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Short communication

Name conditioning in event-related brain potentials

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A R T I C L E I N F O

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A B S T R A C T

Four experiments are reported in which two harmonic tones (CS+ and CS−) were paired with a participant's own name (SON) and different names (DN), respectively. A third tone was not paired with any other stimulus and served as a standard (frequent stimulus) in a three-stimuli oddball paradigm. The larger posterior positivity (P3) to SON than DN, found in previous studies, was replicated in all experiments. Conditioning of the P3 response was albeit observed in two similar experiments (1 and 3), but the obtained effects were weak and not identical in the two experiments. Only Experiment 4, where the number of CS/UCS pairings and the Stimulus-Onset Asynchrony between CS and UCS were increased, showed clear CS+/CS− differences both in time and time–frequency domains. Surprisingly, differential responses to CS+ and CS− were also obtained in Experiment 2, although SON and DN in that experiment were masked and never consciously recognized as meaningful words (recognition rate 0/63 participants). The results are discussed in the context of other ERP conditioning experiments and, particularly, the studies of non-conscious effect on ERP. Several further experiments are suggested to replicate and extend the present findings and to remove the remaining methodological limitations.

1. Introduction

Effects of classical conditioning on human Event-Related Brain Potentials (ERPs) have been examined in a number of studies (for review, see Christoffersen & Schachtman, 2016; Miskovic & Keil, 2012). Most of them used highly aversive unconditioned stimuli (UCS) (e.g., Hermann, Ziegler, Birbaumer, & Flor, 2000; Pizzagalli, Greishar, & Davidson, 2003). As a rule, CS are complex visual stimuli, e.g., faces (Begleiter & Platz, 1969) or words (Montoya, Larbig, Pulvermüller, Flor, & Birbaumer, 1996). Very few studies employed both CS and UCS of auditory modality (Heim & Keil, 2006; Hugdahl & Norby, 1991; Juan et al., 2016; Pauli & Röder, 2008).

Because auditory classical conditioning, due to its technical simplicity, can be applied in children and severely disabled individuals, and because using highly aversive UCS in these groups is ethically problematic, looking for other kinds of UCS is important. Having in mind the potential application in patients with severe brain damage, in the present study we intended to explore the effect of classical conditioning on ERP to simple stimuli. Relatively simple harmonic tones were chosen as CS, based on the finding that harmonic tones elicit more distinct and stable ERP effects than sine tones in both healthy individuals (Tervaniemi et al., 2000) and neurological patients (Kotchoubey et al., 2003). An individual's own name, which has been suggested to possess particular significance for the individual, was used as a non-aversive UCS. The effects of a subject's own name (SON) on ERPs have been established in normal populations (Fischler, Jin, Boaz, Perry, & Childers, 1987) and severely brain-injured patients (Perrin et al., 2006), in waking state (Holeckova, Fischer, Giard, Delpuech, & Morlet, 2006) and during sleep (Perrin, Garcia-Larrea, Mauguiere, & Bastuji, 1999). In a three-stimulus oddball, in which SON and a control stimulus (usually, a different name: DN) are presented as two rare stimuli, SON elicits a larger P3 component than DN (e.g., Kotchoubey, Lang, Herb, Maurer, & Birbaumer, 2004; Perrin et al., 2006). We expected to obtain a similar effect in response to harmonic tones (presented as CS) paired with names.

2. Methods: General

Three different groups of healthy participants took part in the study: one group (nine males and 14 females, aged 22–29) in Experiment 1, the second group (nine males and 13 females, aged 22–29) in Experiments 2 and 3, and the third group (twelve males and 13 females, aged 19–42) in Experiment 4. In the second group Experiment 2 always preceded Experiment 3. Data of two males in Experiment 2 were excluded (thus the group contained 7 males).

None of the participants had had any disease of the nervous system or hearing disorders in the past, or reported use of any drugs during the last week before the experiment. Participants were seated in a

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comfortable chair and asked to close their eyes and to listen attentively to the stimuli. Informed consent was obtained from each participant. The study was approved by the Ethical Committee of the University of Tübingen.

The EEG in all experiments was recorded using 64 active ActiCHamp electrodes (Easycap GmbH, Herrsching, Germany) located according to the extended 10–20 system. The vertical and horizontal electrooculagram were also recorded. The resistance was below 15 kOhm. Online reference was at Cz, offline re-referenced to average mastoids. The digitalization rate was 1000 Hz.

Off-line inspection of the recordings revealed in some traces poor data quality in one or two of the 64 channels. These channels were replaced with interpolation of the adjacent electrodes. After this, an Independent Component Analysis (ICA) was employed for each participant to separate and remove activity due to ocular artifacts using the AMICA algorithm (Palmer, Kreutz-Delgado, & Makeig, 2012). Components clearly related to eye movements were removed using EEGLAB. Additionally, components that were mapped onto one electrode and could be clearly distinguished from EEG signals were subtracted from the data. EEG segments that still contained artifacts after ICA correction were dismissed. The ERPs were filtered within a band from 0.1 to 30 Hz and averaged in relation to a baseline from −200 ms to 0 ms. As we supposed that the responses would change during the roughly 7-min test phase, ERPs were averaged separately for the first, second, and third thirds of the whole sequence of 400 stimuli. The three periods, corresponding to stimuli 1–133, stimuli 134–266, and stimuli 267–400, will be referred to as T1, T2, and T3, respectively. Each average included at least 18 (usually 20) CS+ and CS−.

