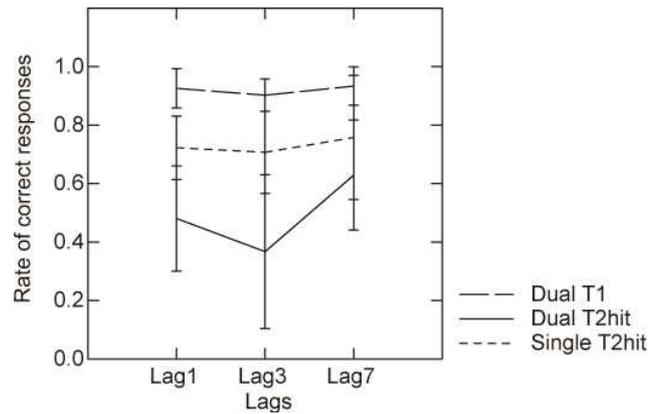


Figure 2. Behavioral results

Method

Participants

Four male and four females (mean age: 23.75 years-old) participated to the experiment. All had normal or corrected-to-normal vision.

Task

On each trial, a rapid sequence of visual stimuli was presented (RSVP) at a rate of 100 ms each (stimulus presentation duration was 25 ms, followed by 75 blank). T1 (blue character) occurred in 100 % and T2 (“O”) in 50 % of the trials. T2 occurred 100, 300, or 700 ms after T1 (Lag-1, Lag-3, Lag-7, respectively). Trials were presented in experimental and control blocks; Experimental conditions require both categorization of T1 (whether the blue stimulus was letter or digit) and detection of T2 (if letter “O” was present); control conditions require detection of T2 only (See Figure 1).

EEG recording and processing

We recorded 62 EEG and 2 EOG channels at a 1000 Hz sampling rate. Linked ears were used as reference and re-referenced with averaged activity of the 62 channels (cf. Guevara et al., 2005). Five frequency bands were chosen to represent delta, theta, alpha beta, and gamma band activity. The respective central frequencies were 3, 6, 10, 20 and 40 Hz; bandwidth was ± 2.5 %. Instantaneous phase was computed using the Hilbert transform. A dynamic phase synchronization index (dcPSI) was computed for 565 electrode pairs that cover the whole head (See Nakatani et al., 2005, for the computation details of dcPSI).

Results and Discussion

Behavioral results

As shown in Figure 2, the percentage of successful T2 report was lowest in the Lag 3 condition, lower than those in the Lag 1 and Lag 7 conditions, $t(7) = 3.25$, $p < .05$, $t(7) = 2.83$, $p < .05$ for the comparison between the Lag-3 and Lag-1, and the Lag-3 and Lag-7, respectively (Probabilities were adjusted using Bonferroni’s method). Thus, AB and Lag 1 sparing were obtained.

EEG results

Fig. 3 shows the number of electrode pairs that showed higher dcPSI in dual than in single task conditions ($p < .05$ based on t-value distributions generated by using a bootstrap method. See Nakatani et al 2005 for details). Higher values indicate more synchronization between regions. Values are larger when T2 was detected (thick line) than when T2 was missed (thin line) in all bands. This result shows that synchrony in a wide range of frequencies correlates with successful T2 detection

A cycle of whole-head synchrony took different duration among bands. In the gamma band (the lowest panel in Figure 3), the whole-head synchrony oscillated in an approximately 4Hz rhythm, opposite in phase at T2 onset between T2-hit and T2-miss trials – near the lowest point of its cycle when the T2 was successfully detected, at the maximum of its cycle when the target was missed. The result may be understood if the gamma-synchrony reflects inhibitory activity (Fries et al, 2007). In the beta band, the synchrony also oscillated in an approximately 4Hz rhythm, but the pattern was reversed from those in gamma synchrony. In particular, in the Lag-1 condition, the beta synchrony was at the peak of its cycle around the T2 onset when T2 was detected (i.e., Lag-sparing). There is no such clear relationship in the Lag-3 and 7 conditions. Taken together, the results suggest that Lag-1 sparing occurs when inhibition due to gamma-synchrony is weak, and beta-synchrony is strong. We may understand this as a combination of weak inhibition plus binding events across time (Gross, et al, 2004). In the alpha, theta and delta band, the frequency of the oscillation was 1- 3 Hz. In the Lag-3 condition, large-scale synchronization was observed after T2. The peak latency is around 300 ms from T2 onset. The peaks may relate to P300 ERP (Vogel, et al., 1998). In the Lag-1 condition, however, such peaks were not observed. This may indicate that T2 processing in the Lag-3 condition requires more neural resources in post T2 period than that in the Lag-1 condition.

