Fractionating impulsivity: Commentary on "choice impulsivity" and "rapid-response impulsivity" articles by Hamilton and colleagues.

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Fractionating impulsivity: Commentary on Hamilton and Colleagues (this issue)

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In this issue, Hamilton and colleagues present two timely review papers on aspects of impulsivity. To quote William James, “Every one knows what attention is...” Is the same true of impulsivity? At face value it might appear easy to define. However, then the realization dawns that impulsivity cuts across many psychiatric disorders in various guises, and that it is not simply ‘one thing’. Broadly speaking, impulsivity has been defined as a tendency to engage in behaviors that are premature, risky, and/or poorly thought out, and which result in unwanted or negative outcomes (Daruna & Barnes, 1993; Evenden, 1999). Impulsivity can be understood from a hierarchical perspective. At the top level are particular psychiatric disorders linked with impulsivity (e.g., gambling disorder, substance use disorder, attention-deficit hyperactivity disorder [ADHD], certain personality disorders), for which the underlying impulsive behaviors (e.g., repeated gambling, escalating substance use, acting out of turn, or aggression/self-harm, respectively) are central to the psychopathology. Aspects of personality and behavior relating to impulsivity can be captured using questionnaire-based approaches, such as the Barratt Impulsiveness Questionnaire (Barratt, 1965). Underlying these behaviors, it is suggested, are various dissociable neurocognitive sub-types of impulsivity (cognitive deficits), which in turn can be linked with particular neural circuits and neurochemical systems. The endophenotype approach in psychiatry (Gottesman & Gould, 2003) holds that intermediate biological markers, such as measures of cognition and brain function, may be closer to the underlying aetiology of psychiatric disorders than overt symptoms, and therefore allow us a ‘window’ or means of better understanding such conditions and the genetic factors that predispose towards them. Cognitive deficits are likely to be a key area of importance in this regard, in that they may be more readily linked with brain structure and function than more complex higher level phenotypes (Fineberg et al., 2014), and more readily modelled in other species (Dalley, Everitt, & Robbins, 2011). Hamilton et al. (this issue) focus on two important sub-types of impulsivity that are defined by the underlying cognitive deficit: Rapid Response Impulsivity and Choice Impulsivity.

Rapid Response Impulsivity refers to the impaired ability to suppress or inhibit responses that are pre-potent (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001); put differently, it refers

to a lack of top-down control governing behavioral response tendencies, particularly when environmental circumstances change. Response inhibition is typically measured using Stop-Signal tasks (in which participants attempt to suppress an already initiated pre-potent response when a 'stop cue' such as an auditory tone occurs), and Go/no-go tasks (in which participants withhold a not-already-triggered response when presented with particular cues). Outcome measures from these tasks are quite well defined: Stop-Signal tasks provide Stop-Signal Reaction Time, which is an estimate of the time taken for the individual's brain to stop a pre-potent response, whereas Go/No-Go tasks quantify impulsivity in terms of 'commission errors' (i.e., inappropriate motor responses to no-go trials). The neural circuitry underlying response inhibition is also quite well defined. Data from patients with focal neurosurgical lesions and functional imaging implicate distributed circuitry in response inhibition, notably the right inferior frontal cortex, anterior cingulate cortex, insula, and pre-supplementary motor area (Bari & Robbins, 2013). Similar regions (or their putative functional homologues) are implicated in animal models using this task. Interestingly, as discussed in Hamilton et al. (this issue), there do appear to be some differences in neural activation between Stop-Signal and Go/No-Go tasks and other tasks potentially capturing response inhibition. Furthermore, the precise role of different neural regions in inhibitory control and whether or not response inhibition is a 'discrete' cognitive function remain under hot debate – issues expanded upon in recent work (Aron, Robbins, & Poldrack, 2014).

The neurochemical modulation of response inhibition has received considerable scrutiny. For example, manipulations of the noradrenergic system (such as with the selective noradrenaline reuptake inhibitor atomoxetine) can enhance this function in humans and rats, and this has been linked to modulatory actions on the right inferior frontal gyrus and insula in humans and functionally related regions in rats (Bari & Robbins, 2013; Chamberlain et al., 2008). Stop-Signal inhibitory deficits have been confirmed in various psychiatric disorders through meta-analysis, including ADHD, obsessive compulsive disorder (OCD), and certain substance use disorders (Lijffijt, Kenemans, Verbaten, & van Engeland, 2005; Lipszyc & Schachar, 2010; Smith, Mattick, Jamadar, & Iredale,

2014). Unaffected first-degree relatives of ADHD, OCD, and certain substance use disordered patients also exhibit Rapid Response Impulsivity, suggestive of a candidate vulnerability marker.

Choice Impulsivity refers to a tendency to select more immediate, smaller rewards rather than larger delayed rewards, to the detriment of longer-term goals or outcomes. Choice Impulsivity relates to the concepts of temporal discounting, or delay discounting. It is typically measured using tasks (or questionnaires) that present individuals with a range of decision-making options involving different magnitudes of rewards given at different delays (Kirby, 2009). From this sampling of decision-making, these tasks can produce a discounting curve, describing how quickly the value of a reward decreases as time increases: the steeper the curve, the more impulsive the individual is deemed to be. The neural underpinnings of Choice Impulsivity are perhaps less clearly delineated than those for Rapid Response Impulsivity. Preference for smaller, more immediate choices has been associated with activation in reward-related neural circuitry (especially the ventral striatum, but also the medial prefrontal cortex), whereas preference for delayed larger rewards has been associated with activation in the dorsolateral and ventrolateral prefrontal cortices.

In terms of neurochemical modulation of Choice Impulsivity, Hamilton et al. (this issue) discuss various examples of Choice Impulsivity tests, including the computerized Experiential Discounting Task (which is sensitive to the anti-impulsive effects of methylphenidate medication in ADHD and pro-impulsive effects of dopamine agonists; (Voon et al., 2010). Although elevated Choice Impulsivity has been identified in various psychiatric contexts, including ADHD, meta-analytic confirmation is not yet available for the most part. It is also less clear whether Choice Impulsivity also exists in unaffected first-degree relatives of patients with impulsive disorders.

In all, research in these areas has made important steps towards understanding impulsivity. Rapid Response Impulsivity and Choice Impulsivity appear to be dissociable in terms of underlying neural circuitry and associated neurochemical modulation. Although various cognitive paradigms have been developed that tap these two functions, as Hamilton and colleagues correctly argue,

there is a need for standardized measurements to be validated and agreed upon, and for academics and clinicians to work together in order to tackle several pressing and related questions, such as:

- How do these cognitive abilities develop normatively, across the lifespan? What are the neural and neurochemical substrates in the normative state?

- What are the similarities and differences in cognitive dysfunction across clinical disorders? What are the neural and neurochemical substrates in the disordered state?

- What is the relationship between such dysfunction and psychiatric symptoms? Are cognitive deficits directly causative, e.g. linearly related, or might they represent vulnerability markers, perhaps more closely related to genetic factors?

- What are the implications of the above for diagnostic classification systems, neurobiological models, and treatment approaches?

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