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ScienceDirect
International Journal of Psychophysiology 64 (2007) 81 – 90
INTERNATIONAL JOURNAL OF PSYCHOPHYSIOLOGY
www.elsevier.com/locate/ijpsycho

# Brain oscillations differentiate the picture of one's own grandmother

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Received 20 May 2006; received in revised form 24 June 2006; accepted 13 July 2006
Available online 25 September 2006

**Abstract**

The present report introduces, as a first study, the concept and methods of oscillatory brain dynamics to analyze well-known (familiar) and unfamiliar face processing in the 800 ms following a face presentation. We analyzed event-related oscillations in young, healthy subjects ($N=26$) by using three types of stimulation: (1) a simple light signal, (2) the picture of the face of an anonymous elderly lady and (3) the picture of the subjects' own grandmother. We found a number of significant peak to peak amplitude measures in all frequency bands in the time period of 0–500 ms, allowing a differentiation between perception of the subjects' own grandmother, the unknown elderly face and the light stimulation. The results showed increased event-related oscillatory responses elicited by the unknown face compared to the known grandmother a) in the theta responses (4–8 Hz) at $T_6$ (46%), b) in the gamma (28–48 Hz) responses at $C_z$ (22%) and $C_3$ (38%) and c) in the beta responses at $F_4$ (46%), $C_z$ (47%) and $P_3$ (105%). In contrast, the subjects' own grandmother elicited 20% increased fast theta (6–8 Hz) oscillations at $F_4$ compared to the unknown face. Delta responses dissociated face from simple light processing, as reflected in the observation of approx. 50% higher amplitudes at the occipital compared to the frontal locations during face perception. We conclude that the described multiple brain oscillations clearly differentiate the known and unknown faces with varied degrees of selective-responsiveness in a short time window between 0 and 800 ms. Furthermore, the results are in conceptual accordance with the "selectively distributed processing" hypothesis.
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*Keywords:* Delta; Theta; Alpha; Beta; Gamma oscillations; EEG; ERP; Face recognition; Semantic; Episodic; Memory

## 1. Introduction

The face recognition process in the brain has attracted increasing attention in neuroscience research (Haxby et al., 2001; Grill-Spector et al., 1999; Rotshtein et al., 2004; Quiroga et al., 2005). Although, several publications using functional Magnetic Resonance Imaging (fMRI) and conventional Evoked Potential (EP) reports are to be found in the literature, there are almost no reports taking into account the concept and approach of selective multiple oscillations and the long established fundamental physiological facts stated by Luria (1966), Lashley (1929), Fuster (1995, 1997), Mesulam (1990, 1994), Damasio and Damasio (1994), and Goldman-Rakic (1996). Their approaches include the concept that even a simple percept, such as a light stimulation, involves memory processing and that our memories are distributed across the entire brain, instead of being concentrated in specific regions (Lashley, 1929; Fuster, 1995, 1997). According to Luria (1966) mental functions too, are, similar to vegetative functions, a product of complex systems, a component part, which may be distributed through the structures of the brain. The task of neuroscience is therefore not to localize "centers", but rather, to identify the components of the various complex systems that interact to generate the mental functions. Luria called this task "dynamic localization". A recent study tested the possible interplay between the working and long-term memory systems and indicated the relevance of this dynamic localization (Sauseng et al., 2002). Especially Fuster (1995, 1997) emphasizes that complex stimuli processing includes simultaneous and successive activity of diffusely interconnected and another overlapping memory

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0167-8760/$ - see front matter © 2006 Published by Elsevier B.V.
doi:10.1016/j.ijpsycho.2006.07.002

networks. One neuron or group of neurons in the cortex can be part of many networks, and thus, many memories: this is why it is virtually impossible, by any method, to localize a memory. Nevertheless, many studies investigating face recognition have attributed functional correlates of this processing to the temporal cortex and not to distributed and interconnected neuronal networks.

The present report aims to fulfill this gap and introduces as a first study the concept and methods of oscillatory brain dynamics to analyze face recognition in the first 800 ms following a face presentation. In the Sherringtonian view, "the grandmother neuron" is defined as a neuron, which responds to nothing else but the face of one's grandmother. According to Barlow's (1995) concept we would have a specific neuron in the brain firing while seeing the face of a particular grandmother. Following the relevant work of Eckhorn et al. (1988) and Gray and Singer (1989) on gamma oscillations Stryker (1989) raised the question "Is grandmother an oscillation?", commenting that neurons in the visual cortex activated by the same object, tend to discharge rhythmically and in unison.

