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Abstract

Neuroeconomics is a new, interdisciplinary field in which economics, psychology, computational science, and neuroscience converge to allow for examinations of the neural basis of reward-related decision making in social and nonsocial contexts. The aims of this paper are, first, to discuss recent advances in the use of neuroeconomic games to examine social decision making in children and adolescents with externalizing behavior disorders, as an alternative to approaches based on Social Information Processing theory and Theory of Mind; and, second, to summarize the potential neuroeconomics holds for the study of social decision making in populations with externalizing (and other) disorders.

Keywords

neuroeconomics, behavioral economics, reward-related decision making, psychiatric disorders

Introduction

Externalizing disorders are a group of disorders characterized by antisocial behavior, aggression, rule-breaking, impulsivity, and overactivity (Achenbach & Edelbrock, 1978; Hill, 2002; Hinshaw, 1992); these disorders include conduct disorder, oppositional defiant disorder, attention-deficit/hyperactivity disorder, antisocial personality disorder, psychopathy, and borderline personality disorder. Externalizing behavior problems (acting-out behaviors) are distinct from internalizing problems, which are characterized by depression, withdrawal, dysphoria, and anxiety (Quay, 1986). Interpersonal difficulties form a core feature of most DSM-IV criteria for externalizing disorders. A leading approach for understanding interpersonal problems associated with externalizing disorders in children and adolescents has been to examine the social-cognitive deficits and distortions associated with these disorders. Studies doing so have been guided by either Social Information Processing theory (SIP) or Theory of Mind (ToM; Sharp, Fonagy, & Goodyer, 2008).

The SIP model describes a set of sequential cognitive processing steps that are presumed to function interdependently, in real time (albeit rapidly), and largely without conscious awareness (Dodge, 1986): encoding of cues; interpretation and representation; clarification or identification of goals; response generation, access, or construction; response selection or decision making; and behavioral enactment. Biases and deficits in these processing steps are thought to be the proximal mechanisms for aggressive interpersonal behavior in specific social situations (Mize & Pettit, 2008). Researchers assessing social cognition in the SIP context typically present children or adolescents with hypothetical social scenarios and ask them what they would think and do in these circumstances.

The term ToM (sometimes referred to as "mentalizing") was coined by primatologists Premack and Woodruff (1978) and adapted in developmental psychopathology to refer to children's capacity to interpret the behavior of others within a mentalistic framework—that is, children's ability to ascribe thoughts, feelings, ideas, and intentions to others and to employ this ability to anticipate and influence the behavior of others. A variety of measures have been developed to tap into either deficits or distortions in ToM that are related to psychopathology. A range of such deficits and distortions associated with externalizing behavior disorders in children and adolescents have been described (Sharp, 2008).

Although the impact of SIP and ToM has been substantial in elucidating the deficits and distortions underlying social decision making in children and adolescents with psychiatric disorders, there are both theoretical and methodological limitations to these approaches. Both approaches are based on the

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theoretical assumption that social cognition can be defined only in terms of individual people and not in terms of relationships or interactions between two or more people. This conceptual approach to social cognition ignores the stochastic nature of social interaction, which is intrinsically dynamic: The thoughts and actions of one agent critically depend on the changing actions (and mental states) of other social agents (Rilling, King-Casas, & Sanfey, 2008). Conceptualizing social cognition as an individual characteristic results in associated methodological limitations of SIP and ToM tasks. Such tasks are typically "off-line" by virtue of their reliance on hypothetical scenarios in which research participants may have no investment. These tasks are not administered in real time, do not sample actual social interactions, and are unlikely to elicit full emotional and behavioral engagement. Most social-cognitive tasks are also characterized by an overreliance on self-report data, thereby potentially eliciting socially desirable responses (Mize & Pettit, 2008). As a result, effect sizes of relations with outcome measures are typically modest in social-cognitive research. Importantly, because of task limitations (ceiling effects associated with ToM tasks in older age groups), the ability to track normative developmental changes using SIP and ToM approaches has been seriously limited, such that most SIP research has been conducted in elementary-school-age children and most ToM research in preschoolers (Sharp, Fonagy, & Ha, 2011).

