NeuroImage 104 (2015) 373–385

Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/ynimg

Influence of neurobehavioral incentive valence and magnitude on alcohol drinking behavior

Jane E. Joseph [a,*], Xun Zhu [a], Christine R. Corbly [b], Stacia DeSantis [a,1], Dustin C. Lee [b], Grace Baik [a,2], Seth Kiser [b,3], Yang Jiang [b], Donald R. Lynam [b,4], Thomas H. Kelly [b]

[a] Medical University of South Carolina, 96 Jonathan Lucas Street, Charleston, SC 29425-0616, USA
[b] University of Kentucky, 410 Administration Drive, Lexington, KY 40508-0001, USA

ARTICLE INFO

Article history:
Accepted 14 September 2014
Available online 23 September 2014

Keywords:
Monetary incentive delay
fMRI
Sensation seeking
Impulsivity
Problem drinking
Alcohol use

ABSTRACT

The monetary incentive delay (MID) task is a widely used probe for isolating neural circuitry in the human brain associated with incentive motivation. In the present functional magnetic resonance imaging (fMRI) study, 82 young adults, characterized along dimensions of impulsive sensation seeking, completed a MID task. fMRI and behavioral incentive functions were decomposed into incentive valence and magnitude parameters, which were used as predictors in linear regression to determine whether mesolimbic response is associated with problem drinking and recent alcohol use. Alcohol use was best explained by higher fMRI response to anticipation of losses and feedback on high gains in the thalamus. In contrast, problem drinking was best explained by reduced sensitivity to large incentive values in mesolimbic regions in the anticipation phase and increased sensitivity to small incentive values in the dorsal caudate nucleus in the feedback phase. Altered fMRI responses to monetary incentives in mesolimbic circuitry, particularly those alterations associated with problem drinking, may serve as potential early indicators of substance abuse trajectories.

Introduction

Alcohol abuse is a major public health concern with devastating physical and mental health consequences (Shalala, 2000). Understanding the neurobehavioral profile of individuals at risk for alcohol abuse has important implications for prevention and early intervention efforts. Individual differences in impulsivity and incentive motivation may be particularly important in alcohol dependence; therefore a deeper understanding of the biological manifestations of these factors may be informative for the design and implementation of substance abuse prevention programs (Conrod et al., 2011). Using fMRI, the present study characterizes neurobehavioral responses to monetary rewards and losses in people who vary in level of risk for alcohol dependence.

Two motivational states seem particularly important in the transition from alcohol (or other substance) use to dependence: anticipatory and consummatory behaviors. Anticipatory behaviors are often referred to as appetitive states of "wanting" whereas consummatory behaviors refer to the "liking" involved when a particular stimulus is delivered or consumed. Wanting and liking may be equally strong motivators during initial drug use, but according to Robinson and Berridge (1993) the trajectory to dependence is marked by increased wanting and no change or a subtle decrease in liking. Ostafin et al. (2010) also showed that people who had been drinking for longer showed a dissociation in wanting and liking compared to people who had been drinking for fewer years. The present study investigated whether non-alcohol dependent people who report drinking problems show different neural activation profiles (using functional magnetic resonance imaging, fMRI) between the anticipatory and consummatory stages of a monetary incentive delay (MID) task.

Another important consideration in understanding motivational tendencies in people at risk for alcohol dependence is whether anticipatory or consummatory behaviors are driven by positive outcomes or avoidance of negative outcomes. To address this, the present study examined the type of reinforcement contingency on the MID, with positive reinforcement trials associated with anticipation or receipt of monetary gains and avoidance trials associated with anticipation of avoidance or receipt of monetary losses. In other words, the present study determined whether people at risk for alcohol addiction are more sensitive to gains or losses, and we refer to this as incentive valence.

