# Neural bases and hemispheric lateralization for phonological processing in regular languages: an fMRI study on Italian adults

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## Introduction

Phonological encoding is an important component of reading, in fact several studies suggest that a deficit in the domain of phonology underlies developmental dyslexia [1]. Recent neuroimaging studies demonstrated hypo- activation of the left temporo-parietal cortex and hyper- activation of the left inferior frontal gyrus in dyslexic subjects during rhyming and reading tasks [2, 3]. However it is still unclear whether such an abnormal pattern of activation holds for different types of developmental dyslexia in different languages. Moreover the involvement of anterior and posterior language areas in reading tasks must be further established also in normal subjects. Some studies found the predominant activation of the left temporoparietal cortex during processes of recoding the visual input into a phonological representation and the predominant activation in the LIFG and in the left dorsolateral prefrontal cortex (LDLPF) during phonological tasks involving the articulatory planning for speech production [2, 4]. It is not yet clear whether these patterns of activation change with the orthographic regularity of the language and with several other factors, such as the type of the phonological task and the stimuli used [5, 6]. With the aim of conducting an fMRI study of phonological processing in Italian dyslexic adolescents, we investigated, by an fMRI study performed on a group of Italian normal adult readers, how the involvement of the anterior and posterior language areas change with the type of the phonological task and the characteristics (type and duration) of the stimuli used.

## Materials and Methods

12 healthy adults with e-level or university degree performed two types of tasks, a rhyme generation and a rhyme judgements task. In the rhyme generation task, participants had to find a word rhyming with the visually presented target and, in the rest condition, they had to passively view strings of four ‘x’. In the rhyme judgement tasks participants had to judge whether two stimuli, visually presented, rhymed and, in the rest condition, they had to judge whether two Cyrillic strings matched. In the rhyme judgement task stimuli were varied, in different sessions, for type (letters, words and pseudowords), duration time (1000, 750, 500 ms) and orthographic characteristics (CaNe-pAnE vs. CANE-pane). Participants were also tested with behavioural tasks aimed to measure phonological processing skills and the hemispheric specialisation for language (dichotic listening paradigm). Subjects lay on their backs and view binocularly stimuli displayed in a virtual reality sep-up (VisuaStim XGA - Resonance Technology). BOLD responses were acquired by 1.5 T General Electric Signa Horizon LX System (GE, Milwaukee, USA), equipped with Echo-speed gradient coil and amplifier hardware. Activation images were acquired using echoplanar imaging (EPI) gradient-recalled echo sequence (TR/TE/flip angle = 3 s/50ms/90°, FOV = 280x280 mm, matrix = 128 x 128, 3-4 mm thick slices). Time-course series of 64 images for each volume were collected usually in 6 epochs alternating between control and active conditions, each 30 seconds in duration. The first epoch always lasted 13 sec more to allow the signal to stabilise. This initial period was eliminated from any successive analysis. An additional set of anatomical high resolution 2D fastSPGR data set (TR/TE/flip angle = 150 ms/2.3ms/120°; FOV=280x280 mm, matrix = 256x256) matched to the fMRI images were acquired and a volumetric set of data (3D FSPGR: TR/TE/TI/flip angle = 21.1 ms/3.8 ms/700 ms/10°; FOV = 280 x 280 mm, matrix = 256 x 256) were acquired to generate a 3-dimensional whole brain reconstruction. BOLD maps for signal intensity changes were generated by using the software package BRAIN VOYEGER. The effective probability has been set to a value less than 0.001, with the additional requirement of a cluster size of 5 voxels. A multi-subjects analysis was conducted on each ROI, this consisted in a GLM analysis conducted on the means of the signals, obtained for each subjects, to permit the computation of the mean grade of signal across subjects. A Fourier analysis was conducted on the signal obtained in some selected ROI in the left hemisphere for those subjects who activated a specific area and a value of signal to noise ratio was calculated, in order to compare the parametric differences in the stimuli. Hemispheric specialization for each subject was calculated on the base of the signal in the temporo-parietal (BA 22, BA 21-39-40), frontal (BA 47-45-49; BA 44-45-46) and dorsolateral prefrontal (BA 46-9). For each area it was calculated the mean signal percentage variation in the right and in the left hemisphere and a lateralization index computed as the natural logarithm of the variation in the left hemisphere on the variation in the right hemisphere.

## Results and Discussion

During both the rhyme generation and the rhyme judgement of written pairs of letters, words and pseudo-words, participants activate mainly the anterior components of the neural phonological network (the posterior inferior frontal gyrus and the dorsal prefrontal area) and to a less extent in the posterior temporal areas with stronger activation for pseudo-words than for words. The characteristics of the stimuli affected the magnitude and the consistency of the activation, but within the same brain regions. The fMRI measures of hemispheric lateralization correlated, particularly for the left temporo-parietal area with the degree of hemispheric specialisation measured by the dichotic listening test. Results are interpreted with the cognitive models of phonological processing.

## References

[1] Snowling, M.J. (2001). Dyslexia, 7(1), 37-46. [2] Temple, E., et al. (2001). NeuroReport, 12, 299-307. [3] Paulesu, E., et al. (2001). Science, 291, 2165-7. [4] Bokde, A. L-W., et al. (2001). Neuron, 30, 609-17. [5] Xu, B., et al. (2001). Cerebral Cortex, 11, 267-277. [6] Mechelli, A., et al. (2003). Journal of Cognitive Neuroscience, 15(2):260-71, 2003.