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Dissociable elements of human foresight: a role for the ventromedial frontal lobes in framing the future, but not in discounting future rewards

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Abstract

Impaired future thinking may be a core aspect of impulsive decision making. Recent efforts to understand the brain processes that underlie impulsivity have suggested a role for the frontal lobes. However, future thinking is unlikely to be a unitary process, and the frontal lobes are not a homogeneous entity. The present study contrasted the effects of dorsolateral and ventromedial frontal lobe damage on two distinct aspects of future thinking in humans. Temporal discounting, the subjective devaluation of reward as a function of delay, is not affected by frontal lobe injury. In contrast, a normal future time perspective (a measure of the length of an individual's self-defined future) depends on the ventromedial, but not dorsolateral, frontal lobes. Furthermore, investigation of the relationship of these two measures with classical symptoms of frontal lobe damage indicates that future time perspective correlates with apathy, not impulsivity. Apathy may deserve more attention in understanding both impaired future thinking and the impaired decision making that may result.

Keywords: Ventromedial prefrontal cortex; Dorsolateral prefrontal cortex; Lesion; Decision making; Impulsivity; Apathy

1. Introduction

The making of poor choices is characteristic of several disorders, ranging from substance abuse, to attention deficit hyperactivity disorder (ADHD), to frontal lobe damage (Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001; Bechara, Damasio, Damasio, & Anderson, 1994; Bechara, Dolan, Denburg, Hindes, Anderson, & Nathan, 2001; Evenden, 1999; Kirby, Petry, & Bickel, 1999). A common theme of impaired impulse control may link these disparate conditions, which in turn suggests the possibility that they share a common neural basis. However, impulsivity is a variably defined construct that encompasses several distinct factors, and that are presumably manifestations of different brain processes (Evenden). Virtually all definitions of impulsivity include the idea of impaired cognition about the future, whether as impaired awareness of the future, or use of information about the future, or consideration of the future consequences of present actions. In the words of Bechara and co-workers, the poor decision making that may follow ventromedial frontal lobe (VMF) damage seems to reflect a "myopia for the future"(Bechara et al., 1994; Bechara, Tranel, & Damasio, 2000). One way of dissecting this complex behavioral phenomenon is by identifying dissociable features of poor impulse control in humans with focal brain damage.

A clearer understanding of any impairments in future thinking in patients with focal frontal lobe damage is directly relevant to elucidating the underlying brain processes, and has potentially broad implications for understanding disorders with similar behavioral profiles, but in which the underlying neuropathology is much less clear. The existing evidence for a role for the frontal lobes in future thinking, drawn from studies of decision making, is at best either indirect (Bechara et al., 1994; Bechara, Tranel, et al., 2000; Goel, Grafman, Tajik, Gana, & Danto, 1997) (Miller & Milner, 1985), or rests on single case reports (e.g. (Ackerly, 1950/2000) and see reviews by (Atance & O'Neill, 2001; Loewenstein, Weber, Hsee, &

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Welch, 2001)). We undertook to directly assess two aspects of future thinking that may result in the ill-considered behavior that often follows frontal lobe damage: the first concerns how steeply rewards are devalued as their delivery is pushed into the future, a phenomenon known as temporal discounting, while the second concerns the perceived dimensions of future time, sometimes labeled 'future time perspective'.

Weighing future outcomes requires comparing relative reinforcement values across delays. A large body of research has demonstrated that organisms ranging from pigeons to people discount delayed reinforcement (reviewed in (Ainslie, 2001; Critchfield & Kollins, 2001)); 10 dollars today is worth more to most people than 10 dollars that will not be received for a month. The rate at which a reinforcer loses its value across a delay is relatively consistent within individuals, and can be described by a hyperbolic function (Ainslie; Kirby & Herrnstein, 1995; Madden, Begotka, Raiff, & Kastern, 2003; Mitchell, 1999). Some pathological forms of impulsive behavior have been related to steep discounting functions: cigarette smokers, problem drinkers, cocaine or heroin addicts, and individuals with ADHD are more likely than normal subjects to prefer smaller, immediate gains over larger, delayed rewards (Barkley et al., 2001; Bickel & Marsch, 2001; Coffey, Gudleski, Saladin, & Brady, 2003; Mitchell; Vuchinich & Simpson, 1998).

