



# Learning Morse code results in cortical plastic changes: evidence from ERPs.



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## Abstract

This study examined the possibility that learning Morse code could result in cortical changes in processing of acoustic features, as indexed by the mismatch negativity (MMN) and P3a components of the auditory event-related potential (ERP). ERPs were recorded in 9 subjects who were learning Morse code. The subjects were presented with auditory stimuli at 3 different times relative to their training (before, during and after). These stimuli were presented within an auditory 'oddball' paradigm, with repetitive standard stimuli interspersed by one of 3 infrequent deviant stimuli (duration, frequency or SOA). The data showed that there was a significant increase in the P3a only for frequency deviants as a function of training. There were no differences in MMN amplitude as a function of training. These data are interpreted in terms of an attentional switching to unfamiliar changes that would not be expected whilst receiving Morse code.

## Introduction

Acquiring high competence in auditory-related tasks is known to induce plastic changes in the adult brain (e.g. Pantev et al., 2001a,b). However, for an adult, an auditory skill is hardly ever completely novel. The learning of Morse code communication, where alphabets are replaced with tone combinations, provides a rare case where the effects of intensive training of a totally new skill on the auditory system can be studied. Previous work from our group (Kujala et al., 2003) already showed that learning Morse code results in cortical plastic changes for processing Morse syllables. The present study extends this work by determining whether learning the code would also affect the perception of purely physical features of simple non-speech acoustic tones that have no semantic meaning in Morse. We hypothesized that with the development of expertise in Morse code, participants would show corresponding changes in brain activity in the form of heightened processing of physical features of the acoustic environment.

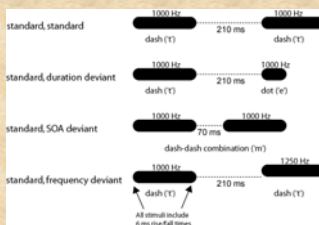


Figure 1: Diagrammatic representation of stimulus sequences. Starting from the top, the first sequence shows a sequence of 2 repetitive standard stimuli. The second sequence shows a sequence of 1 standard followed by a duration deviant. The third sequence shows a sequence of otherwise identical stimuli where the second stimulus in the sequence is an earlier than usual SOA deviant. The fourth sequence shows a sequence of 1 standard stimulus followed by a frequency deviant. All stimuli include 6-ms rise/fall times.

## Methods

### Participants

Nine participants (healthy and normal hearing) were recruited from the Finnish Navy (aged 18-20, all males and right handed). These recruits underwent a Morse-coding course as part of their service. The training comprised a large amount of rehearsal in which the participants listened to Morse code and translated it to written letters. The training lasted at least 2 hours per day for 5 days a week and continued for 3 months.

### Materials and procedure

The ERP measurements were carried out before, during (halfway through), and immediately after the Morse code training course. All the 3 different deviant stimuli occurred in the same sequence in which a 'standard' sinusoidal tone with 1 kHz frequency and 210 ms duration was repeated at a constant SOA of 420 ms. The standard tone was replaced occasionally by one of the 3 different deviant tones differing from the standard in either SOA, frequency or duration (see Figure 1). The frequency and duration of the standard tones corresponded to that of the tones used in the Morse code course and could conceivably (though not through deliberate instruction) be perceived by the participants as a stream of Morse code letters (see Figure 1). Each of these 3 deviants occurred randomly and with a probability of 6%. The duration of the stimuli also included 6 ms rise and fall times. The stimuli were presented binaurally at 50 dB above hearing threshold.

In each measurement, the participants were presented with the same sequences of stimuli via earphones while they concentrated on watching a self-selected video. During the experiment, EEG was continuously recorded (pass band D.C. to 50 Hz, sampling frequency 250 Hz) in an acoustically and electrically shielded room with Ag-AgCl electrodes placed at Fpz, Fz, F3, F4, F7, F8, Cz, C3, C4, Pz, left and right mastoids of the 10-20 system. The horizontal and vertical eye movements were monitored with electrodes placed at the outer canthus of and above the right eye. The reference electrode for the EEG and EOG was placed on the nose. The EEG was averaged off-line separately for the standard and the different types of deviant stimuli. The difference curves were calculated by subtracting the responses to the standard stimuli from those to the deviant stimuli.