There are also differences in the way that people at risk for substance dependence respond to different magnitudes of reinforcement and punishment. Whereas, for most people, higher magnitude incentives are

* Corresponding author at: Medical University of South Carolina, 96 Jonathan Lucas Street, Charleston, SC 29425-8900, USA.
E-mail address: josep@musc.edu (J.E. Joseph).
[1] University of Texas Health Sciences Center, 1200 Hermann Pressler Dr, Houston, TX 77030-3900, USA.
[2] Uniformed Services University of the Health Sciences, 4301 Jones Bridge Rd, Bethesda, MD 20814-4712, USA.
[3] The Catholic University of America, 620 Michigan Ave NE, Washington, D.C., DC 20064-0001, USA.
[4] Purdue University, 610 Purdue Mall, West Lafayette, IN 47907-2040, USA.

http://dx.doi.org/10.1016/j.neuroimage.2014.09.037
1053-8119/

more motivating than lower magnitude incentives, people at risk for substance dependence (due to sensation seeking personality trait) may be less sensitive to magnitude (i.e., work equally hard to earn small and large drug doses, Stoops et al., 2007). Similarly, non-dependent heroin users work equally hard to earn a small dose of morphine as higher doses even though subjective effects were only evident for higher doses (Lamb et al., 1991). These findings indicate that individual differences in sensitivity to the reinforcing effects of drugs may vary as a function of dose, with greater sensitivity occurring at low doses in individuals at risk for dependence. Consequently, the present study also varied magnitude of monetary gains and losses in order to probe individual differences in sensitivity to reinforcement and punishment magnitude; we refer to this as incentive magnitude.

An important neural substrate for alcohol dependence is the mesolimbic reward system. The monetary incentive delay (MID) task (Fig. 1a, Knutson et al., 2000) has been used to investigate mesolimbic reward circuitry involvement in risk for alcohol and substance abuse, where risk is indicated by high levels of trait impulsivity, problematic and externalizing behaviors, or positive family history of alcoholism (Yau et al., 2012; Bjork et al., 2008a, 2011a; Hahn et al., 2009; Simon et al., 2010; Andrews et al., 2011a; Guyer et al., 2006a; Schneider et al., 2012; Weiland et al., 2013). In the MID task, participants can earn or lose money depending on their speed of responding to a briefly presented visual target. Each trial consists of cue, target and feedback phases. The cue phase displays a monetary value that can be won (positive reinforcement trials) or lost (avoidance trials). The target phase consists of a brief presentation of the target, and participants are instructed to respond within the duration of the target display (on the order of 250 ms). If the response time is less than the target duration, the participant earns or avoids losing the money. If the response time exceeds the target duration, the participant does not receive or loses the money. According to the Robinson and Berridge (1993) model, behavior during the cue phase would be categorized as anticipatory and during the feedback phase categorized as consummatory.

Whereas some studies report greater mesolimbic sensitivity to gains on the MID task in individuals at risk compared to those not at risk (Yau et al., 2012; Hahn et al., 2009; Simon et al., 2010; Bjork et al., 2010a, 2008b, 2011b), other findings indicate reduced sensitivity to gains (Yau et al., 2012; Schneider et al., 2012; Andrews et al., 2011b; Guyer et al., 2006b). The focus on monetary gains rather than losses is well motivated, but loss sensitivity may also differentiate individuals at risk for substance abuse (Simon et al., 2010; Andrews et al., 2011b; Bjork et al., 2010b). Therefore, an understanding of individual differences in incentive motivation should include a comprehensive index of both loss and gain-sensitivity, or incentive valence. In addition, isolating sensitivity to incentive magnitude may also reveal differences in mesolimbic response (Cooper and Knutson, 2008), but this has not been explored as extensively as incentive valence. Therefore, the present study focused on both incentive valence (positive reinforcement v. avoidance contingencies during the cue phase; gain v. loss during the feedback phase) and magnitude (large v. small incentives).

