We have calculated that the embedding dimension for our macroscopic signal is 4, so the expected dimension of phase space should be 9. Practically, by increasing the dimension up to 9, we achieve the maximal value of correlation, and further increase of the dimension doesn't increase the efficiency of the prediction.

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ASSOCIATIVE SEMANTIC LEARNING IN THE DEVELOPING BRAIN: ACTION-PERCEPTION CIRCUITS IN RAPID WORD ACQUISITION

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Introduction

A growing body of literature indicates tight integration between perceptual and motor systems in the adult brain, particularly crucial for the normal functioning of the language system (Pulvermuller & Fadiga, 2010; Vukovic et al., 2017). However, neurophysiological data regarding this linkage in early developmental populations (i.e., young children) is lacking, and neurocognitive mechanisms subserving efficient integration of action and perception in linguistic function during brain maturation and its contribution to the word acquisition processes in early development remain unexplored. The present study used event-related potentials (ERPs) to investigate the effect of sensorimotor (articulatory) training combined with associative semantic learning task in young children.

Methods

Eleven healthy monolingual Russian preschool children (5-7 y.o.) performed a child-friendly word-picture associative learning (so-called *fast mapping*; Vasilyeva et. al., 2019) task accompanied by a brief articulation session. The task employed a counterbalanced set of familiar and novel words presented auditorily in conjunction with novel and familiar images appearing on the screen. A new word's meaning had to be inferred by exclusion from the existing semantic context through a single-shot exposure to the novel item. During the task, the child had to select the new object defined by the previously unfamiliar word form and then articulate the word form overtly three times. Acoustic stimuli were fully controlled dissyllabic (CVCV) word forms of two types: (i) four meaningful Russian words, (ii) four phonotactically and phonologically legal meaningless novel word forms (pseudowords). Visual stimuli consisted of two-dimensional photos of familiar and unknown objects. To define learning-related brain dynamics, passive auditory ERPs to newly learnt words were recorded immediately after the task, with familiar words and untrained pseudowords as control stimuli.

Results

Amplitude analysis carried out for the fronto-central electrode cluster revealed a significant effect of learning, indicating neural activation decrease after the training at 282-322 ms (after the word divergence point) for both familiar and novel words, but not for control word forms, likely reflecting the integration of novel items into the children's mental lexicon. LORETA source analysis indicated that this activity was generated bilaterally in fronto-temporal areas, with maxima in BA21 (familiar items) and BA22 (novel learnt items).

Conclusions

We propose that a single-shot associative word learning task accompanied by brief articulation training leads to an enhanced build-up and/or reinforcement of neural memory traces for both novel and familiar items, reflecting the developing brain's capacity for rapid acquisition of words with native phonology. Further research is needed to clarify the cortical sources of the learning-related ERP dynamics and to generalize the current result to larger stimulus groups.

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References

1. F. Pulvermuller, L. Fadiga, Active perception: Sensorimotor circuits as a cortical basis for language. Nat. Rev. Neurosci., 2010, 11(5), 351-360.
2. N. Vukovic, M. Feurra, A. Shpektor, A. Myachykov & Y. Shtyrov, Primary motor cortex functionally contributes to language comprehension: an online rTMS study. Neuropsychologia, 2017, 222–229.
3. M.J. Vasilyeva, V.M. Knyazeva, A.A. Aleksandrov & Y.Y. Shtyrov, Neural signatures of fast mapping in developing brain: ERP evidence of single-shot word learning in preschool children. Proceedings of the 3rd International Workshop «Neurobiology of Speech and Language», 2019, 40-41.

ANALYSIS OF THE HEMODYNAMIC RESPONSE IN THE MOTOR CORTEX USING THE FNIRS TECHNIQUE

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The study of the principles and physical laws of the brain is one of the most important and actively studied problems of modern science. One of the most promising and powerful noninvasive neuroimaging tools for recording brain activity is functional near infrared spectroscopy (fNIRS) [1, 2]. This technology uses near infrared light to detect changes in oxygenated (HbO) and deoxygenated (HbR) hemoglobin levels due to hemodynamic brain activity and rapid delivery of oxygenated blood to active cortical areas via the neurovascular junction. It should be noted that fNIRS has the same physiological basis as functional magnetic resonance imaging (fMRI), so both technologies provide interrelated data. At the same time, fNIRS has many advantages: portability, ease of use, real-time monitoring, low sensitivity to motor artifacts, higher temporal resolution, the ability to separately record changes in both deoxyhemoglobin and oxyhemoglobin [3, 4].

This research presents the results of the analysis of the hemodynamic response of the brain when performing various types of movements. The dynamics of oxyhemoglobin, deoxyhemoglobin, total hemoglobin and blood oxygen saturation were considered as analyzed by the signal. The design of the experiment is considered, in which the subject performs two types of movements: single movement - the subject clearly squeezes and unclenches the hand once; a series of movements - the subject clearly squeezes and unclenches the hand several times at a convenient pace for 10 seconds. In this work, we present the results of comparing these types of movement, and also consider various methods for analyzing the hemodynamic response.

The fNIRS data collection and preprocessing procedure were performed using the NIRScout software. It is well known that the experimental data of fNIRS are often influenced by side physiological noises and artifacts, the characteristic frequencies of which are in the frequency range of fNIRS, including Mayer waves (with a typical frequency close to 0.1 Hz), respiration (close to 0.25 Hz) and heartbeat (about 1 Hz). As mentioned in the review article [5], in many cases, bandpass filtering is sufficient to remove low-frequency physiological noise in the fNIRS data. In this regard, a 0.01–0.1 Hz bandpass filter was also applied to the fNIRS signals using NIRScout to prevent the effect of physiological side effects. The arrangement of the optodes was similar to [6] and covered the premotor cortex of M1.