ABSENCE OF HEMISPHERIC DOMINANCE FOR MENTAL ROTATION ABILITY: A TRANSCRANIAL DOPPLER STUDY

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Abstract

Mean blood flow velocity (MFV) of the middle cerebral arteries was monitored in 19 healthy, adult, right-handed subjects during the resting phase and the execution of a series of neuropsychological tests: two right/left discrimination tasks, two mental rotation paradigms (the Ratcliff's test and a cube comparison test) and a phonemic fluency task, which was utilised as an internal control.

In the group as a whole, the Ratcliff's test was associated with a significant bilateral increase in MFV versus both the resting state (right: $p < .000001$, left: $p < .000001$) and right/left discrimination tasks (task 1: right: $p = .003$, left: $p = .005$; task 2: right: $p = .001$, left: $p = .001$). The cube comparison in turn produced a significant increase in MFV versus both the baseline conditions (right: $p < .000001$, left: $p < .000001$) and the Ratcliff's test (right: $p = .01$, left: $p = .002$). As expected, the fluency task was associated with a significant asymmetric increase in cerebral perfusion (left > right: $p = .0001$). Increasing task difficulty (right/left discrimination < Ratcliff's test < cube comparison) was paralleled by a roughly proportional rise in MFV values (right: $r = .424$, $p < .01$; left: $r = .331$, $p = .01$).

In conclusion, we were able to demonstrate that (1) in addition to the amount of MFV variation due to right/left discrimination (when required), mental rotation per se causes a biemispheric activation irrespective of the experimental paradigm; (2) the MFV variation is proportional to the difficulty of the tasks.

Key words: mental rotation, functional transcranial Doppler, cerebral perfusion, cerebral lateralization

Introduction

Mental rotation is a visuo-spatial function requiring different sequential abilities: constructing a "mental image" of the object, mentally turning or rotating it and matching the "rotated" image to a standard stimulus. The specific role of the right hemisphere in processing visuo-spatial information is well established, while a possible involvement of the left hemisphere has been suggested more recently. In particular, Mehta and Newcombe (1991) suggested that the contribution of the left hemisphere might include: "(1) handling extraneous and/or distracting visual information; (2) generating visual images; (3) more intellectually demanding spatial analysis and (4) understanding Euclidean geometrical principles". In this view, mental rotation should be regarded as a complex function, simultaneously involving different areas of the brain.

Most of the research on the neural basis of mental rotation has focused on its possible cerebral lateralization in normal subjects and brain-damaged patients, using several experimental procedures, and has yielded conflicting results (Mehta and Newcombe, 1991; Ditumno and Mann, 1990; Mehta, Newcombe and Damasio, 1987; Peronnet and Farah, 1989; Deutsch, Bourbon, Papanicolaou et al., 1988; Cohen, Kosslyn, Breiter et al., 1996; Alivisatos and Petrides, 1996) (see Discussion).

In recent years Transcranial Doppler (TCD) has been employed to assess cerebral perfusion changes during various types of neuropsychological tasks (Droste, Harders and Rastogi, 1989a, 1989b; Kelley, Chang, Scheinman et al., 1992; Silvestrini, Cupini, Matteis et al., 1994; Hartje, Ringelstein, Kistinger et al., 1994; Thomas, Harer, Altenmuller et al., 1995; Rihs, K. Gutbrod, B. Gutbrod et al., 1995; Cupini, Matteis, Troisi et al., 1996; Bulla-Hellwig, Vollmer, Gotzen et al., 1996). Indeed, TCD is able to detect almost instantaneous mean blood flow velocity (MFV) changes in the basal cerebral arteries and it can be considered a reliable indicator of rapid short-lasting perfusion changes in the territory supplied by the cerebral artery under investigation (Aaslid, Markwalder and Nornes, 1982; Bishop, Powell, Rutt et al., 1986; Aaslid, 1987; Kontos, 1989).

The primary aim of our study was to investigate the effects of two different paradigms of mental rotation on cerebral perfusion in a homogenous sample of subjects by means of simultaneous bilateral monitoring of MFV in the middle cerebral arteries (MCA). Possible inter-hemispheric asymmetries of cerebral activation and the relationship between the level of difficulty of the mental rotation task and the concurrent MFV variations were evaluated.

Materials and Methods

Subjects

After giving informed consent, 19 right-handed volunteers (12 females and 7 males; mean age 28.3 ± 2.4) were enrolled in the study. Handedness was determined by means of the Hand Preference Test (Annett, 1970). The subjects were all medication-free, without medical diseases and/or history of neurological disorders. All the subjects had 19 years of education.

Apparatus and Procedure

The study was carried out in a quiet room with subjects in a comfortable, supine position. They were asked to relax and breathe regularly during both the resting phase and the neuropsychological tasks. Before the start of the experiment, they were instructed to solve each item of the different tasks as correctly as possible, but without time pressure. Each item was presented immediately after the subject had given his/her response to the preceding one (see below). An observer checked the accuracy of the answers.

MCAs were simultaneously monitored by means of a Multidop DWL Elektronische System, GMBH (Esaote Biomedica, Italy). Two 2 MHz probes were attached to the right and left temporal windows and fixed by a head-band. The sample depth was set to between 45 and 55 mm, by choosing the depth at which the optimal amplitude of the Doppler signal was obtained. The instrument allowed continuous recording of the Doppler spectra throughout the experimental session. In all subjects, recording was carried out continuously both during the resting phase and each neuropsychological task.