The amplitudes of ERP components were measured as the area under the curve within the time windows slightly different for UCS (N1: 70–120 ms, P3a: 240–300 ms, P3b: 300–400 ms, Late Time Window [LTW]: 400–600 ms) and CS (N1: 100–140 ms, P3a: 220–280 ms; P3b: 280–380 ms; LTW: 380–550 ms). The LTW was not designated as "P" or "N" because the amplitude was negative in anterior but positive in posterior leads. The time–frequency analysis was performed using Morlet wavelet by means of the Fieldtrip toolbox and followed the method of Cavanagh, Frank, Klein, and Allen (2010). The entire epochs were defined as [−1500 2500] ms to avoid edge artifacts. Baseline correction and decibel normalization was performed in respect to [−400 −100] ms interval. After a visual exploration of grand averages across all subjects, conditions, channels, and experiments, two time–-frequency (TF) windows were extracted: "P3" (200–350 ms, 9–12 Hz) and "LTW" (400–650 ms, 6–8 Hz).

For brevity, the present report describes only those data that are related to the critical comparison between the CS+ and CS− responses at the midline electrodes Fz, Cz, and Pz, were the effects were best pronounced. The statistical analysis was performed using a repeated measures ANOVA with factors Stimulus, Site, and Time. When appropriate, we used Greenhouse-Geisser non-sphericity correction for degrees of freedom.

3. Experiment 1

3.1. Methods

ERPs were recorded to three chords, each consisting of five harmonic tonal frequencies (e.g., 330, 660, 1320, 2640, and 5280 Hz). One of the chords was used as standard and the other two served as CS+ and CS−. During the *acquisition phase*, CS+ was paired 21 times with SON, and CS− was randomly paired 21 times with three different names (DN). All names were spoken with the official German pronunciation by a female speaker, not familiar to any participant. The control names originated from the same pool of the most frequent German names used for each subject's own name. They always had a very similar duration as the own name (means 669 ms and 676 ms) and contained the same number of syllables. The standard was presented 21 times, not accompanied by any other stimulus. Tone duration was 200 ms, and the intensity was 75 dB above the average threshold. The stimulus-onset-asynchrony (SOA) within a pair tone-name was 300 ms. The SOA after a tone-word pair was 1700–1800 ms, and after standards it was 1150–1250 ms. All stimuli were presented binaurally through aerodynamic earphones, in a pseudorandomized order, in which none of the three tones appeared more than three times in a row.

In the *test phase*, which followed immediately after the *acquisition phase*, the standard was presented 280 times, and CS+ and CS− 60 times each. No other stimuli were presented. The SOA varied between 950 and 1050 ms. The order of presentation was randomized except that CS+ and CS− could not be delivered more than twice in a row.

3.2. Results

All participants reported after the experiment, that they had heard "two or three" different harmonic tones, and that at the beginning one of the tones was linked to their own name, and another tone, to other names.

The *acquisition phase* replicated the already known effect of a larger P3 to SON. The effect was most clear in the P3a window ($F(1,22) = 11.55$, $p = 0.003$, $\eta^2 = 0.34$). Also in the LTW, the amplitude was negative to DN but positive to SON at Cz and Pz, yielding a significant Stimulus × Site interaction: $F(2,44) = 5.37$, $p = 0.014$, $\eta^2 = 0.20$. Importantly, the P3a amplitude was larger to CS+ than CS− (mean amplitudes 3.47 versus 1.78 μV; $F(1,22) = 10.63$, $p = 0.004$, $\eta^2 = 0.33$). The P3(a) effect, was, however, instable and disappeared in the *test phase*, in which no differences between CS+ and CS− responses were observed. The average ERP waveforms are shown in Figs. 1 and 2.

4. Experiment 2

4.1. Methods

In Experiment 2 the names were completely masked while preserving their acoustical features. The first 25% of time points of an original name were multiplied by a linearly spaced vector of coefficients from 1.5 to 0, and the remaining 75% points were set to 0. Then, the first 25% of time points of the same name played backwards were multiplied by a linearly spaced vector of coefficients from 0 to 1.5, and the last 75% time points remained unchanged. Finally, the two files were added. This technique permitted to attain the same intensity-by-time dynamics as in the original names. In a pilot experiment the stimuli were presented to forty healthy participants. None of them was able to recognize any name including their own.

4.2. Results

Participants reported that they had heard "two or three" different harmonic tones, and that at the beginning of the stimulation also other stimuli had been presented that sounded like non-comprehendible words of an exotic (non-European) language.

Despite the lack of subjectively perceived differences between the two UCS, P3b had a larger amplitude to SON than DN, particularly at Pz (main Stimulus effect: $F(1,20) = 5.04$, $p = 0.035$, $\eta^2 = 0.20$; Stimulus × Site interaction: $F(2,40) = 5.85$, $p = 0.017$, $\eta^2 = 0.23$). P3a, in contrast to Experiment 1, did not differ between SON and DN. During the *test phase*, N1 and P3a were significantly larger to CS+ than CS− ($F(1,20) = 20.21$, $p < 0.001$, $\eta^2 = 0.50$; and 4.95, $p = 0.038$, $\eta^2 = 0.20$, for N1 and P3a, resp.).

5. Experiment 3

5.1. Methods

Although CS+ and CS− differed in the perceived pitch, in