Specific Aims: The aim of this project is to examine the neurobehavioral development of mechanisms underlying socially cooperative behavior during adolescence. This project will use a neuroeconomic paradigm, the Prisoner’s Dilemma, in order to explore patterns of cooperative behavior. This paradigm has not previously been studied from a developmental perspective. In addition, this project will use psychophysiological and structural neuroimaging measures to examine biological and neural correlates of development of behavior on the Prisoner’s Dilemma.

Background: The developing field of neuroeconomics considers the psychological and emotional factors that influence decision-making. Neuroeconomic paradigms, one of which is the Prisoner’s Dilemma, involve economic games that require players to make decisions that are socially mediated. In the Prisoner’s Dilemma, two players make repeated decisions about whether to cooperate or not with one another. (Lack of cooperation is referred to as “defecting”). This paradigm serves as a model for ‘synchronous and symmetric trust situations’; that is, for social cooperation. The Prisoner’s Dilemma formalizes strategic options (i.e. cooperation or exploitation) in situations where individuals are likely to interact again in the future. During the game, a person is required to balance immediate gains (obtained through defection against a partner) and long-term gains (obtained through cooperation) while simultaneously responding to a partner’s strategy. The human capacity for long-term social cooperation is thought to be mediated by such decisions, so paradigms like this one are of interest to social psychologists, economists, and neuroscientists.

The prefrontal cortex (PFC) is the part of the brain responsible for the highest levels of reasoning, problem-solving, and reward-guided decision-making. Although there is evidence that non-socially-mediated decision-making develops during adolescence as the PFC matures, there is little to no research on the neurobehavioral development of socially-mediated decision-making, i.e. cooperative behavior, which might also be PFC-mediated as evidenced by several recent neuroimaging studies. In addition to providing information about normative development, such research could illuminate mechanisms that underlie developmental failures of cooperative behavior, manifested as poor social decision-making or perhaps even antisocial tendencies.

Evidence suggests that the PFC is not fully mature during much of adolescence. Because of its immaturity, adolescents participating in decision-making tasks (such as the Iowa Gambling Task (IGT), which measures non-social decision-making) show deficits like those of patients with ventromedial PFC lesions. As previously demonstrated by our laboratory, older adolescents (age 14-17) make more advantageous decisions than younger adolescents (ages 9-10 and 11-13) on the IGT. Further, 14-17 year-olds showed poorer performance than adult participants. Thus, non-social decision-making abilities that are mediated by the ventromedial PFC may not fully mature until after age 17, and a similar pattern might characterize the development of social decision-making skills.

One method of examining neural correlates of decision-making involves recording either peripheral or cortical psychophysiological responses during task performance. Although there is no prior research on psychophysiological responses to the Prisoner’s Dilemma, research on non-socially mediated decision-making tasks indicates that participants show heart rate slowing and increased skin conductance responses (SCRs) in response to negative consequences of decisions. Also, ‘good’ (but not poor) performers show these changes prior to making disadvantageous responses. In terms of cortical responses, there has been little research regarding event-related potentials (ERP’s) produced by the brain during complex decision-making. More basic decision-making tasks have yielded components such as the error-related negativity (ERN), produced when a person realizes that he or she has made an error on a speeded task. Investigating the types of ERP’s produced during the Prisoner’s Dilemma would yield information about how the brain processes various components of the task (i.e., thinking about the decision, acting on that decision, and receiving information about the partner’s choice and the outcome of the interaction) and how these processes emerge over time in the course of task performance.

Another method of examining neural correlates of decision-making involves correlating task performance with structural or functional aspects of the PFC. Participants in this study will undergo a diffusion tensor neuroimaging (DTI) scan, which will measure white matter integrity in several PFC regions of interest as well as the anterior cingulate cortex and posterior brain regions.

Hypotheses: The 4 main hypotheses of this study relate to (1) age-related behavioral changes, (2) peripheral psychophysiological correlates, (3) cortical psychophysiological correlates, and (4) PFC white matter integrity in association with the development of socially cooperative behavior.

1. Prisoner’s Dilemma behavior will develop during adolescence such that older players will become more responsive to a partner’s behavior. They will delay gratification by selecting a predominantly cooperative strategy when paired with a cooperative partner and defect more with a predominantly non-cooperative partner.