Future time perspective is a second aspect of future thinking that may also underlie some kinds of impulsive behavior. The development of future goals and plans occurs within a temporal framework, whether or not this window of time is explicitly specified (Atance & O'Neill, 2001). The dimensions of this window contribute to determining what priorities will be set and what anticipated outcomes, rewards, or punishments will be considered. Aesop's ant and grasshopper were both making appropriate future plans, but from the perspective of very different future time horizons. Similarly, when human subjects contemplate the future in an open-ended fashion, within any given context, the actual chronological time being considered varies across individuals. Measures of future time perspective have been shown to correlate with more adaptive profiles on personality inventories, and have been applied in a variety of populations as a method of assaying the capacity for forward thinking or future orientation (Kastenbaum, 1961; Lessing, 1968; Wallace, 1956). A foreshortened view of future time has also been linked to pathological impulsive behavior: Heroin addicts have a significantly shorter future time perspective than controls (Petry, Bickel, & Arnett, 1998).

Although these two aspects of future thinking seem similar, they are not equivalent. Future time perspective measures a spontaneously chosen time horizon, which would not necessarily affect the way a person evaluates an event at a specific time in the future when explicitly cued to do so. Similarly, the rate at which reward decays across a specified delay may differ across individuals, even if they have a similar future time perspective.

How are these aspects of future thinking instantiated in the brain? Decades-old observations that frontal lobe damage inclines patients to 'live in the here and now' (e.g. (Ackerly, 1950, 2000) have been bolstered by more recent experimental work that has indirectly suggested a role for the frontal lobes in general (Goel et al., 1997), and the VMF in particular in various kinds of future thinking. Damage to ventromedial prefrontal cortex may lead to personality change marked by impulsive behavior and poor decision making. It has been claimed that these patients make poor decisions in a laboratory gambling task because they neglect future consequences (Bechara et al., 1994; Bechara, Dolan, & Hindes, 2002). Given that the assessment of future consequences hinges on both the conception of future time, and the discounting of future reinforcers, we asked whether damage to the VMF systematically impairs either process. We were also interested in whether these two constructs were dissociable, a finding that would suggest that they measure distinct aspects of impulsivity. Because the experience of suffering a brain injury might, in and of itself, lead to changes in future thinking, control data were acquired from both age-matched normal individuals, and a group of patients with brain lesions that spared the frontal lobes. In order to determine whether deficits in future thinking were a specific effect of VMF damage, or a more general effect of frontal damage, we also evaluated a group with dorsolateral frontal lobe (DLF) damage.

2. Methods

2.1. Subjects

Background information about the participants is provided in Table 1. Normal controls had no history of neurologic or psychiatric disease, closed head injury, or substance abuse, and were not taking psychoactive medication. Controls passed a screening neurological examination and scored at least 28/30 on the Folstein mini-mental state examination. ANOVA revealed no significant difference between

Table 1
Background information (mean (S.D.))

Group	Age (years)	Education (years)	IQ estimate	BDI score	Lesion volume (cm^3)
CTL (n = 26)	56.8 (14.7)	15.2 (2.8)	122 (9.9)	5.4 (4.4)	
VMF (n = 12)	54.5 (10.7)	13.5 (2.3)	118 (8)	9.2 (7.7)	23 (29)
DLF (n = 13)	61.3 (11.2)	15.6 (2.7)	120 (11)	9.0 (3.2)	19 (20)
NOF (n = 13)	59.6 (12.7)	13.5 (4.0)	119 (9.7)	9.6 (6.7)	23 (15)