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## Results

The frequency, duration, and SOA changes elicited clear MMN responses before, during, and after the course (Figs.2 & 3). The training had no significant effect on the amplitudes of the MMN elicited by the frequency, duration, and SOA changes. Instead, training only affected the amplitude of the frequency P3a, which increased significantly (main effect of Training,  $F(2,14) = 12.3$ ,  $p < 0.01$ ; 2-way ANOVA with factors Training and Electrode, see Figs 2 & 3). A subsequent post-hoc comparison revealed that the amplitude of the P3a response to the frequency change was larger when recorded after the training course compared with the amplitudes of the P3a responses recorded before ( $p < 0.001$ ) and during ( $p < 0.005$ ) the course (see Figs 2 and 3).

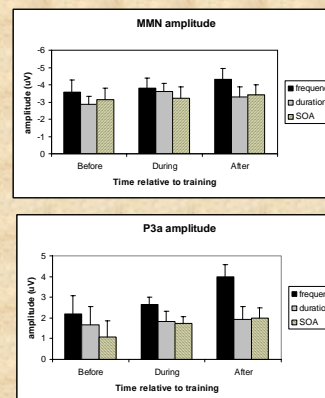


Figure 2: MMN and P3a component mean amplitude and peak latency as a function of training.

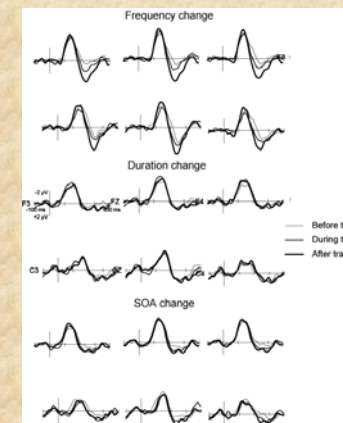


Figure 3: Difference (standard minus deviant) ERP waveforms for frequency, duration and SOA changes as a function of training at frontal and central sites.

## Discussion and Conclusions

Prima facie, one would expect that Morse training would have resulted in increased involuntary attention to changes in temporal features (duration and SOA). However, we found an increase in involuntary attention to frequency. This finding seems to be most likely related to the fact that these Morse coders were presented with Morse code at the same given frequency during their training. Hence, tones at a standard frequency would have been a sign of a familiar 'carrier' frequency through which the Morse message was transmitted. Thus, frequency becomes an attribute which could signify the input channel for important stimuli, thereby serving as an 'attentional gating' mechanism, at least in a context of Morse-like stimulation.

In a sense, the frequency deviant was the only 'true' deviant as the other deviants were 'usual' or 'familiar' changes that participants had come to expect as part of receiving Morse code. For example, the duration and SOA changes presented within our paradigm were all usual changes that participants might perceive as part of ordinary Morse present in their daily environment. On the other hand, the frequency deviation used in our study was from a standard 1000 Hz tone (the pitch at which they usually processed Morse) to a less familiar 1250 Hz frequency (see Figure 1). Therefore, the frequency deviant change to 1250 Hz could have signified an attentional switch to 'unfamiliar' or 'novel' sound that was not the same as their standard Morse signals. Furthermore, the fact that the P3a to duration and SOA was not enhanced with training would imply that this was not a simple chance effect of P3a enhancement. Of course, the issue of whether the unfamiliar frequency change would have been processed as 'non-morse' or simply 'unfamiliar Morse' is one which could only be resolved with further study contrasting, for example, 'non-Morse' changes in duration or indeed in other 'Morse-irrelevant' dimensions such as intensity.

Nonetheless, the finding that there were plastic changes in the neural processing of pitch changes as a function of training clearly suggests that participants become more sensitive to novel changes in the carrier frequency of tones than they otherwise would without training. These findings also suggest that attentional switches can therefore function to mediate important changes in the environment that signal unusual changes in the acoustic environment.

In summary, the present data suggest that training in Morse code does indeed result in plastic changes for processing simple physical features in a Morse-like context. The finding of enhanced P3a for frequency but not SOA or duration suggests that these changes result in a selective 'gating' or 'tuning' for specific frequencies corresponding to the frequency at which Morse code was being delivered.

## References

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