Functional MR Imaging and Stuttering Patients: A Technical Challenge

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Purpose
Stuttering is a disorder of speech production characterized by repetitions, cessations, or prolongations of phonemes and syllables. In stutterers, PET studies showed increased right hemisphere activation and a widespread overactivation in the motor system compared to normal subjects (1–4). Isolated exams looking for the effects of fluency treatment indicated a trend towards normal activation with persistent differences (1–3). It would be beneficial to use functional MR imaging for a more detailed analysis of regional brain activation. Especially for a long term monitoring of therapy effects, functional MR imaging is superior to repeated PET scans. However, major problems arise from effects related to overt speech with the investigation of stuttering patients (5). Stimulus correlated signal fluctuations are caused not only by direct head motion but also by magnetic field variations due to the changing pharyngeal space during speaking.

We therefore wanted to develop an experimental design which allows the effective suppression of stimulus correlated artifacts. Since it is hardly possible to separate artifactual from hemodynamic signal intensity changes if stimulus related motion is synchronized with the expected task-related response, we intended to achieve a temporal segregation of the respective effects. Ideally, speaking should be finished completely prior to data sampling.

We assumed using a short stimulus duration (event-related design) should lead to this separation. In order to allow for almost natural speaking conditions, we used stimulus durations of 3 sec. This should limit the effects of motion to the early portions of the hemodynamic response (BOLD effect) and leave at least the maximum undisturbed.

The aim of this study was to investigate whether the use of a 3 sec stimulus duration allows the effective suppression of speech related artifacts in conjunction with the sensitive detection of task related activation.

Materials & Methods
We investigated a total of 11 healthy volunteers and 5 stuttering patients. All subjects gave informed consent prior to the investigation. They performed a reading paradigm under two conditions in order to assess directly the potential benefits of the proposed event-related experiment. Once in a blocked design (12 periods alternating 24 sec of rest and 24 sec of reading, TR 4 sec) and once in an event-related design (78 events, stimulus duration 3 sec, fixed interstimulus interval 15.5 sec, TR 3 sec). The subjects were advised to stop talking as soon as the respective text presentations ended. The final event-related design included control events consisting of nontext symbols. Imaging was performed on a 1.5 T Siemens Vision Scanner using gradient echo EPI (voxel size 3.6 x 3.6 x 6 mm3, 18 slices, TE 50 ms). Evaluation was performed using SPM99 (Wellcome Department for Cognitive Neurology): For the event-related...
data a correction for acquisition time (slice timing) was performed. Motion correction (realignment), spatial normalization, and smoothing (FWHM 10 mm) were applied to all data. Within the framework of the general linear model the expected hemodynamic responses were modeled by corresponding model functions included in SPM99. Statistical inference was based on the Gaussian random field theory. Data from stutterers and controls were preliminarily compared using a group analysis based on random effects.

Results
The automated motion correction algorithm detected significant motion due to overt speech in all subjects and conditions (see Fig 1). The difference became apparent after statistical analysis (see Table 1): With blocked design 11 out of 16 subjects showed moderate to severe artifactual activation located at CSF-tissue boundaries. With event-related design only 2 out of 13 subjects showed slight artifacts. Thus, the influence of motion on the resulting statistical maps could be reduced drastically using the short stimulus duration. Statistical analysis for the group of healthy subjects revealed consistent activation in speech related areas (Broca and Wernicke area) as well as in motor areas. Our limited number of patients prohibits definite statements, but there was a tendency of increased motor and bilateral frontal activation in stutterers compared to normal volunteers.

Conclusion
The use of short stimulus durations significantly reduces the influence of stimulus correlated motion due to overt speech. The resulting statistical maps were virtually free of typical artifacts near CSF-tissue-boundaries. Based on the limited number of patients investigated up to now, we cannot give definite results yet concerning the differences of activation patterns. Nevertheless, preliminary findings of the group analysis tend to confirm previous results obtained by PET studies. In our opinion, event-related functional MR imaging offers the opportunity to reliably investigate paradigms that depend on overt speech.

References
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