Understanding Emotion Regulation Using Immersive Virtual Environments

Submission for the PCF 2007-2008
Awarded July 1, 2007

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A. Project Aims

This initiative aims to utilize the recently constructed Duke Immersive Virtual Environment (DiVE; see Figure 1) to develop and begin evaluating innovative methodologies capable of advancing translational science on the behavioral and neurobiological measurement of emotion regulation. By placing subjects in a fully immersive virtual environment, the DiVE provides exciting new opportunities for enhancing the understanding of complex human phenomena. Using an interdisciplinary approach and a contemporary theoretical model of emotion regulation (Gross, 1998), we propose to develop and evaluate the promise of experimental paradigms designed to assess problems with emotion regulation in the DiVE.

Accordingly, our primary aims for the initial pilot phase of this project are:

(1) Convene a new collaborative team of Duke Investigators that will develop novel approaches to the measurement of problems with emotion regulation using the DiVE infrastructure. The investigative team will meet weekly during the project period, and will include a computer scientist (Rachael Brady), a geneticist (Dr. Allison Ashley-Koch), a cognitive neuroscientist (Dr. Kevin LaBar), and two clinical psychologists (Drs. Lynch and Rosenthal).

(2) Collect preliminary data needed for obtaining subsequent extramural (e.g., NIH) funding. The DiVE is the only fully immersive environment in the world that is directly affiliated with a medical center. When coupling the DiVE facilities with the extensive expertise among the investigative team members in the area of emotion, attention, and the regulation of these neurobehavioral processes, Duke University is positioned to be a world leader in translational research using immersive environments. To achieve this goal, however, it is necessary to establish a track record with this collaborative team in order to demonstrate the feasibility of this experimental approach.

(3) Utilize collaborative team and preliminary data in the submission of an R01 to NIH.

B. Background and Significance

Emotion Regulation and Health Problems

In recent years the topic of emotion regulation has garnered significant interest across a diversity of fields in the behavioral sciences (e.g., cognitive neuroscience, clinical psychology, genetics, etc.). On the one hand, all humans have, at times, problems regulating the experience and expression of emotions. However, *chronic* problems with

emotion regulation underlie most psychiatric disorders, including mood (e.g., major depressive disorder), anxiety (e.g., post-traumatic stress disorder), eating (e.g., bulimia), personality (e.g., borderline personality disorder), and substance use disorders (American Psychiatric Association, 2000; Gross, 2006). In addition, difficulties regulating emotion have been shown to exacerbate an impressive array of non-psychiatric health problems (e.g., cardiovascular problems, immunological functioning, health care utilization) and other adverse life outcomes (e.g., decreased grade point average in college students; e.g., Smyth et al., 1999).

Conceptual Framework for Emotion Regulation

Emotion regulation is a complex and multi-dimensional construct (Gross, 1998). To understand how humans regulate emotion a coherent and comprehensive conceptual framework is needed. In the proposed project, we plan to use a contemporary and influential theoretical model of emotion regulation outlined by James Gross (e.g., Gross, 1998, 2001, etc.). This model accounts for the complexity of emotion regulation by characterizing problems as either antecedent-focused (i.e., prior to an emotional response occurring) or response-focused (i.e., after an emotional response occurs). Antecedent-focused problems include difficulties with: (1) Situation Selection (i.e., choosing to be in environments that are *likely* to evoke aversive emotional arousal), (2) Situation Modification (i.e., once in emotionally evocative environments, difficulties changing the context to reduce the likelihood of emotional arousal, (3) Attentional Deployment (i.e., allocating and/or sustaining attention maladaptively), and (4) Cognitive Change (e.g., dysfunctional appraisals and interpretations).

Following an emotional elicitation, response-focused problems include any maladaptive responses to emotions (e.g., attempting to suppress or inhibit emotional experience, physiological arousal, or motoric expression of emotions) that ultimately function to increase further vulnerability to emotional arousal. Although a considerable amount of previous research on each domain in Gross's model has been conducted (Gross, 2006), no singular experimental paradigm has been used to investigate problems with emotion regulation across these domains. We propose that the next generation of translational scientific studies of emotion regulation can be advanced using an experimental paradigm that assesses problems with emotion regulation, *across* domains in the Gross model, using multiple neurobehavioral measures and ecologically valid methodologies.