Beyond the conceptual and methodological limitations outlined above, an additional limitation of SIP and ToM approaches to studying social cognition is the fact that they do not allow for the development of mathematically tractable models of social decision making. There are several advantages to such models; perhaps the most important is that they can be used to examine brain activity corresponding to decision making through neuroimaging methods such as functional neuroimaging (fMRI). Linking brain activation at the endophenotyptic level with behavior through decision algorithms allows social decision making to be studied across multiple levels—thus truly adhering to the principles of not only developmental psychopathology, but translational science.

Neuroeconomics is a new, interdisciplinary field in which economics, psychology, computational science, and neuroscience converge to allow for examinations of the neural basis of reward-related decision making in social and nonsocial contexts (Glimcher & Rustichini, 2004). For social decision making specifically, neuroeconomics combines fMRI with multiplayer exchange games drawn from behavioral economics and computational approaches to examine interpersonal functioning. Recently, there has been a steady increase in studies using neuroeconomic games to examine reward-related decision making in psychiatric populations (Sharp, Monterosso, & Montague, in press). My aim in this article is to discuss recent advances in the application of neuroeconomic games to examinations of social decision making in children and adolescents with externalizing behavior disorders as an alternative to SIP and ToM approaches.

The Application of Game Theoretical Principles to Studies of Social Decision Making in Populations With Externalizing Behavior Disorders

Table 1 presents a selection of the behavioral economic constructs (see also Hasler, 2011) that have been used to study social decision making in adults, children, and adolescents with externalizing behavior disorders. Although my focus in this article is explicitly on children and adolescents, I also discuss studies of adults because of the dearth of studies in youths and the potential for the downward extension of adult tasks to children and adolescents.

What these constructs have in common is that they and their associated experimental paradigms have mostly been developed from game theory—the tasks associated with each construct consist of games played by a set of players who have a series of options or strategies to choose from in order to maximize their payoffs. By varying task characteristics (e.g., strategies, payoffs, and structural features of interactions, such as context and communication between players), seemingly simple games can be adapted to probe a remarkable range of social phenomena, including social influence, prosocial behavior, trust, social-norm violations, social-cognitive biases, group dynamics, and higher-order social cognition (King-Casas & Chiu, in press).

The Trust Task

In the context of behavioral economics and neuroeconomics, "trust" is defined as an exchange between two players in which cooperation and defection can be parametrically encoded as the amount of money a player allocates for his or her partner. The basic one-shot trust task was initially proposed by Camerer and Weigelt (1988) and further developed by Berg, Dickhaut, and McCabe (1995). One player (the "investor") is endowed with a certain amount of money (or points as proxies for money). The investor can keep all of the money or decide to "invest" some amount with the partner (the "trustee"). The amount invested is tripled in value when it is given to the trustee, who then decides what portion to return to the investor.

King-Casas et al. (2008) used the iterated version of the trust task to examine trust in adults with borderline personality disorder. Participants played the game 10 times, after which the total points earned were displayed to both parties. Results showed that when cooperation began to falter in the iterated exchange, normal control participants responded with increased hemodynamic activity in the anterior insular cortex, and this neural response preceded an attempt to coax cooperation from their partner by signaling increased trust. In contrast, a relative insensitivity of the insula was observed in patients with borderline personality disorder; this insensitivity was associated with a failure to coax back partners into the game. Similarly, Unoka, Seres, Aspan, Bodi, and Keri (2009) showed

Table 1. Neuroeconomic Games for Examining Social Decision Making in Adults and Youths With Externalizing Disorders

Construct and task	Research	Psychiatric disorder studied
The Trust Task: an exchange between two players in which cooperation and defection can be parametrically encoded as the amount of money allocated to the partner		
Iterated two-person trust game	King-Casas et al. (2008)	Borderline personality disorder
Trust vs. risk simulated trust game	Unoka, Seres, Aspan, Bodi, and Keri (2009)	Borderline personality disorder
One-shot trust game (anonymous vs. familiar)	Sharp, Fonagy, and Ha (2011)	Adolescent externalizing problems
Iterated trust game with peer reputations	Sharp, Fonagy, et al. (2011)	Adolescent externalizing problems
The Prisoner's Dilemma: the balance between economic self-interest vs. reciprocity and equity		
Iterated version of the Prisoner's Dilemma	Mokros et al. (2008); Rilling et al. (2007)	Psychopathy
Two-person Prisoner's Dilemma	Widom (1976)	Psychopathy
Computer vs. person Prisoner's Dilemma	Montanes Rada, de Lucas Taracena, and Martín Rodrıguez (2003)	Antisocial personality disorder
Frustration-inducing Prisoner's Dilemma	Fairchild et al. (2008)	Conduct disorder
The Dictator Game: the balance between economic self-interest and reciprocity/ equity		
The Dictator Game	Koenigs, Kruepke, and Newman (2010)	Psychopathy
Social discounting: the fact that most people assign more value to the welfare of close affiliates than they do to the welfare of distant affiliates		
Social-discounting task	Sharp, Barr, et al. (2011)	Adolescent conduct problems

