ATTENTION ENHANCES POSITIVITY IN AUDITORY EVOKED POTENTIALS: EVIDENCE FOR AN INHIBITORY PROCESS FACILITATING STIMULUS SALIENCY

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INTRODUCTION

The level of vigilance strongly modulates the shape of evoked potentials. With decreasing levels of vigilance, the N1 of the human auditory evoked potential is attenuated\(^3,4\). The N1 is regarded as indicative of stimulus registration\(^2\), presumably underlying the perception of the stimulus\(^9\). N1 is largest under wake conditions, but seems relatively insensitive for the attention towards the stimulus. The P2 component is often interpreted as a further processing of the stimulus, although there is a tendency to become larger in sleep. P2 is shaded off into P3 or P300, with unclear boundaries. The slow P300 wave is mostly elicited with an oddball paradigm and is generally associated with stimulus recognition\(^10\), related to a high sensitivity for attention. A debate is still going on whether a P300 can be generated in sleep. Components of the auditory evoked potentials in humans recorded during the several sleep-wake states can be interpreted by taking into consideration the phenomenon of sensory gating, which reduces components underlying stimulus registration reflected in N1. The growth of P2 in sleep, on the other hand, seems to be related to the change in neuronal firing patterns associated to the transition of the wake into the sleep state\(^7\). The present research aimed to extend the previous experiment\(^4\), investigating the shape of the evoked potential in sleep-wake states, by modulating the factor attention towards the stimuli in the waking state. Two conditions were created: an attended situation and an unattended situation. All circumstances were identical to the previous experiment and only pure tones were used. This is in contrast to most attention experiments, which are often carried out by using the oddball paradigm. Subjects were exposed to pure tones and got the instruction to count the tones (attend condition) or to ignore the tones, by performing a covert calculation (unattended condition). In this way, the level of attention in wakefulness was changed within one modality. Both conditions were investigated with eyes open and eyes closed, to see whether there were differences in the amount of attention or ignorance paid to the stimuli.

METHODS

Eleven healthy students (8 males and 3 females, mean age 21.2 ± 0.7) were tested in an electrically shielded and sound-attenuated chamber. Brain electrodes were placed according to the 10-20 system and attached to the left and right mastoid to record the electroencephalogram. The signal was filtered between 0.1 and 45 Hz, and recorded at a sampling rate of 1000 Hz. EOG electrodes recorded eye blinks as well as lateral and vertical eye movements. All electrode impedances were kept below 3 kΩ. Auditory stimuli were tones of 1000 Hz and 40 dB (calibrated to white noise background sound) with a duration of 50 ms.
Tones were presented through a loudspeaker standing right behind the subjects. Inter-tone intervals were between 2 and 7 seconds. The experiment consisted of two blocks; starting after a short habituation period. In the first block subjects had to count the number of tones and report the result at the end to the experimenter. In the second block subjects were instructed not to pay attention to the tones, by covertly performing a calculation. Both blocks consisted of two parts: one with eyes open and one with eyes closed. Each part of these two blocks consisted of about 60 auditory stimuli and had an average duration of 5 minutes. The total experiment lasted for about 30 minutes. Evoked potentials were constructed off-line for an epoch of 1000 ms including a pre-auditory stimulus baseline of 250 ms. All epochs including eye movements changes exceeding 150 μV in amplitude were removed. The resulting auditory evoked potentials were averaged over subjects (grand averages).

RESULTS AND DISCUSSION

In Figure 1 the grand averages of the auditory evoked potentials of the attended and unattended condition of 11 subjects are shown, in the eyes open and closed condition. First of all, the general patterns of the auditory evoked potentials from the eyes open and eyes closed condition are quite similar. The unattended evoked potential clearly shows a large negative peak around 100-200 ms (N1) and a positive wave around 200-300 ms (P2). The shape of the potentials is very similar to earlier findings in the awake, unattended condition 3, 4, 8. The small difference in N1 amplitude with the eyes open (larger in the attended than in the unattended condition) disappears when the eyes are closed. N1 is thought to reflect the primary excitation and is associated with the firing response of cortical cells towards an auditory stimulus 3. From this point of view it is also understandable that this component is relatively insensitive to the state of the brain.

![Figure 1](image_url)

**Figure 1.** Grand averages of auditory evoked potentials made from position Cz. The attended condition involves counting of the tones whereas the unattended condition involves calculating. Negativity is directed upwards.
In particular, the later positive component is more sensitive to attentional processes and differs significantly between the attended and unattended condition. The P2 is enhanced and longer lasting (around 200-400 ms), going over in P3 or P300. This extensive positive complex is the main difference between the attended and unattended evoked potential, being much larger in the attended condition. A positive deflection of an evoked potential has been associated with inhibitory processes \(^1,5,6,7\), while a negative potential is linked to excitation \(^5\). This could mean that after the initial excitation seen in N1, neurons undergo a long-lasting inhibition in the attended condition, reflected in a prominent P2-P3. Additional evidence for this view is proposed by Araki and colleagues \(^1\). Perhaps, this presumed active inhibition is meant to suppress irrelevant information and improves the signal-to-noise ratio, making the stimulus-bound-activity even more salient. This interpretation suggests that the auditory attention process involves mediation of inhibition of irrelevant information, rather than a focus on relevant information.

CONCLUSION

Auditory evoked potentials are often used to investigate the effects of vigilance and attention. In the current experiment, the level of attention was changed in wakefulness by counting tones (attended condition) versus performing a calculation during tone presentation (unattended condition). Evoked potentials show a remarkable difference in positivity between the attended and unattended condition. This is interpreted in a way that positivity reflects an active inhibitory process; this inhibitory process is much more prominent in the attended condition compared to the unattended condition. A probable function of this strong inhibitory process could be that irrelevant information is more suppressed in the attend condition, resulting in more salient relevant information.

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