Capabilities of Immersive Virtual Environments

Fully immersive virtual reality technologies come in two forms: either a Head Mounted Display (HMD) or a projection-based system. HMD's are cheaper, have smaller computational requirements, and are easier to transport, but have a smaller field of view and are more likely to invoke cybersickness and claustrophobia. The DiVE is a projection-based system that provides full immersion by rear-projecting stereographics onto all six surfaces of a 3m x 3m x 3m room (floor, ceiling and walls). The participant has the sensation of being immersed in a 3D environment through the use of stereo glasses and tracking technology. The tracking information is used to present a correct perspective and allow natural 3D interaction with the virtual world (walking, grab-and-drag manipulation). Visual stimuli in the DiVE can be synchronized with psychophysiology sensors giving full control over a participant's visual and aural experience while recording their location, orientation, gestures, and physiological

measures such as heart rate and skin conductance. Accordingly, the DiVE maximizes *both* the precision and internal validity of a controlled laboratory setting with the real-world implications of ecologically valid experimental paradigms that are engaging and highly realistic. The combination of sensor display and recording, set in fully immersive simulated real-world settings, provides the ideal experimental context needed to understand how humans regulate their emotions.

Figure 1. An illustration of the DiVE

C. History of Collaboration and Preliminary Research

The Investigative Team

The interdisciplinary team includes a computer scientist (Rachael Brady), a geneticist (Dr. Allison Ashley-Koch), a cognitive neuroscientist (Dr. Kevin LaBar), and two clinical psychologists (Drs. Lynch and Rosenthal) across multiple schools and departments within Duke University and Duke University Medical Center. Although this proposal represents a new collaborative team endeavor, the investigators in this application have a history of collaboration with each other on research germane to this project. Drs. Lynch and Rosenthal, for example, have worked closely together for the past five years on numerous studies related to understanding emotional functioning in psychopathology. Drs. LaBar, Lynch, and Rosenthal have conducted laboratory research examining classical conditioning and emotion regulation in healthy adults and psychiatric populations. Dr. LaBar and Rachael Brady originally discussed using the DiVE in fear conditioning studies while preparing the MRI/NSF grant that funded the hardware for the DiVE, and have designed new virtual environments over the last six months. In addition, Rachael Brady and Dr. Rosenthal have held planning meetings for this application over the past year.

Rachael Brady is an expert in visualization and virtual environments. She promotes the use of visualization and virtual reality technologies for improved understanding of scientific data and human cognition. In this project, she will coordinate computer programming of emotion regulation experimental prototype environments in the DiVE, through the existing 3D graphics designer and software engineers under her direction in the Visualization Technology Group. Dr. Ashley-Koch is an expert in psychiatric genetics. With specialized training in genetic epidemiology, she has expertise in study design and genetic analysis of complex endophenotypes such as those that will develop from this collaboration. Dr. LaBar is an expert in cognitive neuroscience, with a rich line of research in the neurobiology of emotional and attentional systems. Drs. Rosenthal and Lynch have published extensively and have ongoing studies investigating emotional functioning and emotion regulation, both in healthy individuals and in psychiatric populations. In line with each of the primary aims of this application, during

weekly in-person meetings across the project year, Drs. Rosenthal, LaBar, Lynch, and Ashley-Koch will accomplish the following: (a) design prototype environments (see below: *Developing Immersive Environments*), (b) plan the implementation of pilot data collection through the Visualization Technology Group (see budget justification for details), and (c) coordinate the submission of an R01 to NIH using the preliminary data from this project to strengthen the application.

Previous Studies Using the Gross Model

Drs. Rosenthal, LaBar, and Lynch have published laboratory studies examining emotion regulation using the Gross model in the present project. For example, Dr. LaBar has found that different emotion regulation strategies – cognitive reappraisal and suppression -- have opposite effects on memory (Dillon et al., in press) and that cognitive reappraisal of both positive and negative emotion elicit similar effects on startle responses (Dillon & LaBar, 2005). Furthermore, his lab was recently shown that up- and down-regulation of emotion to pictures using cognitive reappraisal strategies elicits a common electrophysiological signature of top-down attentional control (Dillon et al., 2007). In another study examining response-focused emotion regulation problems, Dr. Rosenthal and colleagues found that individuals with borderline personality disorder were quicker than controls to terminate an emotionally arousing laboratory task, even in the face of incentives to persist (Gratz, Rosenthal, et al., 2006). In a series of studies, both Drs. Lynch and Rosenthal have shown that attempts to suppress emotional experiences mediate the relationship between temperament and psychopathology (e.g., Lynch et al., 2001; Rosenthal et al., 2005). In addition, Drs. Lynch and Rosenthal recently found that individuals with borderline personality disorder have problems with antecedent-focused regulation, whereby they are more sensitive to facial emotional expressions than healthy controls (Lynch, Rosenthal, et al., 2006).

