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Information routing in the basal ganglia: Highways to abnormal connectivity in autism? Comment on “Disrupted cortical connectivity theory as an explanatory model for autism spectrum disorders” by Kana et al.

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This review by Kana and colleagues proposes a neural mechanism linking the diverse behavioral and cognitive impairments in autism. Specifically, they describe the “Disrupted Cortical Connectivity Theory” of autism spectrum disorder (ASD), proposing that cognitive deficits in ASD can be explained by the combination of underconnectivity between distant brain regions and overconnectivity within local regions. We find this review important, and the theory compelling; however while it is uncontroversial that both structural and functional connectivity are abnormal in ASD, it is unclear whether the two phenomena are related (see Tyszka, Kennedy, Adolphs, & Paul, 2011).

We would like to extend the Disrupted Connectivity Theory by proposing that abnormal functional connectivity in ASD results, in part, from impaired functioning of the basal ganglia (BG). Specifically, we suggest that the BG selectively route information from distributed cortical processing centers to the frontal lobes (O’Reilly & Frank, 2006; Stocco, Lebiere, & Anderson, 2010), and that this function is impaired in individuals with ASD. Including this neural mechanism for information routing and synchronization improves the current theory by providing a link between atypical motor behaviors and cognitive impairments in ASD, and by identifying the key computations that link impairments in cognitive flexibility, language, selection and inhibition, and set shifting processes.

Investigations of BG function in ASD have primarily focused on the overlap between abnormal motor behavior in ASD (e.g., repetitive or ritualistic movements, abnormal gait) and other populations with BG pathologies (e.g., Obsessive-Compulsive Disorder, Parkinson’s disease: Nayate, Bradshaw, & Rinehart, 2005). Recently, research has also shown that the BG are abnormally connected to the frontal cortex in ASD, and that, as predicted by the conditional routing model, this decreased connectivity is associated with impaired cognitive abilities (Langen et al., in press).

Although the BG have been historically associated with fine motor control and motor planning, the past 20 years of research have provided overwhelming evidence of their centrality to cognitive processes (Middleton & Strick, 2000; Packard & Knowlton, 2002), spanning areas as diverse as working
memory (McNab & Klingberg, 2008), language (Prat & Just, 2011), decision-making (Frank, Seeberger, & O’Reilly, 2004), and set-shifting (Yehene, Meiran, & Soroker, 2008). As illustrated by Kana et al., individuals with ASD are impaired in all of these functions, which can be characterized as different instantiations of a unique processing ability—flexible information routing.

In fact, recent theories have described how cognitive flexibility emerges from BG computations (O’Reilly & Frank, 2006; Stocco et al., 2010). According to these theories, the general function of the BG is to quickly “select” or “prioritize” signals from throughout the cortex and route them to the frontal lobes. As described by Kana et al., (section 4.1.1), these selection functions are particularly impaired in ASD. More generally, impairments in routing in the BG can explain deficits observed in a variety of complex cognitive tasks, including those that are not particularly reliant upon information integration (e.g., set shifting), and don’t require distant cortical collaborations (section 3.2); whereas the Disrupted Connectivity Theory postulates that impairments in complex cognition arise primarily when information integration demands are high, and when processing requires contributions from distant cortical centers, and therefore cannot readily explain deficits in task shifting or inhibition.

The BG are particularly important for adapting to novel situations, where task-dependent rules can be quickly learned in the dopamine rich BG before they are ultimately stored within cortico-cortical connections (Seger & Spiering, 2011). A recent fMRI study of learning in ASD reported that controls showed increased activation in the BG along with cortical adaptability (decreased activation in processing centers and increased functional connectivity between them) following training, whereas individuals with ASD showed no increase in the BG and had smaller training related changes in synchronization and activation (Schipul, Williams, Keller, Minshew, & Just, in press). These results, combined with the model of information routing in the BG, suggest that the efficiency and adaptability of cortico-cortical connectivity is ultimately shaped by information routing in the BG. In summary, we postulate that a deficit of the information routing functions of the BG in autism can extend the Disrupted Connectivity
Theory by simultaneously offering a mechanistic explanation of abnormal functional synchronization and of complex cognitive impairments in ASD. We see this as an exciting avenue for future research.
References


