Published in final edited form as:

Psychol Addict Behav. 2012 December ; 26(4): 895–905. doi:10.1037/a0029034.

Profiles of Executive Functioning: Associations with Substance Dependence and Risky Sexual Behavior

Sarit A. Golub,

Department of Psychology and Center for HIV Educational Studies and Training, Hunter College and Graduate Center of the City University of New York.

Tyrel J. Starks,

Department of Psychology and Center for HIV Educational Studies and Training, Hunter College and Graduate Center of the City University of New York.

William J. Kowalczyk,

Nicotine Psychopharmacology Section of the National Institute on Drug Abuse.

Louisa I. Thompson, and

Department of Psychology and Center for HIV Educational Studies and Training, Hunter College and Graduate Center of the City University of New York.

Jeffrey T. Parsons

Department of Psychology and Center for HIV Educational Studies and Training, Hunter College and Graduate Center of the City University of New York.

Abstract

The present investigations applied a theoretical perspective regarding the impact of executive functioning (EF) on sexual risk among substance users, by using a methodological approach designed to examine whether EF subtypes differentially predict behavior patterns. Participants included 104 substance-using HIV-negative gay and bisexual men. Participants completed five neuropsychological assessment tasks selected to tap discrete EF components, and these data were linked to data on substance dependence and behavioral reports of substance use and sexual risk in the past 30 days. Cluster analysis identified three EF subtypes: a) High-performing (good performance across all measures); b) Low Performing (poor performance across all measures); and c) Poor IGT Performance (impairment on the Iowa Gambling Task (IGT) and its variant, but good performance on all other tasks). The three subtypes did not differ in amount of substance use, but the Low-Performing subtype was associated with greater rates of substance dependence. The Low-Performing subtype reported the highest rates of sexual behavior and risk, while the Poor IGT-Performance subtype reported the lowest rates of sexual risk-taking. Global associations between substance use and sexual risk were strongest among the Low-Performing subtype, but event-level associations appeared strongest among individuals in the High-Performing subtype. These data suggest complex associations between EF and sexual risk among substance users, and suggest that the relationship between substance use and sexual risk may vary by EF subtypes.

Keywords

Executive Functioning; Substance Dependence; Sexual Risk-Taking; Decision-Making

A better understanding of mechanisms underlying the association between substance use and risky sexual behavior has important implications for both psychology and public health. A vast body of research links substance use to high-risk sexual behavior, especially among gay and bisexual men (GBM), the group with highest incidence of HIV infection in the United States (Prejean et al., 2011). Studies examining global associations between substance use and sexual risk taking have found that problematic use covaries with sexual risk taking, and have demonstrated bivariate associations between reported substance use and sexually transmitted infection (STI) incidence, potential HIV exposure, and HIV seroconversion (Brewer, Golden, & Handsfield, 2006; Buchbinder et al., 2005; Drumright, Gorbach, Little, & Strathdee, 2009; Drumright, Patterson, & Strathdee, 2006; Koblin et al., 2006). Studies examining situational associations, i.e., associations between frequencies of reports of sex under the influence and reports of high-risk sex, have demonstrated higher rates of unprotected sex among individuals who report recent sexual behavior under the influence of a range of different substances, including alcohol, amphetamines, cocaine, ecstasy, and amyl nitrates (Celentano et al., 2006). And finally, event-level studies have demonstrated associations between substance use and increased odds of unprotected sex using both timeline follow-back interview (Irwin, Morgenstern, Parsons, Wainberg, & Labouvie, 2006) and daily diary (Mustanski, 2008) methodologies.

Theoretical models explaining the association between substance use and risky sex highlight changes in cognitive, emotional, and behavioral functioning pursuant to substance use. For example, alcohol myopia theory (Steele & Josephs, 1990) focuses on the extent to which substance use produces “shortsightedness” on the part of users, causing them to focus more strongly on immediate environmental cues rather than personal values or long-term goals in determining their behavior. Similarly, cognitive escape theory (McKirnan, Ostrow, & Hope, 1996) argues that the avoidance of risk behavior requires effortful cognitive restraint and thought suppression. Over time, these restraining processes become burdensome both cognitively and emotionally, and substance use provides a vehicle for escape and behavioral rebound. In both models, sexual risk-taking results from a failure to adequately control behavior in the face of environmental pressure and/or conflicting priorities.

