Convergence of auditory and cingulate input in frontopolar area 10: synaptic substrate for complex cognition

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Frontopolar area 10 in primates is thought to be a central cortical node for highly complex cognitive processes, but its precise role has remained elusive. We have previously shown (Medalla and Barbas 2010, J Neurosci 30: 16068-16081) that area 10 receives strong input from the anterior cingulate cortex (ACC), a medial prefrontal region associated with attention, emotions and drive. Interestingly, the extrinsic connections of area 10 are largely comprised of strong bidirectional pathways with auditory association cortices in the superior temporal gyrus. The convergence of ACC and auditory pathways in area 10 suggests a pivotal role of both motivational context and the auditory modality in the high-order cognitive processes mediated by area 10, such as multi-tasking, reasoning and abstract thought. However, the precise mechanism that underlies these processes is unknown, which is likely dependent on the synaptic circuits of the ACC and cortical auditory pathways in area 10.

Simultaneous labeling of pathways from auditory association cortex and ACC in rhesus monkeys showed strong overlap of labeled axon terminals in area 10. At the synaptic level, we found striking differences between these pathways. In both pathways, most synapses targeted excitatory spines in layers 2-3a of area 10 (~90% of synapses in the auditory pathway; ~80% in the ACC pathway), and the rest innervated dendritic shafts of cortical inhibitory neurons. However, the axonal boutons from auditory cortices terminating in area 10 were significantly smaller in volume (about half) than the boutons from ACC ($p < 0.05$). The size of presynaptic boutons is linearly correlated with the size of the postsynaptic element, and these features are highly correlated with synaptic efficacy. Thus, the highly efficient large boutons from ACC may drive and redirect activity in area 10 for flexible behavior. On the other hand, the auditory pathway may also elicit excitatory effects in area 10 through concerted action of small boutons, which may be suited for retaining and resolving the constant streams of auditory information. The interplay of these distinct synaptic influences in area 10 suggests a mechanism for processing, organizing, and selecting 'thought' streams encoded as auditory signals for complex planning and cognition.

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