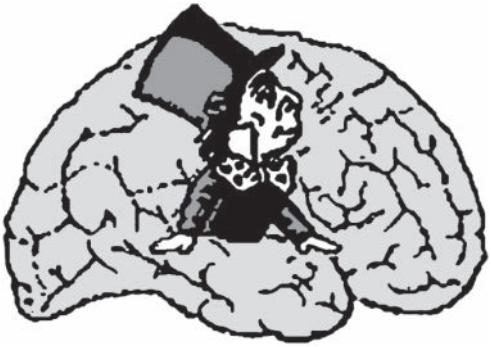
КОГНИТИВНАЯ НАУКА В МОСКВЕ

НОВЫЕ ИССЛЕДОВАНИЯ



МАТЕРИАЛЫ КОНФЕРЕНЦИИ 2017

ПОД РЕД. Е.В. ПЕЧЕНКОВОЙ, М.В. ФАЛИКМАН

УДК 159.9

ББК 81.002

К57

К57 Коллективный

Когнитивная наука в Москве: новые исследования. Материалы конференции 15 июня 2017 г.

Под ред. Е.В. Печенковой, М.В. Фаликман. – М.: ООО «Буки Веди», ИППиП. 2017 г. – 596 стр.

Электронная версия

ISBN 978-5-4465-1509-7

УДК 159.9

ББК 81.002

ISBN 978-5-4465-1509-7

SOFTWARE FOR QUANTITATIVE ASSESSMENT OF THE RESULTS OF NAVIGATED TMS MAPPING

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Abstract. Transcranial magnetic stimulation (TMS) is a modern non-invasive approach to study brain organization in humans. In TMS a time-varying magnetic fields generate induced electrical currents in the targeted brain regions with focal location of its maximum. Using of MRI navigation systems allows to fully realize the advantages of TMS focality for brain mapping purposes. Due to this development, nowadays motor and speech navigated TMS (nTMS) mapping is becoming a routinely used procedure in neurosurgery. However, nTMS mapping for dynamic cortical assessment, for example, to study cortical neuroplastic changes is still limited. An important reason for that is a lack of a standardized methodology for nTMS mapping results assessment. Here we propose TMSmap — a free standalone graphical interface software for quantative analysis of the results of motor nTMS mapping (http://tmsmap.ru/), which allows considering both standard parameters like the size of the cortical muscle representation and the center of gravity location, as well as the additional ones such as the volume of the representation, the 3D profile of the muscle cortical area and the overlap between the cortical representations and other user-defined parameters. The input data for the software includes the coordinates of the coil position and the response in each point of stimulation as well as the individual structural MRI data.

Keywords: motor cortex, transcranial magnetic stimulation (TMS), functional brain mapping, earth mover's distance (EMD)

The study has been partly funded by the Russian Academic Excellence Project '5-100' and RFBR grant № 16-04-01883.

Transcranial magnetic stimulation (TMS) is a modern non-invasive approach to study human brain organization. In TMS, time-varying magnetic fields generate electrical currents in the targeted brain regions with a focal activation area of less than 1 cm^2 (Ruohonen, Karhu, 2010). MRI navigation for TMS became available in the past decade and made it possible to fully use the focality of the TMS approach (Ruohonen, Karhu, 2010). Using MRI navigation systems during TMS provides navigation with millimeter-level accuracy. Such spatial specificity of navigated TMS (nTMS) is particularly useful for the purposes of cortical

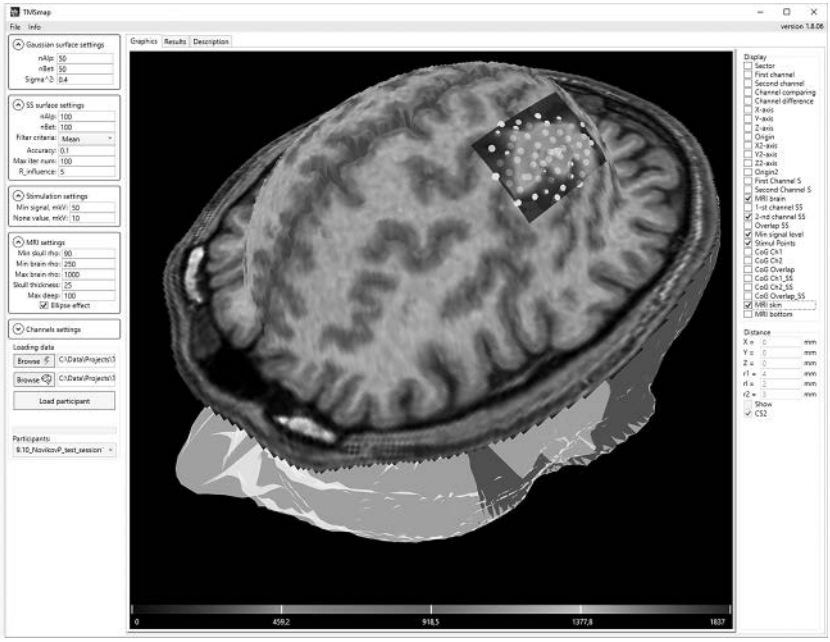

Figure 1. General view of the software interface.