The first results related to selectively distributed and selectively coherent multiple oscillatory responses as large-scale approach were described by Başar et al. (1975; Başar, 1980) in the cat and human brain (for reviews see Başar, 1999 and Başar et al., 2001). In the last years, the large-scale hypothesis has become a keyword in an increasing number of publications (e.g. Bressler and Kelso, 2001; von Stein and Sarnthein, 2000; Varela et al., 2001; Makeig et al., 2002; Fell et al., 2001; Mesulam, 1990, 1994).

In the analysis of the grandmother percept the experimenter is confronted with the process of face processing, which comprises (i) perceptual and memory processes required for the recognition of complex stimulation as a face, (ii) the identification of the particular face in view (here the grandmother), (iii) the analysis of facial expression (McCarthy, 2000) and (iv) the concept of dynamics in integrative brain function. In addition to the processes pointed out above, face recognition requires integration of attention, perception, learning and memory. Recent publications favor the idea that attention, perception, learning and memory are inseparable as described by Hayek (1952) (see also Fuster, 1995, 1997; Damasio and Damasio, 1994; Baddeley, 1996, Desimone, 1996; Başar, 2004). Therefore, face recognition can be considered as a prototype of complex signal processing in the brain.

From the methodological viewpoint, Mountcastle (1992) indicated that the paradigm change introduced by using brain oscillations became one of the most important conceptual and analytic tools for the understanding of cognitive processes. He further stated that a major task for neuroscience is to devise ways to study and to analyze the activity of distributed systems in waking brains, including particularly human brains. As a consequence of this chain of reasoning, the analytical and conceptual framework of the present study is premised on the methodological advice of Mountcastle (1992) and the conceptual statements of Luria (1966) and Lashley (1929). Furthermore, the study takes the principle of selectively distributed systems into account (Mesulam, 1990, 1994; Başar, 1999, 2004). Within this framework, the present study investigated event-related oscillations in young, healthy subjects using three types of stimulation assumed to activate partly overlapping and partly distinct neuronal networks: (1) a simple light signal, (2) the picture of the face of an anonymous elderly lady and (3) the picture of the subjects' own grandmother.

## 2. Materials and methods

### *2.1. Experimental strategy and procedure*

We used a strategy consisting of the application of three different types of visual stimulation:

1) A simple light stimulation as control signal, its luminance and size was approximately the same as for pictures 2 and 3 described in the following (app. 30 cd/m$^2$).
2) The picture of an 'unknown face': an anonymous elder lady.
3) The picture of a 'known face': the subjects' own grandmother.

A total of 26 subjects in the age range of 15–36 years (17 females and 9 males) participated in the study. They had normal or corrected to normal binocular visual acuity and were right-handed. The pictures were presented in black and white (17 × 17 cm) and displayed on a screen at a distance of 120 cm from the subjects. Stimulus duration was set to 1000 ms with intervals varying between 3.5 and 7.5 s. The subjects were instructed to minimize blinking and eye movements, and they sat in a soundproof and dimly illuminated echo-free room (Fig. 1).

Data recording set: The stimuli were randomly presented in 75 trials, such that each type of stimulation was similarly distributed. The grandmother (known face), unknown face and light responses were analyzed separately in subsets. All subjects reported clearly recognizing and differentiating the face of their own grandmother.

### *2.2. Electrophysiological recording*

The EEG was recorded from $F_3$, $F_4$, $C_z$, $C_3$, $C_4$, $T_3$, $T_4$, $T_5$, $T_6$, $P_3$, $P_4$, $O_1$ and $O_2$ locations according to the 10–20 system (Jasper, 1958). For the recordings an EEG-CAP was used. For the reference and EOG recordings Ag/AgCl electrodes were used. Linked earlobe electrodes (A1 + A2) served as reference. EOG from the medial upper and lateral orbital rim of the right eye was also registered. The EEG was amplified by means of a Nihon Kohden EEG-4421 G apparatus with band limits 0.1–100 Hz 24 dB/octave. The EEG was digitized online with a sampling rate of 512 Hz. For the analysis stimulus-locked epochs of 2000 ms, with 1000 ms serving as the pre-stimulus baseline, were used.

### *2.3. Computation of selectively averaged event-related potentials (ERP)*

Before the averaging procedure, the epochs that contained artifacts were rejected by an off-line technique. In the off-line procedure, single sweep EOG recordings were visually studied

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