Executive functioning (EF) is a complex construct used to refer to a broad set of processes related to goal-directed behavior, including (but not limited to) planning, self-monitoring, strategizing, and self-regulating (Goldberg, 2002). Specific abilities that are considered within the rubric of EF include: abstract reasoning, problem-solving, set-shifting, decision-making, and behavioral inhibition (Goldberg, 2002). As such, EF governs the processes necessary for sexual behavior and risk reduction independent of substance use; however, impairment in EF processes may also be a good candidate for the mechanism through which substance use – at either the global or event levels – impacts sexual behavior. Research demonstrates significant impacts of substance use on varied elements of EF; these effects are present during active use and persist into periods of abstinence (Rapeli et al., 2006; Simon et al., 2000; Verdejo-García & Pérez-García, 2007). Users of cocaine, methamphetamine, and other stimulants evince deficits in attention, working memory, and impulse control compared to non-users (Anand, Springer, Copenhaver, & Altice, 2010); these deficits are consistent with patterns of cortical damage that may result from chronic abuse (Berman, O'Neill, Fears, Bartzokis, & London, 2008; Paulus et al., 2002; Sim et al., 2007). To the extent that substance users evince deficits in these critical processes, impaired EF in this population may increase sexual risk behavior globally, and specific substance use instances may tax EF capacities at the event-level, exacerbating its influence. As such, investigations into the causes and correlates of sexual risk-taking among substance users must consider the role of EF and/or moderating variable.

One body of research in this area focused on similarities in behavioral myopia evinced by both substance users and patients with damage to the ventromedial (VM) prefrontal cortex (Bechara & Damasio, 2002; Fellows & Farah, 2005; Wardle, Gonzalez, Bechara, & Martin-Thormeyer, 2010). Data from these studies suggest an asymmetrical relationship between two aspects of EF: working memory capacity and reward processing. Among those with substance dependence, performance on decision-making task that rely on reward processing, such as the Iowa Gambling Task (IGT), appears dependent on intact working memory, as those with working memory deficits demonstrate consistently poor performance on the IGT. However, some substance users with intact working memory still display significant deficits on these decision-making tasks, suggesting that other EF processes may be driving myopic behavior in this group (Bechara & Martin, 2004; Noel, Bechara, Dan, Hanak, & Verbanck, 2007). The identification of different patterns of EF deficits among substance users has lead some to call for the use of neurocognitive criteria to “subtype” disorders in order to guide intervention efforts (Bechara & Martin, 2004).

However, a central challenge in the study of EF and its effects is the definition and operationalization of the construct. Some researchers consider EF to be a unified construct, while others consider it a set of distinct (albeit related) component processes (Miyake et al., 2000). Recently, theorists have argues that measurement and examination of discrete EF components can enhance our understanding of its effects by allowing for the development of specific predictions about the relationship between each component and behavioral outcomes (Bates, 2000; Giancola, 2000; Giancola, Godlaski, & Roth, 2011). Supporting this approach, evidence suggests the ability to distinguish among three target EF functions -- updating, shifting, and inhibiting -- and indicates that these functions differentially impact performance on commonly used EF tasks (Miyake, et al., 2000). In this framework, the updating function is most closely aligned with working memory, including monitoring and coding incoming stimuli or information and then manipulating this information in a dynamic process that supports task management. The shifting function refers to processes that are commonly termed attention-switching or task-switching, including the ability to shift back and forth between mental sets, tasks or operations. And finally, inhibiting is defined in term of the ability to deliberately suppress a dominant or prepotent response. When placed in the context of research on patterns of deficits among substance users, this triadic model provides a potential approach for exploring the role of EF in behavior. Such and approach would examine performance on each of these three EF components (i.e., updating, shifting, and inhibiting), but would also assess performance on tasks designed to measure processing of punishment and reward.

The present study combines a theoretical perspective regarding the impact of EF on sexual risk among substance users with a methodological objective to examine whether distinct patterns of EF performance in these four areas -- updating, inhibiting, shifting, and reward/punishment processing -- differentially predict behavior patterns. Informed by previous findings regarding the asymmetrical relationship between working memory and reward processing in this population (c.f. Bechara & Martin, 2004; Noel, et al., 2007), our analysis focuses on the extent to which performance in these four areas may covary or diverge in discrete patterns, or subtypes. As such, we chose a neuropsychological assessment task to correspond with each of the EF areas, and conducted a cluster analysis to examine whether scores loaded on a single EF factor across all participants, or whether some groups of participants were characterized by good performance in some areas and poor performance on others. For example, we hypothesize that there will be one subgroup of substance users who demonstrate deficits in both updating (i.e., working memory) and reward processing, while another subgroup will perform well on the updating task but demonstrate impairment in reward processing. Past research in this area has not included the other two components of the triadic model (i.e., shifting and inhibiting); therefore, this research was designed to

explore the extent to which performance in these two additional areas would correlate with updating/working memory capacity (reinforcing the existence of only two subgroup patterns of EF performance) or would diverge to form additional subgroups of asymmetrical relations.

