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 schedule (before, during, and after). These stimuli included an auditory ‘oddball’ paradigm, with a deviant deviant stimulus interspersed by one of 3 infrequent deviant stimuli (duration, frequency or SOA). The standard and deviant stimuli were identical in all respects except for one of the parameters (e.g. frequency). The deviant stimuli occurred at random times during the course of the experiment. The ERP waveforms were analyzed to determine whether the learning of Morse code would also affect the perception of purely physical features of simple non-speech acoustic tones that have no semantic meaning to trained Morse readers. The hypothesis is 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.

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 extended previous work on 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 to Morse readers. We hypothesised 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.

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 3 different deviant stimuli occurred in the same sequence in which a ‘standard’ stimulus was followed by 1 kHz sine wave and 270 ms duration was repeated and replaced by a different deviant. The standard tone was replaced occasionally by one of the 3 different deviant stimuli differing from the standard in either SOA, frequency or duration (see Figure 1). The frequency and duration of the standard tones corresponded to all of the tones used in the Morse code course and could consequently (though not through deliberate instruction) be perceived by the participants as a stream of Morse code (see Figure 1). Each of these 3 deviants occurred randomly and with a probability of 6%. The duration of the stimulus also included 6 ms rise and fall times. The stimuli were presented binaurally at 50 dB above threshold. In each measurement, the participants were presented with the same sequence of stimuli via earphones while they concentrated on watching a self-selected video. During the experiment, EEG was continuously recorded (pass band DC to 50 Hz, sampling frequency 250 Hz) in an acoustically and visually shielded room with Ag/AgCl electrodes placed at Fz, F2, P3, P4, F7, F8, Cz, C3, C4, Pz, left and right mastoids of the 10-20 system. The vertical and horizontal eye movements were monitored with electrodes placed over 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 stimulus. The difference curves were calculated by subtracting the responses to the standard stimuli from those to the deviant stimulus.

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 deviant, 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 deviant 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).

Discussion and Conclusions

Prima facie, one would expect that Morse code training would result in increased involuntary attention to changes in temporal features (duration and SOA). However, we found an increasing 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 become a signal of the 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 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 become accustomed to during their training. For example, the duration and SOA changes presented within our paradigm were all usual changes that participants might perceive as part of ordinary Morse code 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 changed to a 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 was only seen in our training data as a result of increased ‘novel’ or simply unfamiliar Morse is one which could only be resolved with further study concerning, for example, non-Morse changes in duration or indeed in other Morse-like 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 sounds 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 of tones in a Morse-like context. The findings 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.

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References

