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fMRI of developmental stuttering: A pilot study

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Abstract

The purpose of this investigation was to explore the feasibility of fMRI in the study of developmental stuttering. Speech contrasts (loud versus silent reading) and language contrasts (reading of semantically meaningful text versus nonsense words) of six developmental stutterers and six nonstutterers were compared using a commercial 1 Tesla MR-Scanner (Siemens Expert). Results indicate that mapping cortical function in persons who stutter is indeed feasible, even with a 1TMR-system. Compared to normals the stutterers seemed to employ different and particularly less differentiated auditory and motor feedback strategies in speech. They apparently rely on auditory processing and on cerebellar contribution as much during silent reading as during reading aloud. Moreover, they showed a greater involvement of the right hemisphere in language processing, activating not only the typical language areas on the left but also and with equal magnitude the right side homologues of these areas. In spite of the promising results, at present several practical problems such as possible movement artifacts and possible masking through scanner noise still hamper a more straightforward use of fMRI in the study of developmental stuttering.

Keywords: Developmental stuttering; Dysfluency; Brain imaging; fMRI

1. Introduction

Developmental stuttering is a disorder of speech in which an individual knows precisely what he wishes to say, but at the time is unable to say it because of an involuntary repetition, prolongation or cessation of a sound (World Health Organization, 1977). Stuttering has an estimated prevalence of 1% worldwide and occurs three to four times more frequent in males than in females (Bloodstein, 1995). Onset of the disorder is usually between 2 and 5 years of age (Silverman, 1992).

One of the puzzling things about developmental stuttering is that its etiology is still unknown. In the course of the years numerous theories relative to etiology have been formulated. One line of thinking has been that stuttering is of neurogenic origin. The first formal theory of this kind was the ‘cerebral dominance theory,’ proposed by Orton (1927) and Travis (1931). They hypothesized that in stutterers there is a lack of cerebral dominance for speech creating mistiming of the motor impulses to the bilateral innervated speech muscles. However, failure to clearly demonstrate a lack of cerebral dominance, along with the failure of therapies aimed at installing hemispheric dominance in stutterers, caused the theory to lose its initial popularity. For some decades environmental theories of stuttering prevailed. The basis of the cerebral dominance theory, however, was not refuted. Moreover, the theory of Orton and Travis regained interest again when Jones (1966) suggested bilateral speech representation in four stutterers, using the Wada technique. The ensuing years several studies of the cerebral dominance of stutterers were reported. A whole variety of neuropsychological approaches were used including dichotic listening, auditory tracking, tachistoscopic investigation, verbal manual time-sharing and electroencephalography (see Bloodstein, 1995, for a review). The results of these studies range from equivocal to the conclusion that

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there is in stutterers a bilateral language representation, an inverse cerebral dominance, less outspoken left cerebral dominance, right hemisphere dominance, interference of the right hemisphere with left hemisphere activities, or more right hemispheric speech production but no difference for speech perception.

In recent years, PET has opened new avenues in the search for the neurogenic basis of stuttering. Although interpretation of the PET findings in stuttering is not straightforward and most if not all studies can be criticized as to the subjects used and the methodology employed (Logan, 1999), the results yet largely confirm that stutterers show differences in cerebral dominance when compared to normal controls (Braun et al., 1997; Fox et al., 1996; Ingham, Fox, & Ingham, 1994; Ingham et al., 1996; Kroll, De Nil, Kapur, & Houle, 1997; Wu et al., 1995, 1997). Areas found to be of particular interest are the cerebellum, Broca's and Wernicke's area, the supplementary motor area and limbic structures.

The purpose of the present investigation was to examine the feasibility of fMRI in the study of stuttering. Compared to PET, fMRI has the undeniable advantage of being noninvasive. Furthermore, spatial and temporal resolution and endogenous contrast are far better in fMRI than in PET and it might be hoped for that fMRI helps to determine with greater precision which brain areas are involved in stuttering (Cherry & Phelps, 1996; Cohen, 1996). There are, however, also potential problems in the use of fMRI in the study of stuttering. One issue to be considered is that some stutterers show speech related dyskinesias which may result in movement artifacts. Also, it is well known that in stutterers a masking noise during speech may lead to a temporary speech improvement. Perhaps scanner noise could have the same effect. Another obstacle is that the occurrence of fluency failures in a given patient may vary considerably from time to time. Moreover the population of people who stutter is by no means a homogenous one. Yet, the strengths of fMRI in comparison with more invasive methods are considerable and provided the impetus for the present investigation.

2. Materials and methods

2.1. Subjects

The subjects for this study were six stuttering and six nonstuttering male individuals ranging in age from 19;10 to 37;5 years. The stutterers were recruited with the help of 'VZW Best,' a Flemish self-help organization for stutterers, addressing mainly adult chronic stutterers. The nonstutterers were recruited among undergraduate students and their acquaintances. All participants were native speakers of Dutch and were reportedly right-handed for everyday activities such as writing, combing one's hair, using scissors, et cetera. None of the nonstuttering subjects had any history of speech language problems. In all of the stuttering subjects the dysfluency was of developmental origin and had its onset in childhood. All stuttering individuals were clinically screened to be stutterers without severe synkinesias so that stutter episodes inside the magnet would not create significant artifacts. They had all followed one or more episodes of therapy of variable duration for their fluency problem but none of them was still enrolled in speech therapy at the moment of testing. However, they did attend meetings and encounter-weekends of the self-help organization from time to time. Although the self-help organization does promote the use of prolonged speech and speaking in a sing-song manner, none of the participants of the present study made use of these fluency techniques for controlling their speech behavior.

2.2. Functional magnetic resonance imaging (fMRI)

All imaging was performed on a commercial 1 Tesla MR-scanner (Siemens Expert). The fMRI session consisted of two parts. First, anatomical imaging of the brain was carried out using a 3D-MPRAGE T1-weighted sequence: TR = 9.7 ms, TE = 4 ms, flip-angle = 8°, slices = 178, slice thickness = .9 mm, matrix = 230 × 256, FOV = 250 mm, NEX = 1. For fMRI, subsequent whole-head imaging was performed with an optimized echo-planar sequence (TR = 1.8 ms, TE = 70 ms, flip-angle = 90°, slices = 32, slice thickness = 4 mm, matrix = 64 × 64, FOV = 256 mm, NEX = 1) with a total repetition time of 5 s per volume (Achten et al. HBM99, abstract 1088, Duesseldorf, June 1999). A total of 480 volumes was acquired in each of the subjects.

Because abnormalities in brain activation in subjects with developmental stuttering have been reported in the PET literature to involve several pathways (Logan, 1999), and because it has been suggested that both motor and linguistic processes may underlie stuttering (De Nil, 1999), a dynamical paradigm with both motor-speech and language components was selected. Four levels of performance included reading normal semantically meaningful text both aloud and silent, and reading nonsense text aloud and silent.

The meaningful texts were selected paragraphs from an entertaining booklet on habits and vices of Belgian people (Mason, 1995). The nonsense words contained monosyllabic as well as polysyllabic words of various phonological composition all of them being theoretically permissible word shapes in Dutch. Although no attempt was made to exactly match the nonsense texts with the meaningful texts as to phonological build-up, it was taken care of that in each nonsense text a whole range of different phonological shapes was covered. It is well known that stutterers may show an adaptation effect in