that decreased trust was specific to borderline patients (as opposed to depressed patients) and, in a follow-up study, demonstrated that mistrust was specific to situations involving *social* risk-taking (as opposed to risk-taking in general).

The trust task has been used successfully in healthy children and adolescents (e.g., Harbaugh, Krause, Liday, & Vesterlund, 2003; Sutter & Kocher, 2007; van den Bos, Westenberg, Van Dijk, & Crone, 2010). In the first study to use the trust game to study externalizing behavior problems in youth (Sharp, Fonagy, et al., 2011), two groups of boys (externalizing vs. nonexternalizing) played a trust game under two conditions: an anonymous version in which the identity of the trust-game partner was unknown and a "known-identity" version in which the players' identities were revealed prior to the game. Results showed that whereas the known-identity condition of the task increased reciprocity for normally functioning boys, the opposite was true for boys with externalizing behaviors. Moreover, reduced reciprocity was associated with online social-cognitive reasoning characterized by hostile intentions but was not reflective of a general ToM deficit.

This study was followed by an fMRI study examining the neural correlates of reward-related decision making during a trust task in a sample of adolescents with externalizing behavior problems (Sharp, Burton, & Ha, 2011). The task required participants to decide whether or not to share monetary rewards with partners whom they themselves had identified during a real-life peer sociometric procedure as interpersonally aggressive or kind (vs. neutral). Results supported findings from studies with adults (Delgado, Frank, & Phelps, 2005): Prior social and moral information about partners (i.e., reputations) modulated reward responses in the adolescent brain. Moreover, relative to boys without externalizing problems, boys with externalizing problems showed differential activation in the bilateral insula during the decision phase of the game, as well as in the caudate and anterior insula during the outcome phase of the game. Of particular interest in this study was a trend-level result showing that bilateral insula responses in boys with externalizing problems did not differ between outcomes for partners with aggressive or kind reputations.

The Prisoner's Dilemma Game

Researchers have also studied cooperation in relation to psychopathy using an iterated version of the prisoner's dilemma game. The prisoner's dilemma game captures the essence of a

frequent social quandary, namely, that what is good for a group may differ from what is good for individuals within the group (Sally & Hill, 2006). Rilling et al. (2007) showed that higher levels of mutual defection (noncooperation) among pairs of participants with high psychopathic traits relative to low-psychopathy pairs were related to different patterns of activity in brain areas associated with social emotion regulation (e.g., the dorsolateral prefrontal cortex).

The iterated prisoner's dilemma game has also been used to study fairness, or the balance between economic self-interest and reciprocity/equity. Mokros et al. (2008) assessed the behavior of criminal psychopaths and found that, compared with healthy participants, they were markedly more prone to competitive behavior, as well as to nonadherence to the principles of fairness, as evidenced by greater accumulated rewards and exploitation of partners.

While the prisoner's dilemma game has been successfully used in healthy children and adolescents (e.g., Harbough et al., 2003; Sally & Hill, 2006; Tedeschi, Hiester, & Cahagan, 1969), it has been used in only one study on child and adolescent externalizing disorders. Fairchild et al. (2008) used the prisoner's dilemma paradigm as a stress-induction procedure in boys with conduct disorder and measured their salivary cortisol before, during, and after the task. The researchers found that cortisol and cardiovascular responses to psychosocial stress were reduced in conduct disordered participants compared with control participants.

