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Comments and Controversies: Piecing Together the Neurobiology of Decision-Making

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Abstract

In this paper, we address issues raised by Tierney and Hart (Assessing complex cognitive functioning requires multiple tasks) in response to our recently published findings showing that less advantageous decision-making on the Iowa Gambling Task (IGT) was associated with enhanced right ventral striatal dopamine response to intravenous amphetamine (Oswald et al., 2015). We agree with the overall premise of the paper, which was that decision-making involves multiple components, which may not be tapped by a single measure. While Tierney and Hart also bring up some important issues related to the construct validity of the IGT, we suggest that they are failing to put the findings within the context of the growing body of research that has highlighted the role of DA function in risk-taking behavior across species using a variety of tasks. It should also be noted that it was not our goal to “cover all bases” within the context of a single study. Nevertheless, we appreciate the discussion, which we believe highlights the need for further empirical refinement of the construct to facilitate detection and understanding of the differential role that specific molecular mechanisms may play in the component processes.

We appreciate the interest of Aaron Tierney and Carl Hart (Assessing Complex Cognitive Functioning Requires Multiple Tasks) in our published findings (Oswald et al., 2015) and agree with their overall premise that decision-making and other complex behaviors involve multiple components, which may or may not be tapped by a single measure, such as the Iowa Gambling Task (IGT). Nevertheless, the exclusive use of this measure does not negate the findings of our study or of the numerous other studies that have used the IGT to draw conclusions about the involvement of regional brain function in risky decision-making. Findings of the original article showing associations between IGT scores and right ventral

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striatal (RVS) dopamine (DA) release are certainly not the final word on risk-taking. In fact, we would be surprised if these findings generalized across the gamut of decision-making tasks. Indeed, there is often a lack of correlation among such measures themselves (Brand et al., 2007; Lejuez et al., 2003) and part of the current challenge is to sort out the neurobiological and conceptual distinctions. In spite of differences in paradigms, it is notable that there has been a recent convergence of findings highlighting the role of DA function in risk-taking across human and animal studies using several different kinds of risk-taking measures. This includes evidence of 1) altered striatal DA function in pathological gamblers during amphetamine (AMPH), IGT, or other kinds of gambling-type challenges (Boileau et al., 2013; Linnet et al., 2010; Steeves et al., 2009), 2) associations between D2/D3 receptor availability and risk-taking in healthy humans performing the Balloon Analogue Risk Task (BART) (Kohno et al., 2013), 3) associations between AMPH-induced DA release and risk-taking on the open field test in rodents (Palm et al., 2014), as well as evidence that dopaminergic drugs modify risk-taking behavior on the rodent version of the IGT (van Enkhuizen, Geyer, Young 2013; Zeeb, Robbins, Winstanley 2009). Nevertheless, this body of research is still in its infancy and much remains to be done.

Although Tierney and Hart argued that a drawback of using only the IGT is the inability to tap all components of risky decision-making, we suggest that the relative complexity of the IGT is perhaps a greater concern for the interpretation of findings. The problems involved in deconstructing the IGT make it difficult to know what component of risky decision-making is linked to associated neural function (Schonberg, Fox, Poldrack 2011). We suggested in the discussion of the original article that enhanced DA response to AMPH may reflect enhanced sensitivity to reward, which could be the driving force behind the disadvantageous choices made by the risky decision-makers. However, we recognize that decision-making may be influenced by individual differences in other kinds of processes (e.g., emotional responses to anticipated outcomes, risk attitudes, degree of reward uncertainty, or contingency learning). It is possible that any of these factors could be more closely linked to the underlying neurobiology than the risk-taking behavior itself. To the extent that a combination of risk-taking measures would help to further distill or refine our understanding of these mechanisms, we concur that the inclusion of two or more such measures in a single study would be most informative. This would be an important area for future research given our current findings.

Like Tierney and Hart, we are not aware of any formal validation study being conducted on the IGT and agree that further evidence of construct validity would further support its use. However, while it is widely acknowledged that the relative complexity of the IGT makes the measure difficult to deconstruct, several authors have argued that this complexity is what actually gives it its high ecological validity (Schonberg, Fox, Poldrack 2011; Yechiam et al., 2005). Decision-making impairments have been demonstrated in patients with damage to the mOFC/VMPFC or amygdala (Bechara et al., 1999), older adults (Denburg et al., 2006), and various psychopathological conditions, such as substance use disorder (Bechara and Damasio 2002; Grant, Contoreggi, London 2000; Stout et al., 2004), gambling disorder (Goudriaan et al., 2004), impulsive aggressive disorders (Best, Williams, Coccato 2002), psychopathy (van Honk et al., 2002), and affective disorders with suicide attempts (Jollant et al., 2005). Although mixed results have been reported when the IGT has been compared to

other measures of executive function (Buelow and Suhr 2009), findings of several studies support notions that IGT performance reflects risk-taking behavior (Bartzokis et al., 2000; Brand et al., 2007; Upton et al., 2011; Verdejo-Garcia, Perez-Garcia, Bechara 2006; Weller, Levin, Bechara 2010). Findings from neuroimaging studies have also revealed that poor performance is related to alterations in frontal lobe function (Bechara et al., 2001; Bolla et al., 2003; Kohn et al., 2014). Results such as these (which link performance to theoretical perspectives) led the authors of one recent review article to conclude that the preponderance of evidence supports the validity of this measure (Buelow and Suhr 2009). We believe that the high ecological validity of the IGT, in particular, gives our findings relevance for several psychiatric disorders characterized by both poor decision-making and altered DA function.

Two additional issues were raised by Tierney and Hart. The first was that the use of hypothetical earnings and losses provided no tangible consequences for risky decision-making on the IGT in the original study. There seems to be some confusion about the payoff methods that were employed. To clarify, participants were informed that they would be paid for the session up to the maximum amount specified on the consent form depending on task performance. The only deception involved was that the cash payment was not actually based on performance; all participants received the maximum payment regardless of performance. These methods seem consistent with prior evidence that the possibility of receiving a tangible cash reward functions as a motivating incentive (Vadhan et al., 2009). The last issue that was raised was whether AMPH-induced anxiety or other negative effects may have influenced the data. The vast majority of our participants report pleasurable effects from AMPH. Only 6 participants in this study (13% of the sample) reported peak “anxiety” symptoms > 6 on an analog scale ranging from 0–10 during the AMPH scan and half of these same individuals concurrently reported “good effects” > 6. None of the participants required rescue medications or discontinuation of the scans due to any such symptoms. Thus, it is unlikely that such negative symptoms had a significant effect on the data.

We thank Tierney and Hart for their thoughtful comments and hope that our responses have sufficiently addressed the issues raised. The discussion highlights the need for further empirical refinement of the construct of decision-making to facilitate detection and understanding of the differential role that specific molecular mechanisms may play in the component processes and in the development of psychological disorders characterized by deficits in such processes.

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