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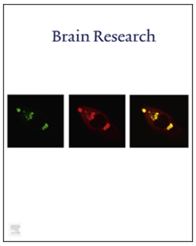

Brain Research

Review

Memory for pure tone sequences without contour

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ABSTRACT

We presented pure tones interspersed with white noise sounds to disrupt contour perception in an acoustic short-term memory (ASTM) experiment during which we recorded the electroencephalogram. The memory set consisted of seven stimuli, 0, 1, 2, 3, or 4 of which were to-be-remembered tones. We estimated each participant's capacity, K, for each set size and measured the amplitude of the SAN (sustained anterior negativity, an ERP related to acoustic short-term memory). We correlated their *K* slopes with their SAN amplitude slopes as a function of set size, and found a significant link between performance and the SAN: a larger increase in SAN amplitude was linked with a larger number of stimuli maintained in ASTM. The SAN decreased in amplitude in the later portion of the silent retention interval, but the correlation between the SAN and capacity remained strong. These results show the SAN is not an index of contour but rather an index of the maintenance of individual objects in STM.

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Contents

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1. Introduction

Maintenance of auditory stimuli is indexed by an event-related-potential (ERP) component called the SAN (sustained anterior negativity, Lefebvre et al., 2013, see also Nolden (2015), for a review). This component is characterised by an increase in negativity correlated with an increase in load in short-term memory (STM). It is induced by sounds that cannot be labelled and are not linked to language. In all studies of the SAN, either pure tones varying in pitch, not corresponding to standard musical scales, (Lefebvre et al., 2013; Guimond et al., 2011; Nolden et al., 2013a; Alunni-Menichini et al., 2014; Grimault et al., 2014), or tones varying in timbre (Nolden et al., 2013b) were used. The SAN is thus unlikely to be the result of processes related to language.

The SAN is usually measured during the second half of the retention interval of a standard short-term memory (STM) task. In such a task, to-be-memorised stimuli are presented, followed by a silent period during which they are simply maintained in memory. Probe stimuli are then presented. The task is to compare probe and memorised stimuli to determine if they are the same or different. By focusing on the later part of the retention interval, we eliminate the possibility of inadvertently measuring unfinished perception and encoding processes, or comparison and response related processes that occur during and after probe presentation. Additionally, we preceded tone stimuli with white noise bursts so that whatever the number of tones to be memorised, the total duration of stimulation and number of events would be the same in all load conditions. This precaution further ensures that the SAN is only related to the maintenance of tones, and not to the processing of a larger amount of stimulation.

Most importantly, however, is that the increase in negativity that characterises the SAN is correlated not necessarily to the number of stimuli presented, but to the number of stimuli actually maintained in memory by each participant (Lefebvre et al., 2013, Alunni-Menichini et al. 2014). This link between individual behaviour and brain activity is what makes this component powerful and interesting as an index of acoustic short-term memory, much like its visual counterpart, the SPCN (or CDA, see Vogel and Machizawa, 2004) for the visual domain.

The SAN is measured at fronto-central scalp sites, mainly AFz (Lefebvre et al., 2013b; Nolden et al., 2013), Fz (Alunni-Menichini et al., 2014), and FCz (Guimond et al., 2011). Its underlying processes were further investigated and localised using MEG. Grimault et al. (2014) used a task similar to Lefebvre et al. (2013) to uncover various areas in which activations correlated with auditory STM (ASTM) load. They identified areas in the right superior/middle and middle/inferior temporal gyrus, superior/middle and middle/inferior frontal gyrus, and the right middle/inferior frontal and pre-central gyrus. Nolden et al. (2013a), this time using a task in which stimuli were presented simultaneously, also identified retention activity in the right superior temporal gyrus, right inferior temporal gyrus, and the right inferior frontal gyrus. They also found activations correlated with load in the right superior parietal lobule, left superior temporal gyrus and right precuneus. It remains to be determined if these differences stem from different stimulus presentation methods (sequential versus simultaneous) or from another cause.

To further remove the possibility that the mere sensory processing of the stimuli triggered the SAN, as opposed to maintenance in memory, previous experiments included various control conditions. In Lefebvre et al. (2013), the same stimulation was presented in both experimental and control trials. The difference was in the task: the control condition required participants to ignore the first sequence of tones, and instead perform a task on the second sequence. This resulted in a small increase in negativity under all load conditions, and therefore showed that the SAN reflected active memory maintenance rather than simple sensory activation (see Lefebvre et al., 2013). Guimond et al. (2011) followed the same logic and obtained similar results, but this time the control task was performed in an entirely different experiment. Consequently, control and experimental trials were presented in different blocks in these two experiments. Being focused on presenting exactly the same data in a different context, we did not mix trials from the experimental and control conditions. This blocked procedure is a good one, but it leaves the possibility that participants may be in a different state in control and experimental blocks, or that they may have prepared differently for experimental and control tasks. Although it is not obvious how these differences could have produced systematic load effects, we want