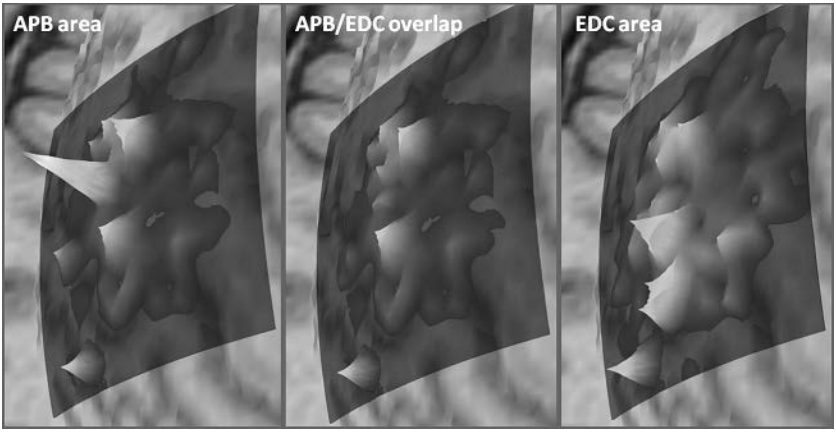

Figure 2. Cortical representation of the two hand muscles and their overlap: left picture — APB cortical representation, right picture — the representation of the muscle extensor digitorum communis (EDC), in the middle — their overlap.

mapping. Theoretically, any responses to TMS elicited from a specific cortical point can be used for nTMS mapping, which makes nTMS cortical mapping a very promising approach for non-invasive investigation of the human brain. Presently, however, only presurgical motor and speech nTMS mapping has a widespread use and is becoming a standard procedure in clinical practice (Tarapore et al., 2016). Meanwhile, nTMS mapping for the study of cortical neuroplastic changes is still limited both in clinical and basic research. There are several reasons for that. First, even for motor nTMS mapping there is no general agreement on which parameters of nTMS cortical representations should be assessed. Second, despite the long history of nTMS cortical mapping, there is still no standardized toolbox or software for the quantitative analysis of nTMS results. One motivation for a standardized workflow is to enable results comparison across sessions, participants and studies and in order to promote a wider use of nTMS mapping for the investigation of dynamic brain changes.

Here we present TMSmap, the software program for the quantitative analysis of nTMS motor mapping results which addresses the challenges mentioned above. The current version is free and available for download at the website http://tms-map.ru/. The software is written in C# on the Windows platform; it is standalone and has a graphical interface. The input data includes coordinates of the coil position (MRI coordinate system) and response parameters such as motor evoked potential (MEPs) amplitude in each point of stimulation and individual structural MRI. The software makes it possible to consider both standard parameters of the nTMS motor maps, like the size of the cortical muscle representation and the center of gravity location, as well as additional parameters enabling researchers to consider the variability of the MEP amplitude in each stimulation spot such as the volume of the representation, the 3D profile of the muscle cortical representation (Raffin et al., 2015) and the overlap between representations. The 3D profile of the muscle representation is built using two approaches: 1) as a total of Gaussians in each stimulation spot depending on the amplitude of the MEP in the spot; and 2) by finding a smooth surface going through all the stimulation points considering the amplitudes of the MEPs in each point (ABOS method). The following possibilities of the TMSmap will be shown: 1) visualization of the 3D view of the TMS muscle cortical representations and their overlaps (see Fig. 1); 2) calculation of standard and additional parameters of the motor maps (see Fig. 2); and 3) comparison of the 3D profiles of the different sessions/different muscles cortical representations using the Wasserstein metric — the so called earth movers distance (EMD) metric. At the present moment, the software is validated in the ongoing test-retest nTMS motor mapping study dedicated to the assessment of the reproducibility of different parameters of motor maps including additional ones such as the 3D profiles of the cortical maps and their overlaps.

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Программное обеспечение для количественной оценки результатов ТМС-картирования

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Аннотация. Транскраниальная магнитная стимуляция (ТМС) является современным методом неинвазивного исследования мозга человека. При ТМС магнитное поле индуцирует в ткани мозга переменное электрическое поле, максимум напряженности которого может быть локализован на участке размером менее 1 см. Появление приборов для ТМС, совмещенных с МРТ-навигацией, открыло широкие перспективы использования ТМС для целей картирования коры. В настоящее время предхирургическое ТМС картирование двигательных и речевых зон получает все большее распространение и становится рутинной клинической процедурой. В то же время использование ТМС картирования для целей динамической оценки коры до сих пор не получило широкого распространения. Одной из главных причин этого является отсутствие единой методологии оценки ТМС карт. В работе представлен разработанный нами программный продукт для количественного анализа результатов двигательного ТМС картирования (бесплатная версия доступна на сайте http://tmsmap.ru/). Программа позволяет количественно оценивать как стандартные параметры ТМС-картирования двигательной коры, так и дополнительные параметры, такие как профиль корковых репрезентаций мышц с учетом плотности распределения вызванных моторных ответов, степень наложения корковых репрезентаций и другие задаваемые пользователем параметры. Входящие данные для программы включают координаты положения катушки, параметры ответа в каждой точке и индивидуальное структурное МРТ.

Ключевые слова: двигательная кора, транскраниальная магнитная стимуляция (ТМС), функциональное картирование мозга, earth mover's distance (EMD)