The Dictator Game

Cooperation has also been studied using the dictator game. The dictator game (Kahneman, Knetsch, & Thaler, 1986) is characterized by the interaction of two players, the "dictator" and the "recipient." The dictator must apportion a sum of money between himself and the recipient, thus deciding unilaterally how the money will be allocated. The dictator game thus tests whether participants are willing to pass some positive amount of money on to a second person even where the recipient has no sanctioning power. Koenigs, Kruepke, and Newman (2010) used the dictator game to show that psychopaths' level of noncooperation paralleled that of patients with frontal-cortex lesions. Although the dictator game has been successfully used in healthy children and adolescents (Benenson, Pascoe, & Radmore, 2007; Sally & Hill, 2006), it has yet to be used in populations of children and adolescents with externalizing problems.

The Social-Discounting Game

Modeled on the notion of intertemporal discounting, the term *social discounting* (Jones & Rachlin, 2006) refers to the fact that people typically assign more value to the welfare of close affiliates than they do to the welfare of distant affiliates (i.e., they *discount* the latter). Using the social-discounting game for the first time in a sample of youths, Sharp, Barr, et al. (2011) found that 10- to 18-year-old boys were willing to forgo greater amounts of money to benefit people with whom they perceived themselves to be more closely affiliated, but that social-discounting curves were significantly steeper for boys with externalizing behavior problems than for boys without them. In other words, boys with externalizing problems were less willing to forgo rewards for affiliates with whom they were close than were boys without externalizing behavior problems.

The Value of Neuroeconomic Games for Examining Social Decision Making in Populations With Externalizing Disorders

The aim of this article was to discuss recent advances in the application of neuroeconomic games to examinations of social decision making in children and adolescents with externalizing behavior disorders as an alternative to SIP- and ToM-based approaches. The studies discussed above have revealed a clear pattern in the game-playing behavior of adults and youths with externalizing behavior problems that is suggestive of deficits in the capacity for tit-for-tat behavior in multiplayer interaction games.

Although several neurobiological systems are likely to be associated with this overall pattern of deficits, findings from the studies discussed here point to the role of the anterior insula and dorsolateral prefrontal cortex. Studies using neuroeconomic games with healthy adults have shown the dorsolateral prefrontal cortex to be involved in the selection of appropriate social responses, whereas the anterior insula and dorsal anterior cingulate cortex are involved with the detection of violations of social norms (e.g., Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003). That these areas show up in studies of externalizing behavior disorders is not surprising, given that antisocial behavior forms a core feature of these disorders. SIP and ToM models of externalizing behavior disorders would predict that additional brain areas that are likely to show up in future studies using neuroeconomic games should be associated with the understanding of intentions and thinking about others—areas such as the temporo-parietal junction and the medial prefrontal cortex. Studies of healthy adolescents have indeed shown these areas to be active during neuroeconomic games involving social interaction (Güroğlu, van den Bos, Rombouts, & Crone, 2011). A further important direction for future research would be the use of these games in longitudinal designs in order to examine the status of these brain anomalies as biological markers or etiological risk factors in the early emergence of externalizing disorders.

In conclusion, it is clear that neuroeconomic games hold significant potential for the study of externalizing disorders. Most importantly, neuroeconomics-derived theoretical predictions about optimal adaptation in changing social environments provide an objective and mathematically tractable metric that, in combination with neuroimaging techniques, can be used to examine externalizing disorders in youths. Research

using neuroeconomic games may build on or be combined with SIP and ToM approaches to characterize promising candidate endophenotypes that may help clarify the basis of high heritability associated with externalizing behavior disorders and that may, in turn, inform treatment.

Recommended Reading

Glimcher, P. W., Camerer, C. F., Fehr, E., & Poldrack, R. A. (2009). *Neuroeconomics: Decision making and the brain*. Amsterdam, Netherlands: Elsevier. A textbook providing a comprehensive, highly accessible overview of the origins and development of and the methods used in neuroeconomics.

Hasler, G. (2011). (See References). A clearly written, reader-friendly, and relatively comprehensive review for readers who wish to expand their knowledge on the value of neuroeconomics for examining reward-related decision making in populations with psychiatric disorders.

Montague, P. R., King-Casas, B., & Cohen, J. D. (2006). Imaging valuation models in human choice. *Annual Review of Neuroscience, 29*, 417–448. A concise introduction to neuroimaging studies of computational models of decision making in humans.

Sharp, C., Monterosso, J., & Montague, R. (in press). (See References). Special issue on the use of neuroeconomics to study reward-related decision making in people with psychiatric disorders across the lifespan.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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