2. Players of all ages will show heart rate slowing and increased SCR’s after learning the consequences of a personally disadvantageous decision. Older adolescents will show increased anticipatory heart rate slowing and SCR’s before making disadvantageous choices (which can be anticipated in the Tit-for-Tat condition, but not the Random condition; see below).

3. ERP data, using a high-density 128-channel system, will be collected on participants while they perform the Prisoner’s Dilemma task. Since ERP data on such tasks is limited, the ERP component of the project is considered exploratory.
4. Adolescents’ behavior on the Prisoner’s Dilemma task will become more sophisticated with the development of white matter in discrete (ventromedial and anterior cingulate) PFC regions, as measured by DTI.

**Research Design and Methods:** Typically developing adolescents, ages 9, 13, 17, and 21 (n=40 per group), will be recruited from an ongoing longitudinal study of adolescent PFC development run by this laboratory. Subjects will participate once at intake and once at a two-year follow-up. At each assessment, participants will undergo a DTI scan and will complete a behavioral testing battery. One task will be a computerized Prisoner’s Dilemma task. They will be introduced to an age and gender-matched confederate ‘partner’ before the game begins. Yet, the true partner will be a computer program. (This deception is necessary because Prisoner’s Dilemma behavior differs for human vs. computer partners; 4). For half of the participants, the computer program will play a Tit-for-Tat strategy, for which the best strategy is cooperation. For the other half, the computer will play a Random strategy, for which the best strategy for participants is defection. These conditions will differentially assess whether participants’ response patterns are due to aspects of the “partner’s” response bias. After introduction to the game and prior to beginning the task, participants will complete a multiple-choice questionnaire to ensure comprehension of the game. Participants will undergo monitoring of psychophysiological functions, including heart rate, skin conductance, and event-related potentials, while playing the game. Other tasks will be included to examine the development of several aspects of PFC function, including non-social decision-making, working memory, cognitive control, task switching and delay discounting. These measures differentially recruit the dorsolateral PFC, ventromedial PFC, and anterior cingulate cortex and will be examined for association with Prisoner’s Dilemma performance.

**Resources/ Feasibility:** As a member of the U of Minnesota’s Center for Neurobehavioral Development (CNBD), I have access to a psychophysiological laboratory that will allow me to collect and analyze the heart rate, SCR, and ERP data. I have already developed an E-Prime version of the Prisoner’s Dilemma that is compatible with psychophysiological and ERP recording. I have submitted an IRB application to obtain project approval and will soon begin pilot testing. I plan to begin testing when the NSF award is granted.

**Data Analytic Plan:** Behavioral data will be analyzed using multivariate and repeated measures ANOVAs. I plan to learn more about appropriate analytic strategies for the other components of the project during my year-long Analysis of Psychological Data course and through hands-on laboratory work. Acknowledge 3.7 software (Biopac Systems) will be used to analyze psychophysiological data.

**Originality and authorship of project:** A literature search has revealed few (if any) studies of the development of socially mediated decision-making. There is no published research on psychophysiological responses to socially-mediated decision-making tasks, even in adults (although there has recently been a surge of interest in neuroimaging studies of this behavior; e.g. 1-7). In addition, I found no studies referring to longitudinal follow-up of Prisoner’s Dilemma game behavior, in adults or adolescents. I am the principal author of this project and am developing it in collaboration with my dissertation advisor, Monica Luciana, Ph.D. The proposed project will recruit existing participants in Monica Luciana’s NIDA-funded study, “Adolescent Brain Development and Effects of Drug Abuse.” However, that study includes no components related to socially-mediated decision-making behavior; therefore, the proposed project will generate a rich and unique body of information that could not feasibly be obtained from the original study.

**Reasons for selection of Graduate Institution:** My primary reason for selecting the U of Minnesota as my graduate institution was the excellent research match with my advisor, Monica Luciana. As a research assistant for the New England Family Study, a longitudinal follow-up to the National Collaborative Perinatal Project, I developed an interest in the neuropsychological evaluation of prefrontal functions. Dr. Luciana’s focus on the longitudinal development of prefrontal functions in adolescence was therefore very attractive to me. The University of Minnesota has a strength in developmental research, including research conducted through the CNBD. Additionally, I felt that the Clinical Science and Psychopathology Research (CSPR) program as a whole was a good match for me because of its focus on biological aspects of behavior. CSPR students are required to develop a supporting program; my supporting program in Developmental Cognitive Neuroscience is closely related to my research interests and to this project in particular.