References

- Broadbent, D. E., & Broadbent, M. P., (1987). From detection to identification: Response to multiple targets in rapid serial visual presentation. *Perception & Psychophysics*, 42, 105-113.
- Fires, P., Nikoloc, D., & Singer, W. (2007). The gamma cycle. *Trends in Neurosciences*, 30, 309-416.
- Gross, J., Schmitz, F., Schnitzler, I., Kessler, K., Shapiro, K., Hommel, B., & Schnitzler, A. (2004). Modulation of long-range neural synchrony reflects temporal limits of visual attention in humans. *Proceedings of National Academy of Sciences U. S. A.*, 101, 13050-13055.
- Nakatani, C., Ito, J., Nikolaev, R. A., Gong, P., & van Leeuwen, C. (2005). Phase Synchronization Analysis of EEG during Attentional Blink. *Journal of Cognitive Neuroscience*. 17, 1969-1979.
- Raymond, J. E., Shapiro, K. L., & Arnel, K. M. (1992). Temporary Suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance*, 18, 849-860.
- Vogel, E. K., Luck, S. J., & Shapiro, K. L. (1998). Electrophysiological evidence for a postperceptual locus of suppression during the attentional blink. *Journal of Experimental Psychology: Human Performance and Perception*, 24, 1656-1674.

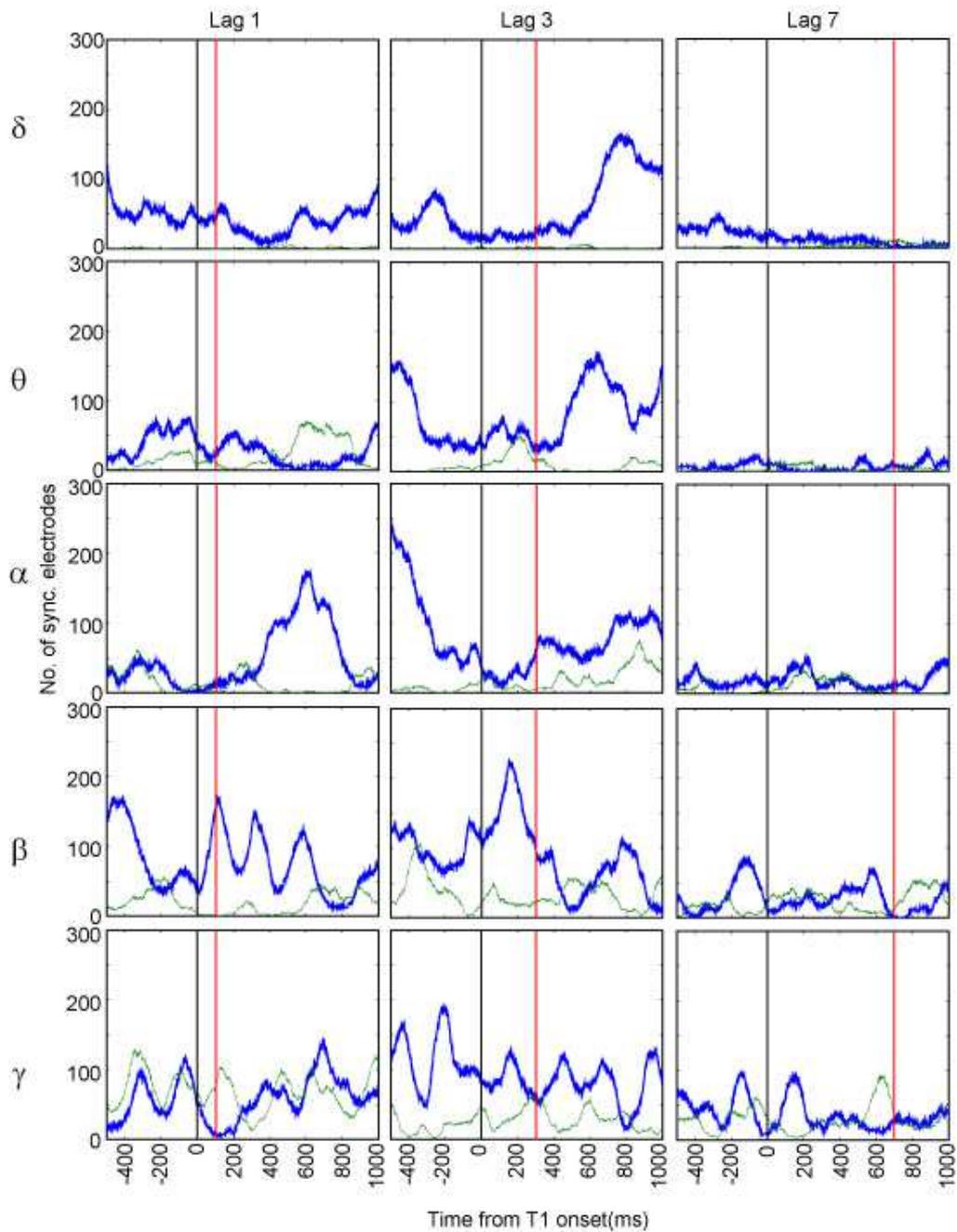


Figure 3. Dynamic EEG phase synchronization during AB task

Rows: delta, theta, alpha, beta and gamma band frequencies. Columns: Lag 1, 3 and 7 conditions. T1 and T2 onset are indicated by vertical lines. Time plots for T2 hit (thick line) and T2 miss (thin line) trials shows the number of electrode pairs with increased synchrony compared to control conditions.