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Note

Focal striatum lesions impair cautiousness in humans

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ABSTRACT

Functional neuroimaging data indicate the dorsal striatum is engaged when people are required to vary the cautiousness of their decisions, by emphasizing the speed or accuracy of responding in laboratory-based decision tasks. However, the functional contribution of the striatum to decision making is unknown. In the current study we tested patients with focal ischemic lesions of the dorsal striatum and matched non-lesion control participants on a speed-accuracy tradeoff (SAT) task. Analysis using a computational model of response selection in a competitive and time-pressured context indicated that the decisions of patients with striatal lesions were less cautious than those of matched controls. This deficit was most prominent when the accuracy of decisions was emphasized. The results are consistent with the hypothesis that the striatum plays an important role in strategically setting response caution, an essential function for flexible behavior.

1. Introduction

Some decisions require a snap judgment, while others require careful deliberation. People exhibit remarkable flexibility in their ability to optimize decision behavior in different contexts. The hallmark signature of this flexibility is the speed-accuracy tradeoff (SAT; Pachella, 1974; Reed, 1973; Wickelgren, 1977): the ability to shift between slow and careful decisions and fast but error prone responses. The SAT is thought to reflect a strategic setting of response caution: the decision maker selectively adjusts the amount of evidence

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they consider prior to committing to a course of action, where collecting a large amount of evidence corresponds to a high degree of response caution, and vice versa.

The SAT is typically studied in the laboratory with perceptual decision-making tasks that emphasize fast responding on some trials and careful responding on others. When participants are instructed to emphasize response speed over response accuracy, there is a larger blood-oxygen-level dependent (BOLD) response in the striatum and the pre-supplementary (pre-SMA) motor cortex (Forstmann et al., 2008; Ivanoff, Branning, & Marois, 2008; Van Maanen et al., 2011; Van Veen, Krug, & Carter, 2008; Winkel et al., 2012). One interpretation of the elevated BOLD response is an increase in baseline firing rates in these regions under speed-emphasis instructions. The additional input required to reach a neural threshold is therefore reduced, resulting in an effectively decreased level of response caution. In addition to functional imaging, anatomical measures of frontostriatal structural connectivity are positively correlated with the magnitude of individual participants' shift in response caution between speed- and accuracy-emphasis conditions (Forstmann et al., 2010). These data are consistent with models of basal ganglia function that emphasize a critical role for the striatum in response selection. Specifically, the basal ganglia are hypothesized to serve as a gate on cortical activation patterns, selectively releasing one or a limited set of responses from globally applied inhibition (Mink, 1996). Within this general framework, striatal dopamine has been hypothesized to provide the neurochemical basis for setting caution levels by altering striatal responsivity (Lo & Wang, 2006; Niv, Daw, & Joel, 2007; Robbins & Everitt, 2007; Winkel et al., 2012).

At a minimum, the imaging data indicate that striatal activity is sensitive to processes associated with setting and adjusting response caution. As with all imaging studies, however, the results are correlational. Stronger tests of functional hypotheses require that the striatum is not only active when decision makers set and adjust response caution, but that it is necessary or sufficient for such adjustment to take place. In one example of this approach, Ding and Gold (2012) showed that stimulating striatal neurons of non-human primates led to faster responses in the direction contralateral to the stimulation. This finding suggests that stimulation induced biased patterns of responding and thus altered response caution.

In the current study, we took a neuropsychological approach to test how focal lesions of the striatum affect performance on a SAT task. In particular, we compared patients with striatal lesions to matched controls on their ability to set and flexibly adjust response caution to meet changing task demands. To ensure that any observed group differences were not due to a global effect of 'general brain damage', we collected a large number of decision trials from each participant that allowed us to use a model-based analysis that separates the relative impact of response caution from general ability to complete the experimental task. We hypothesized that if the striatum is causally involved in setting the level of response caution, patients would have impaired levels of response caution relative to the controls. We additionally hypothesized that patients would show a reduced dynamic range in the level of caution between the speed- and accuracy-emphasis conditions.

2. Method

2.1. Participants

The institutional review board at the University of California, Berkeley, approved the experimental protocol. Five patients with chronic focal ischemic lesions in the dorsal striatum were recruited for the study. The patients were referred by neurologists in the San Francisco Bay area. To assess healthy cognitive functioning, all patients were tested on the Wechsler Adult Intelligence Scale (WAIS) IV (Wechsler, 2008), the Beck Depression Inventory (BDI) (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961), and the National Adult Reading Test – Revised (NART-R) (Spreen & Strauss, 1998). Seven control participants were recruited in The Netherlands, selected to match the patients in terms of age and education. Table 1 provides a complete overview of the participants' demographics and neuropsychology.

The patients' lesions were reconstructed by registering their anatomical scans to a Montreal Neurological Institute template using a 7-parameter transformation (3D rotation, 3D translation, and global rescale) using FLIRT (Jenkinson, Bannister, Brady, & Smith, 2002; Jenkinson & Smith, 2001). The resulting reconstructions for the five patients are shown in Fig. 1. The lesions, while not always constrained to the striatum proper, all affected the putamen. The lesion of patient 2 extended along the claustrum and external capsule.

2.2. Experimental task

We used a modified version of the random dot motion task (Fig. 2A), a popular paradigm in visual neuroscience (Britten, Shadlen, Newsome, & Movshon, 1992; for details see; Forstmann et al., 2008). Speed-accuracy requirements were manipulated on a trial-by-trial basis. Each trial began with a cue that indicated whether the participant should respond on the upcoming trial quickly (speed trial) or accurately (accuracy trial). The cue remained visible for 1000 msec. The cue was then replaced by a fixation cross that remained visible for a randomly selected variable interval (50, 200, 500, or 800 msec). The random dot motion stimulus was then presented for 1500 msec. The motion stimulus consisted of thirty images that were each displayed for 50 msec. Each image contained 120 white dots on a black background. Sixty of these dots were redrawn in the next image, all of which were displaced to the left on 50% of the trials and to the right on the other 50% of the trials. This resulted in the percept of coherent motion to the left or right. The other sixty dots were redrawn in a random position, rendering the signal harder to detect. The set of dots to be redrawn was selected at random on each frame update, resulting in a 'lifetime' of 1 frame update for 30 dots on average, of 2 updates for 15 dots on average, and so on.

Participants indicated their response (left or right moving coherent motion) with a button press. Responses were given with the index and middle finger of the ipsilesional hand for patients and the dominant hand for controls. The response