Habituation and Dishabituation of the Auditory Cortex

B. Pfleiderer[1], H. Vaut[2], and N. Michael[3]

[1]Department of Clinical Radiology, University Hospital Münster, Münster, Germany, [2]Department of Clinical Radiology, University Hospital Münster, Germany, [3]Department of Psychiatry, University Hospital Münster, Münster, Germany

Introduction

Habituation is defined as a decreased response to a repetitive stimulus and is accompanied by a decline in neuronal activity. By contrast, the effect of restoring a former level of response to a habituated stimulus is called dishabituation. Dishabituation results in an increase in response due to a stimulus that enhances arousal. One way to study dishabituation effects is the introduction of a distractor in habituation experiments. The goal of this study was to assess auditory habituation/dishabituation of the auditory cortex to three different speech stimuli by fMRI in healthy volunteers. We tested the following hypotheses: a) repeated presentation of the same stimulus (E-syl; syllables) should result in habituation, while, b) in an experiment with syllables and insertion of a speech-distractor during the second block (extract of an audio book) dishabituation (E-dis, distractor), and c) during presentation of a narrative speech stimulus (extract of an audio book) no habituation should occur (E-spe, speech).

Methods

Subjects: Thirty healthy subjects (15 females, 27 right-handed – based on the Edinburgh Handedness Inventory, age: 32.0 ± 13.0 years, all native German speakers) participated. All subjects filled out a detailed questionnaire about educational level and physical and psychological health (anamnesis of diseases, operations, medication and family history). The sample was very homogenous for age and educational level, 28 out of 30 subjects had a university degree.

fMRI measurements, paradigm and data analysis: 60 functional image volumes (3T Gyroscan, Intera, Philips, Best, NL) were acquired: single shot EPI sequence (TE = 55 ms, TR = 11500 ms (sparse imaging), flip angle 90°, slice thickness 3.6 mm matrix 64 x 64, FOV 230 mm, in-plane resolution 3.6 x 3.6 mm, 36 transversal slices). Every subject underwent three different functional imaging experiments split by a pause of 5 minutes in which the examiner talked to the volunteer in a standardized way using loudspeaker inside. Every experiment had the same structure: scans 1-6 (R1), 17-24 (R2), 35-42 (R3) and 53-60 (R4) without auditory stimulus (OFF); auditory stimuli in scans 7-16 (A1), 25-34 (A2) and 43-52 (A3) (ON), duration 115 sec. each. Paradigm, E-syl, had in all three ON periods a repetitive stimulus of the syllable "bla" (1 syllable/ sec., male speaker), E-dis: presentation of the same syllables as in E-syl in A1 and A3; A2 was split: scans 25-29 (A2a, 57.5 sec.) with the known syllable "bla", scans 30-34 (A2b, 57.5 sec.) contained extracts of an audio book ("Sophie´s World" by Jostein Gaarder, German version, female speaker) ("dishabituation experiment"). Paradigm, E-spe, had in all ON-periods extracts of the audio book "Sophie´s World" ("audio book presentation"). For all subjects the hearing threshold was determined within the magnet and each subject was stimulated with a sound pressure level of 85 dB above the individual hearing threshold. Image Processing and statistical analysis of the fMRI images were done by SPM2 first and second level standard routines and templates (www.fil.ion.ucl.ac.uk/spm) and SPSS 13.0.

Results and discussion: **Syllables (E-syl):** Activation intensity in the auditory cortex BA 41, 42, 22) decreases in ΔA3R3 to 0.14 ± 1.35 % (left) and 0.61 ± 1.45 % (right), habituation occurred (paired two sided t-test: p = 0.012 *, T = 2.7, figure 1A)). **Syllable and distractor (E-dis):** The same syllables as in E-syl were presented in stimulation blocks A1, A2a and A3, A2b contained a speech distractor. The distractor in A2b significantly increased activation in the auditory cortex in ΔA3R3 and no habituation occurred (figure 1B). **Narrative text (E-spe):** In E-spe an increase of activation was present (figure 1C) and no habituation was visible. Mean ΔA1R1 intensity was 0.69 ± 1.27 % (left) and 0.33 ± 0.82 % (right) and for ΔA3R3: 2.03 ± 1.51 % (left) and 0.88 ± 1.19 %, (right), respectively. Activation was significantly higher after the third stimulation block (left: highly significant, p = 0.001 **, T = -3.9, paired two sided t-test and right: trend; p = 0.06, T = -2.0, paired two sided t-test)). Moreover, when comparing activation of ΔA3R3 between paradigms (ΔA3R3 (E-syl) < ΔA3R3 (E-dis) a pronounced activation of exclusively auditory associated brain areas was observed (Fig. 2). Induction of dishabituation by introduction of a speech distractor in E-dis was clearly visible (Figure 2). In conclusion, auditory habituation and dishabituation is highly dependent on the kind of the stimulus and habituation can be disrupted by introduction of a distracting stimulus.

Figure 1

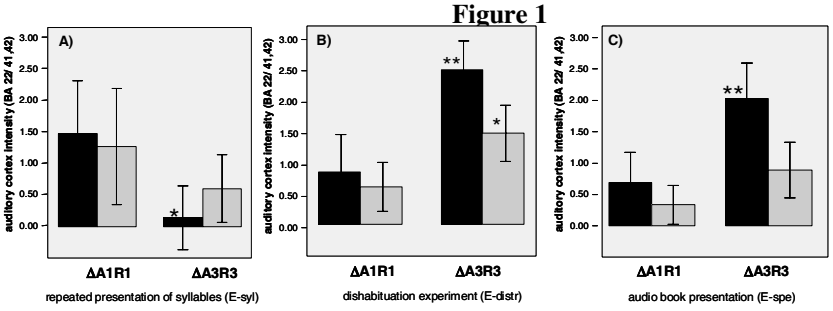

Figure 2

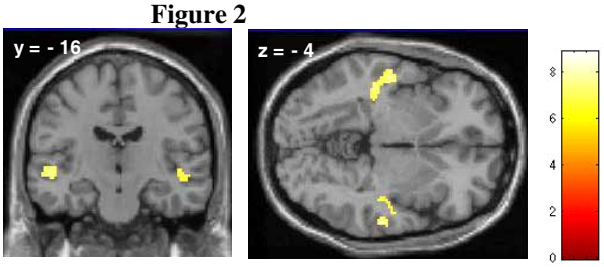

Fig.1: Differences of activation intensities of the right/left auditory cortex dependent on the three auditory stimuli. A) E-syl - repeated presentation of syllables: significant habituation occurred in the left auditory cortex only (paired two sided t-test Δ(A1R1 vs. A3R3) left p = 0.012). B) E-dis – "dishabituation" paradigm: the introduction of a distractor reversed auditory cortex habituation, in particular for the left side (** paired two sided t-test Δ (A1R1 vs. A3R3) left p < 0.0001; * paired two sided t-test Δ (A1R1 vs. A3R3) right p < 0.01). C) E-spe - repeated presentation of audio book extracts: no habituation was seen in the left auditory cortex, instead a strong increase in the left auditory cortex probably due to attention demanding properties of the stimulus (** paired two sided t-test Δ(A1R1 vs.A3R3) left p = 0.001). ■ = left auditory cortex, □ = right auditory cortex.*

*Fig. 2: activation after third auditory stimulation cycle with syllables; ΔA3R3 habituation paradigm (E-syl) < ΔA3R3 dishabituation experiment (E-dis) (two sided t-test after Bonferroni correction: Z = 6.44, k = minimum 4 voxels, p < 0.001 **).*