D. Research Plan

Developing Immersive Environments

We plan to construct and begin validating prototype virtual environments that can be used to assess both antecedent- and response-focused emotion regulation problems. Investigative team members will create innovative paradigms that: (1) are grounded in robust findings from basic and translational cognitive neuroscience, (2) can be feasibly constructed within the project timeframe, (3) yield dependent measures capable of linkage with endophenotypic and genotypic measurement, (4) advance a basic understanding of emotion regulation in healthy adults, and (5) have clear implications for reducing human suffering across a range of clinical populations.

Pilot Testing Prototypes

The exact characteristics of the prototype virtual environments will be iteratively programmed. However, an example of one working prototype is a virtual house wherein subjects must systematically: (a) choose to approach or avoid emotionally evocative objects, such as virtual humans (avatars), (b) choose which aspects of the virtual environment to change, (c) attend or disengage attention from the avatar and/or emotionally evocative household objects, (d) make cognitive appraisals in response to emotionally evocative objects and/or virtual humans in the house, and (e) choose how long to continue remaining in emotionally evocative areas of the house when there is an incentive (e.g., more money can be earned in the study) to do so.

Once programmed, the prototype will be pilot tested in healthy volunteers. Measures of emotional responding will include subjective (self-reported emotional response to virtual environments, motoric/expressive (movement towards or away from virtual objects), and psychophysiological (skin conductance, heart rate, respiration) indices of emotion. The independent variable will be environment type (emotionally evocative v. neutral), and the dependent variables will be (a) choice of situation selection, (b) choice of situation modification, (c) length of attentional deployment, (d) attributional style, and (e) latency to remain in situations. Effect sizes using Cohen's *d* will be computed to provide preliminary effect size estimates for subsequent extramural funding applications. In addition, we will obtain feedback from subjects about the realism, sense of immersion, and acceptability of the prototype environments.

Long Term Goals

To our knowledge this would be the first interdisciplinary effort in the world to utilize fully immersive environments in the neurobehavioral assessment, genotyping, and ultimately, treatment for a wide spectrum of adults with psychiatric disorders. Because emotion regulation is inherently an interdisciplinary topic (Gross, 1998), the implications for this pilot project have trajectories that extend well into numerous fields of both basic and applied science. Moreover, the translational and interdisciplinary framework positions this project well for NIH Funding Opportunity Announcements (FOAs) that are explicitly in support of the NIH Roadmap for Medical Research. Accordingly, after accomplishing our immediate goals during the project year, we will take the next steps in our 10-15 year plan for sustained research by capitalizing on opportunities for ongoing funding through larger and more commonly used extramural mechanisms. At the conclusion of the project year, we plan to submit an R01 to NIH, with the primary aim of extending work from our prototype in order to complete the development and validation of the DiVE-based assessment platform. We further plan to submit an R01 to NIH designed to compare neurobehavioral responses in immersive environments with known genotypic measures, in order to improve the characterization of genetic markers for emotion regulation problems across psychiatric disorders. The seed money from the Provost's Common Fund will provide the critical first step in developing and obtaining pilot data in healthy adults on the initial experimental platform in the DiVE.

Making a Difference: The Impact of this Project on the University's Intellectual Mission

This application is directly in line with the articulated intellectual mission at Duke University. Both the NIH and Duke University continue to strongly emphasize the need for interdisciplinary scientific teams as the critical means by which the most innovative breakthroughs will advance science. The investigators in this application span multiple schools and departments, and include faculty from both Duke University and Duke University Medical Center. In addition to the cross-fertilization of experimental approaches that we expect will emerge from our interdisciplinary team, the explicitly translational nature of this project is directly in line both with the NIH and Duke University's scientific vision. Finally, this project is consistent with the recently approved Strategic Plan at Duke University. In *Making a Difference: The Strategic Plan for Duke University*, a primary means by which Duke is envisioned to build distinction in the future is through the support of creative interdisciplinary research. Indeed, interdisciplinary research is an enduring theme at Duke University that transcends the current Strategic Plan, and is likely to persist well into the 21st century.

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