Hand movement and overt speech assessed by fMRI: does a combined task facilitate the motor execution?

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Introduction

The contralateral primary sensorymotor cortex involvement in hand movement (HM) is well established, as is that of several further cortical areas such as the supplementary motor area (SMA), lateral premotor cortex, anterior cingulate cortex and Brodmann's parietal area 7 (1). For speech production (SP), bilateral regions implicated specifically in the motor component of speech are the inferior part of the primary sensorymotor cortex and the cerebellum, as well as the right thalamus and caudate nucleus (2). While HM and SP separately have been widely investigated using functional imaging methods, combined paradigms incorporating simultaneous verbal and manual tasks have been less studied (3). The latter are of great interest, as they are implicated in complex motor and non-motor sequences which characterize human behaviour. In this study, cerebral activation profiles during SP, HM and concurrent SP/HM tasks have been compared. Analyses of the different and/or similar activation profiles underlying the motor execution of the same motor program through different effectors were performed.

Methods

14 healthy fully right handed (Edinburgh test > 80%) volunteers (9 men, 5 women, 38-75 years old) were studied. All had English as mother tongue and no history of neurological disorder. A 1.5T whole-body MR imaging system (Signa Excite, GE Medical Systems, Milwaukee, WI, USA) was used, with an 8-channel head coil. An Eloquence system (Invivo corporation, Orlando, FL, USA) provided paradigm presentation. Anatomical sagittal 3D T_1-weighted gradient-echo images were acquired with TE/IR preparation time = 2.4ms/450ms, 1mm slices, 1.0mm x 1.2mm in-plane resolution. 6 fMRI runs were acquired in each subject using a T_2*-weighted echo planar imaging sequence with 41 slices 2mm thick, 1mm gap, 3.1mm x 3.1mm in-plane resolution and TE/TR = 50ms/4.2s. In each fMRI acquisition one task was compared to the rest condition in a block design with 16.8s epoch duration and 8 cycles of rest-task. Three tasks (A=HM, B=SP, C=HM+SP) were performed twice, in randomised order both within and between subjects. All tasks were cued by an auditory signal every 2s, heard also during rest, and by the words 'go' and 'rest' displayed on a monitor. In the HM task the subject moved a joystick with the right hand in a direction chosen randomly between 'up', 'down', 'left', 'right'. In the SP task the subject overtly said one word randomly chosen between 'up', 'down', 'left', 'right'. In the HM+SP task the subject moved the hand as in the HM task and said the corresponding word at the same time. The chosen direction/word was recorded in every task. The data were analysed with SPM2 (http://www.fil.ion.ucl.ac.uk/spm/). For the individual subject analysis the images were first realigned and unwarped, normalised to the SPM2 MNI template, and spatially smoothed with a kernel of FWHM=6mm. Then a general linear model was applied voxel-wise to the functional data, with the haemodynamic response function (hrf) and its first time derivative as basis sets. T-contrast images were calculated for each subject for the canonical hrf for the conditions A, B C, A versus B, A versus C, B versus C, and C versus A+B. For the within-group analysis one-sample t-tests were performed for each condition and contrasts were obtained with t-statistics (T contrasts), corrected for multiple comparison with $p<0.05$.

Results and Discussion

The contrasts A>rest and B>rest showed activations in the left (A, Z score=5.05) and bilateral (B, Z score>4.53) primary motor cortex, corresponding to the anatomical somatotopy of the right hand (A) and the orofacial area (B). In A, a wide activation of the right cerebellum (Z score=6.63) and more localised activation of the left cerebellum (Z score=5.02) was observed as well as a lateral premotor activation (Z score=5.31). A bilateral cerebellar activation was observed in B (Z score=4.34 (left), 4.22 (right)). These findings are consistent with previous results on HM (1,4) and SP (2,5). In contrast C>rest, the frontal (primary motor, Z score=5.11 (left) and 4.06 (right) and premotor, Z score=4.51) and cerebellar areas (Z score=4.70 (left) and 5.45 (right)) already noticed in contrasts A and B were both activated. An additional activation in the left superior temporal gyrus (Z score = 5.13) was also observed. The T-contrasts A>B and B>A, which include also information regarding the contrasts A<rest and B<rest, displayed similar activation profiles as A and B respectively, as expected, with the difference that contrast A>B also showed an activation in the caudal SMA (Z score = 4.52), revealing its stronger participation during HM compared to SP. As expected, the involvement of the right cerebellum is also more prominent during HM than in SP (Z score=6.25). It was considered reasonable that the combined task C would activate more regions than the single tasks A and B. Accordingly, the contrasts A>C and B>C resulted in no suprathreshold clusters, while contrasts C>A and C>B displayed activations similar to those observed in B and A respectively: there were no areas that were more activated in A and B than in C. The caudal (Z score=5.20) and the rostral SMA (Z score=5.16) were activated in C>B but not in C>A. The activations observed in the SMA for A>B and C>B confirm that caudal SMA is needed for HM, and suggests that the rostral SMA is activated in the combined task C in order to manage a more complex motor coordination that includes also SP. The contrasts A+B>C and C>A+B gave no suprathreshold clusters at the chosen p threshold. Further analyses are needed to explain the absence of rostral SMA activation in C>A+B. Overall, the results suggest that tasks A and B might be additive, or at least facilitated by the fact that the motor programming is the same for both tasks: only the motor execution profile (hand or orofacial areas) is different.

Conclusion

Our results suggest that the simultaneous motor execution of a similar motor program performed by the hand and the orofacial area, combine the cortical motor and cerebellar activations in addition to the SMA. The added complexity of a combined task requires an additional motor coordination probably mediated by the SMA. This study is part of a larger project aimed at ascertaining differences in brain activation profiles during SP and HM in normal subjects and Parkinson's disease patients.

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