Stopping actions by suppressing striatal plateau potentials

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Abstract

Striatal projection neurons (SPNs) in the basal ganglia gradually increase their firing rate during movement initiation. Arkypallidal neurons in globus pallidus briefly increase their firing rate upon a Stop signal, which cues movement cancellation. This increase potentially leads to the suppression of movement-related activity in striatum by inhibiting SPNs. However, this brief inhibition from arkypallidal neurons may be too short to completely prevent the gradual firing rate increase in SPNs. Here, we investigated the impact of the brief inhibition on the gradual increase in a multi-compartmental model of a SPN. We reproduced the movement-related firing pattern in the SPN model neuron by brief clustered excitation added to a baseline, subthreshold excitation. This brief clustered excitation evoked a dendritic plateau potential leading to a long-lasting depolarization at the soma, which enhanced the somatic excitability and evoked spikes upon the baseline excitation that was formerly subthreshold. A brief inhibition, representing arkypallidal stop responses, applied on the dendritic site where the clustered excitation was present, suppressed the somatic depolarization and attenuated the movement-related activity similar to the firing pattern observed in rats for successful action suppression. We conclude that arkypallidal Stop responses can suppress movement-related activity in the striatum by suppressing the dendritic plateau potentials.

Keywords: Behavioural inhibition; Basal ganglia; Striatum; Dendritic plateau potentials; Globus pallidus

The ability to quickly suppress actions is an important function of the brain. An impaired ability to suppress actions is associated with impulsive behaviour and disorders such as Tourette syndrome and attention-deficit hyperactivity disorder. Several basal ganglia pathways are involved in action cancellation (Schmidt & Berke, 2017). One of these pathways involves the inhibitory projections from arkypallidal neurons to the striatum, the basal ganglia input region. Arkypallidal neurons briefly increase their firing rate shortly after the presentation of the Stop signal in a Stop-signal task (Mallet et al., 2016), a widely-used task to study action suppression. Whether the brief inhibition provided by the arkypallidal stop responses can suppress the gradual movement-related increase in the firing rate of striatal projection neurons (SPNs) is unknown. In terms of firing rates, the temporal profile of the arkypallidal stop responses is shorter than the temporal profile of the SPN movement-related activity and therefore may not be sufficient to completely cancel movement.

We investigated the impact of arkypallidal inhibition on striatal movement-related activity in a multi-compartmental model of SPNs (Lindroos et al., 2018). This model captures the dendritic plateau potentials evoked by brief clustered excitation on distal dendrites (Du et al., 2017). We found that these plateau potentials can enhance somatic excitability and, when added to subthreshold baseline excitation, lead to a spiking pattern similar to the movement-related activity in SPNs (Figure 1). We also found that a brief inhibition, mimicking the arkypallidal Stop responses, effectively prevented the movement-related activity when it was applied on the site of the clustered excitation.

We conclude that dendritic plateau potentials evoked by clustered excitation, potentially from cortex or thalamus, may underlie movement-related activity in SPNs. Brief inhibition targeting the dendritic tree on the site where clustered excitation was present can effectively suppress dendritic plateau potential. We propose that this mechanism for the suppression of the movement-related activity in SPNs may be key for stopping actions.

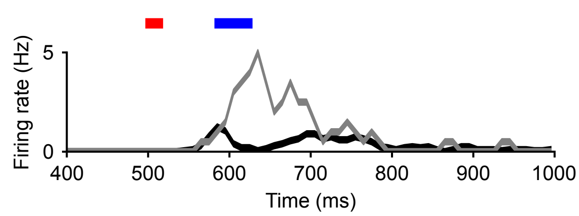

Figure 1: Suppression of movement-related activity via inhibition applied on the site of clustered excitation. Movement-related activity (grey trace) is generated by the combination of baseline excitation (600 Hz) and a brief excitation (1000 Hz) on a distal dendrite (horizontal red bar). 40 ms long inhibition (horizontal blue line) targeting the distal dendrite after the clustered excitation suppressed movement-related activity (black trace).

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