

Multisensory signal association by glutamatergic and GABAergic tecto-thalamic cells

Anna Virág Bakacsi, Péter Berki, Aletta Magyar, Sándor Borbély, Kinga Kocsis, Ferenc Mátyás

Anna Virág Bakacsi (Institute of Experimental Medicine/Research Centre for Natural Sciences, Neuronal Network and Behavior Research Group, Budapest, Hungary), (Eötvös Loránd University, Faculty of Science, Institute of Biology, Budapest, Hungary) Péter Berki (Institute of Experimental Medicine/Research Centre for Natural Sciences, Neuronal Network and Behavior Research Group, Budapest, Hungary), (Semmelweis University, János Szentágotthai Doctoral School of Neurosciences, Budapest, Hungary) Aletta Magyar (Institute of Experimental Medicine/Research Centre for Natural Sciences, Neuronal Network and Behavior Research Group, Budapest, Hungary), (Semmelweis University, János Szentágotthai Doctoral School of Neurosciences, Budapest, Hungary) Sándor Borbély (Institute of Experimental Medicine/Research Centre for Natural Sciences, Neuronal Network and Behavior Research Group, Budapest, Hungary) Kinga Kocsis (Pázmány Péter Catholic University, Roska Tamás Doctoral School of Sciences and Technology, Budapest, Hungary) Ferenc Mátyás (Institute of Experimental Medicine/Research Centre for Natural Sciences, Neuronal Network and Behavior Research Group, Budapest, Hungary), (University of Veterinary Medicine, Department of Anatomy and Histology, Budapest, Hungary)

In an ever-changing multisensory environment, the brain plays an important role in recognizing and integrating the behavioural relevant stimuli. As these are essential for survival, the underlying network level processes must be fast and precise. During fear conditioning, an associated memory trace is formed when a conditioned stimulus (CS) appears alongside an affective (unconditioned) stimulus (US). The anatomical basis for this CS-US pairing includes a network in which these two types of information can converge on a single neuron. Our recent findings have revealed that this could occur in a tecto-thalamic circuit, at the level of the LA-projecting calretinin-expressing lateral thalamic (CR+LT) cells (Barsy B., Kocsis K. et al. 2020). The tectal part of this circuit is formed by the paired structures of the midbrain, the inferior (IC) and the superior colliculus (SC). The superficial SC neurons can convey visual, while the intermediate and deep SC cells transmit multisensory information; however, their exact role in associative learning is largely unknown. In order to investigate these tecto-thalamic circuits, first, we used classical and viral tracing techniques in combination with immunohistochemical approaches in mice. We show that both colliculi are able to form synaptic contact on the same CR+LT cell involving glutamatergic and GABAergic collicular cells. Next, we investigated response properties of local and CR+LT-projecting SC cells driven by unimodal (visual, auditory and somatosensory-pain) and complex signals with optogenetic and electrophysiological approaches. We found that multisensory signals rather than the unimodal ones altered the activity patterns of both glutamatergic and GABAergic cells; however with different time course. While the glutamatergic cells responded faster and showed elevated firing rates for a short time, the GABAergic cells had longer latencies but for a longer timeframe. This could indicate a complex network mechanism between the different SC cell types and the CR+LT cells. In conclusion, complex synaptic transmissions by SC-LT routes can contribute to the fast signal integration during associative fear learning process and promote survival.

This work was supported by the Hungarian Scientific Research Fund NKFIH-FK 135285 (SB), FK144583 (SB), K138836 (FM) and KKP126998 (FM), by the New National Excellence Program of the Ministry for Culture and Innovation from the source of the National Research, Development and Innovation Fund ÚNKP-20-5-ÁTE-3 (FM); ÚNKP-22-2-III-ELTE-539 (AVB) and by ELKH SA-SA-48/2021 (FM).