Neuroscience Letters 579 (2014) 30–34

Contents lists available at ScienceDirect

Neuroscience Letters

journal homepage: www.elsevier.com/locate/neulet

Disrupting SMA activity modulates explicit and implicit emotional responses: An rTMS study

Alessia Rodigari, Massimiliano Oliveri *

Department of Psychological, Pedagogical and Education Sciences, University of Palermo, Fondazione Santa Lucia IRCCS, Roma, Italy

HIGHLIGHTS

- SMA is considered as an interface between the emotional system and motor system.
- We tried to modulate emotional responses using rTMS of the SMA.
- rTMS over the SMA increased the perceived valence of negative visual stimuli.
- SMA has an opposite modulatory role on stimuli with negative and positive emotional value.
- SMA has a role in top-down inhibitory control of conflicting responses.

ARTICLE INFO

Article history:
Received 1 April 2014
Received in revised form 4 July 2014
Accepted 8 July 2014
Available online 17 July 2014

Keywords:
Supplementary Motor Area (SMA)
Emotion
Motor system
Repetitive transcranial magnetic stimulation (rTMS)

ABSTRACT

Supplementary Motor Area (SMA) has been considered as an interface between the emotional/motivational system and motor effector system. Here, we investigated whether it is possible to modulate emotional responses using non-invasive brain stimulation of the SMA. 1 Hz repetitive transcranial magnetic stimulation (rTMS) trains were applied over the SMA of healthy subjects performing a task requiring to judge the valence and arousal of emotional stimuli. rTMS trains over the SMA increased the perceived valence of emotionally negative visual stimuli, while decreasing the perceived valence of emotionally positive ones. The modulatory effect on emotional valence was specific for stimuli with emotional content, since it was not observed for neutral visual stimuli. The effect was also specific for the site of stimulation, since rTMS of the visual cortex failed to modulate either perceived valence or arousal. These findings provide the first example of neuromodulation of emotional responses based on non-invasive brain stimulation.

1. Introduction

A number of evidences support the existence of anatomical and functional connections between the limbic cortex and motor and premotor areas through prefrontal and cingulate cortical regions: this neural network provides the neural system through which emotions can interact and modify motor planning [1–17]. The SMA could have a key role in this process. Anatomical studies in monkeys have shown that the caudal SMA – with direct connections to primary motor area (M1) and spinal cord – is richly linked with the motor and cingulate regions. These areas are in turn connected to other components of the limbic system. In this network, the caudal portion of the SMA could be considered as an interface between the emotional/motivational system and motor effector system. In fact, in agreement with the hypothesis of Goldberg [18], the SMA is primarily involved in the control of movements triggered internally, while the premotor area is mainly involved in the control of movements triggered by external stimuli (visual-spatial, auditory, proprioceptive). Oliveri et al. [19], hypothesized that emotional states can trigger movements by means of SMA, even if these movements are generated by external visual stimuli. Indeed, conditioning single-pulse TMS of the SMA selectively increases the excitability of M1, as measured by the amplitude of motor evoked potentials, during the execution of movements triggered by visual stimuli with a negative emotional content.

Many neuroimaging studies comparing an emotional condition to a neutral one showed activations in the anterior cingulate cortex (ACC). In a study designed to better understand the role of the ACC in emotions, Lane et al. [20], reported a significant focus of activation in the ACC during experimental conditions requiring paying attention to the subjective emotional state, as compared

* Corresponding author. Tel.: +39 0917028429; fax: +39 0917028429.
E-mail addresses: massimiliano.oliveri@unipa.it, maxoliveri@unipa.it (M. Oliveri).

http://dx.doi.org/10.1016/j.neulet.2014.07.012

to conditions requiring paying attention to the environmental context of the stimulus.

On the basis of the evidence that emotional states trigger visceral reactions, it is possible to hypothesize the existence of a common system of cortico-limbic circuits that influence the autonomous functions. Westerhaus and Loewy [21], using the technique of brain mapping by electrical stimulation, found that different brain regions, i.e. infralimbic, insular, ventromedial temporal, and ventral hippocampal areas, are connected via multi-synaptic connections to the sympathetic outflow regulating adrenal medulla, heart and gastrointestinal tract. These findings raise the possibility that these areas form a cortico-subcortical circuit that modulates higher brain functions, such as emotions, and the wide range of sympathetic responses that normally accompany them. Other regions involved in the autonomic nervous system regulation include prelimbic, orbital, and cingulate areas.

Based on experimental studies reporting the involvement of the SMA in the complex emotional circuit [22,23], the present study was aimed at investigating any role played by the SMA in the modulation of emotional responses.