MID fMRI responses have traditionally been used to examine individual differences in motivation. However, more recently, MID fMRI

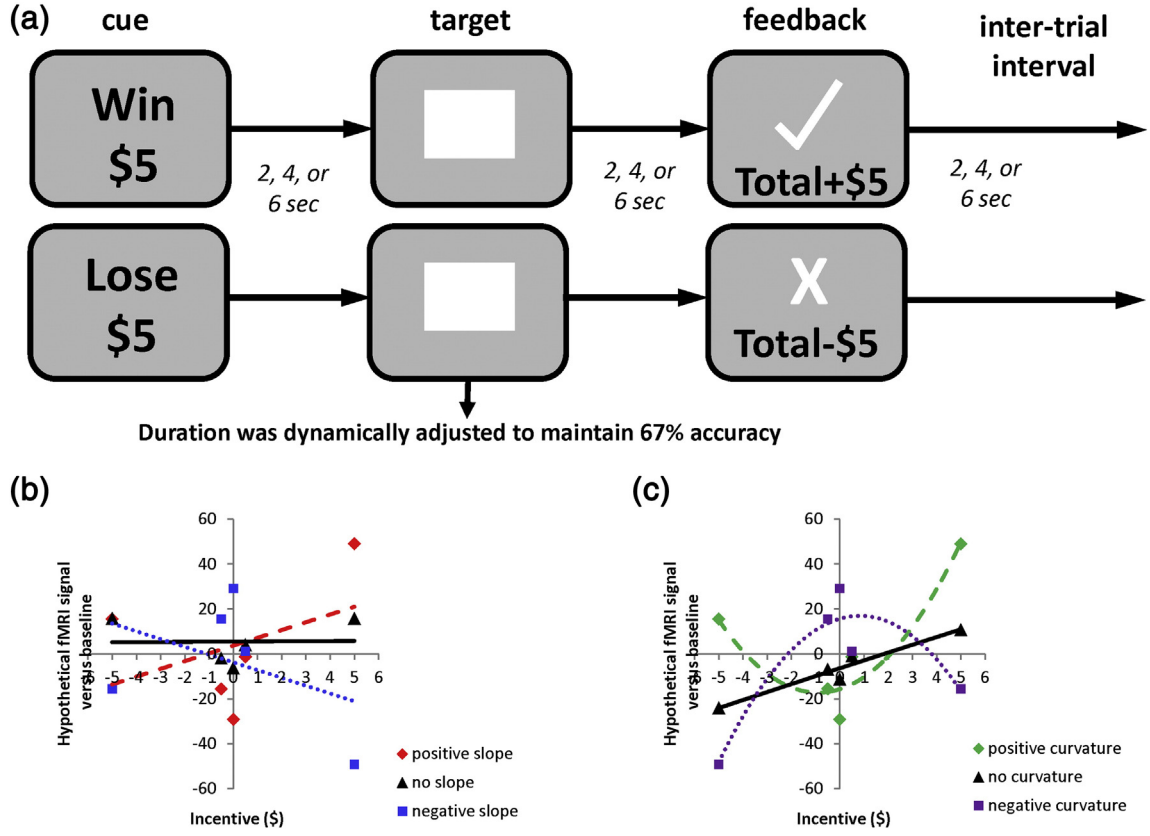

Fig. 1. (a) Monetary incentive delay task used in the present study. Participants could earn or lose money depending on speed of responding to a target stimulus (white rectangle). Each trial consisted of cue, target and feedback phases. The cue phase displayed a monetary value that could be won or lost. The target phase consisted of a simple stimulus presented briefly, and participants were instructed to respond within the duration of the target display (on the order of 250 ms). If the response time was less than the target duration a checkmark appeared on the feedback screen and the participant earned or avoided losing money. If the response time exceeded the target duration, an X appeared on the feedback screen and the participant did not win or incurred a loss of money. Across trials, the target display duration was adjusted to maintain trial accuracy at 67%. (b) The $slope_{fmri}$ parameter indicates the slope of the linear component of a quadratic function fit to the fMRI signal in the different incentive conditions. A positive $slope_{fmri}$ indicates greater fMRI response to positive incentive values and a negative $slope_{fmri}$ indicates greater fMRI response to negative incentive values. (c) The $curvature_{fmri}$ parameter indicates the degree of curvature of the quadratic function. A $curvature_{fmri}$ value of 0 indicates no curvature; a positive $curvature_{fmri}$ value indicates greater concavity and a negative $curvature_{fmri}$ value indicates greater convexity. In other words, a more concave function would reflect greater fMRI signal for the extreme compared to small incentive values but a more convex function would reflect a greater fMRI signal for small values.