2. Materials and method

2.1. Participants

Eighteen healthy young female adults, with a mean age of 22 years (range 19–25) participated in the studies. Nine subjects participated in experiment 1, testing for the effects of rTMS of the SMA. Nine subjects participated in experiment 2, testing for the effects of rTMS over an occipital control region. Both experiments had two experimental sessions, i.e. a baseline session without rTMS and a post-rTMS session.

2.2. Materials

2.2.1. Brain stimulation

rTMS was delivered using a MagStim Rapid2 stimulator connected with a focal coil (external diameter: 70 mm). rTMS was applied in trains of 600 stimuli at the frequency of 1 Hz and at an intensity of 90% of individual motor threshold, defined as the minimal intensity of stimulation able to evoke a visible muscular contraction of muscles of the contralateral hand in three out of six consecutive stimulations. This rTMS protocol is known to neuromodulate the excitability of the stimulated area, i.e. reducing cortical excitability for a period outlasting the time of the stimulation train [24].

2.2.2. Sympathetic skin response recordings

Sympathetic-mediated electrodermal activity was recorded at 20 Hz using a custom-built skin conductance biosensor [25] and synchronized with the video presentation of visual images by generating technical artifacts at the beginning and end of each session for offline realignment.

2.2.3. IAPS

We used a set of pictures of the "International Affective Picture System" (IAPS) [26]. The IAPS is a collection of standardized color photographs, emotionally evocative, whose contents cover a wild range of semantic categories. The goal of this system is to provide a large set of standard emotional stimuli, which can be used for experimental investigations of emotion and attention.

2.2.4. SAM

The "Self-Assessment Manikin", designed by P. Lang [27] is a simple Pictures – oriented scale, which was used to assess valence,

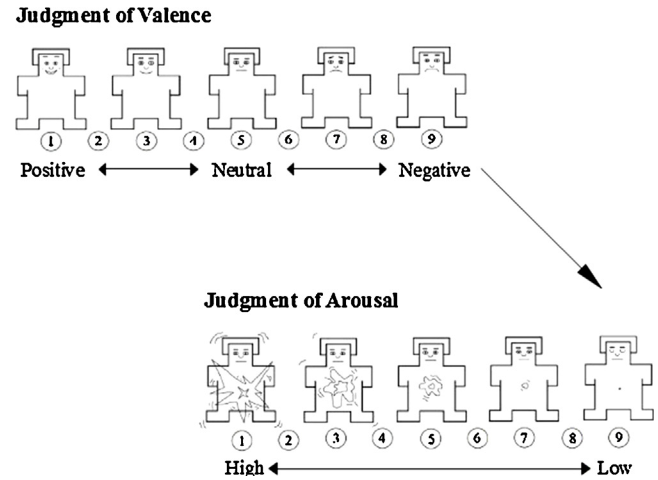

Fig. 1. Experimental set-up. Subjects judged the valence and the arousal of visual stimuli according to a Likert scale as shown in the figure.

arousal and dominance. The version of SAM used in this study consists of two scales illustrated at equal intervals, each formed by a set of five figures (mannequins), and nine corresponding numerical values, that represent the affective dimensions of valence and arousal (Fig. 1).

In the first scale, regarding the valence, the figures range from a very smiley manikin (value 1, very positive), to another with a very sad expression (value 9, negative pole), through a central neutral location (value 5). In the second scale, regarding the arousal, the figures range from a manikin with eyes closed and a very relaxed expression (value 1, absence of emotional impact), to one "explosive", with eyes wide open (value 9, strong emotional impact or excitement).

2.3. Experimental procedure

In each experiment, we presented 30 images, in randomized order. Ten images had a negative emotional content, 10 had a positive emotional content and the other 10 were neutral images. A different set of images, matched for valence and arousal, were used in the two sessions of each experiment (baseline and post rTMS).

Negative images were selected from those evoking disgust and fear that could be classified as 'withdrawal' emotions. Positive images were selected between erotic pictures (Table 1).

Each image was presented on the screen for 5 s, followed by two illustrations that reproduced two Likert scales (from 1 to 9); the first one served for the judgment of the emotional valence of the image, the following one served for the judgment of the arousal evoked by the image. Participants were required to express their judgment with a button press on the keyboard corresponding to the desired value. Synchronously with the presentation of the IAPS images, we recorded the electrodermal activity for 1200 s using custom-written software [25].

Localization of the sites of TMS stimulation:

- SMA: for the stimulation of the supplementary motor cortex, the coil of stimulation was positioned to level of the 45° of the middle sagittal axis, 2–4 centimeters anterior to the vertex (Cz position of the 10/20 EEG system).
- Occipital cortex: The occipital cortex was stimulated as a control site for monitoring the rTMS effects on a cerebral region not directly involved in the emotions' circuits, but implicated in the processes of perceptive analysis of stimuli. The coil of stimulation was positioned to the level of the site Oz of the international 10/20 EEG system.