The next question to consider is the potential association between these EF subgroups and risk behavior. Identification of discrete subgroups may be relevant for understanding differences in etiology or intervention efficacy, but may not necessarily result in observable behavioral differences. If EF deficits among substance users result in myopia at a global level, i.e., regardless of whether substances are being used during decision-making, we would expect high-risk sexual behavior to increase with greater EF deficits across all four areas. And, as past research indicates poor decision-making performance among substance users with and without working memory deficits (Bechara, Damasio, Tranel, & Anderson, 1998; Noel, et al., 2007), we hypothesize that there will be no difference in overall rates of risky sexual behavior across subgroups. If EF deficits among substance users result in myopia only in the context of substance use (and/or has exacerbated effects in the context of use), we would expect to see increased sexual risk-taking only in the presence of substance use. This event-level association is more likely to differentiate between deficit subgroups, as data suggest that working memory capacity is critical to the control of attentional resources in the face of automatic activation of reward seeking or affective conflict by environmental cues (Kane & Engle, 2002). Individuals with better working memory capacity are better able to use attentional resources to consider long-term consequences and apply cognitive processing to resolve conflict (Engle, 2002). As such, we hypothesize that subgroups characterized by poor performance on updating task (i.e., those with working memory deficits) will demonstrate the strongest *event-level* association between substance use and sexual risk, i.e., they will be most likely to report risky sexual behavior under the influence.

Method

Participants

Participants were from the Men's Health Project, a longitudinal study of GBM recruited in the New York City metropolitan area for a study focused on substance use and sexual risk (Golub, Starks, Payton, & Parsons, in press; Lelutiu-Weinberger et al., in press; Wells, Golub, & Parsons, 2011). To be eligible, participants had to be men, at least 18 years of age, self-report a negative or unknown HIV serostatus, and report at least 5 days of substance use (including cocaine, methamphetamine, gamma hydroxybutyrate, ecstasy, ketamine, or amyl nitrates) and at least 1 incident of unprotected anal intercourse with a casual or serodiscordant main male partner in the last 90 days. Data were collected between September 2007 and May 2009. One hundred and thirty eight participants were offered participation in the neuropsychological study component and all (100%) agreed to participate. Of these 138, 130 (94%) showed up for their study appointment and completed the visit. Because of a corrupted computer file, complete data (i.e., useable scores on all five neuropsychological measures) were available for 104 participants (80%). There were no differences between participants with complete and incomplete data on demographic factors, substance use, or sexual risk behavior. The mean age of the sample was 30 years ($SD = 7.46$), and mean years of education completed was 14.5 ($SD = 1.99$). Thirty-eight percent of the sample were white, 19% were black, 30% were latino, and 13% reported another race/ethnicity or reported being multi-racial. Over half the sample (60%) reported an annual income of less than \$30,000.

Neuropsychological Measures

We selected four neuropsychological tasks, each corresponding to one of the four areas of EF functioning discussed above: updating, shifting, inhibiting, and reward processing. In addition, we included a fifth task, a variant of the reward processing task which inverts reinforcement to focus on processing of losses, or punishment, instead of gains.

Counting Span (CS)—The Counting Span (Smyth & Pelky, 1992) was used to measure updating, i.e., monitoring and manipulating information in working memory (Jonides & Smith, 1997; Miyake, et al., 2000). The Counting Span is similar to other complex span tasks (for a review, see Conway et al., 2005), in which participants have to memorize presented information while simultaneously performing a competing processing task. In the Counting Span, participants are shown a screen with various shapes in different colors and are instructed to count and remember a particular stimulus (e.g. blue circles). Within a given trial, participants are given a series of screens in a row (ranging from 2 screens to 8 screens) and are asked to recall the number of blue circles over the entire set. Each set of screens is presented to participants three times (i.e., 21 screen-sets total). Final scores are calculated by adding the number of screens in each set for which all numbers were recalled correctly (possible range 0 to 105), with higher scores indicating better working memory capacity. Although working memory processes are often linked to functioning in the dorsolateral (DL) prefrontal cortex, research suggests activation in multiple cortical areas (Smith, 2000; Smith & Jonides, 1999). Complex span tasks are associated with multiple higher order cognitive abilities, and are believed to better reflect general working memory capacity (Kane et al., 2004).

Wisconsin Card Sort Test (WCST)—The computerized version of the Wisconsin Card Sort Test (WCST; Berg, 1948) was used to measure the EF component of shifting, i.e., moving between multiple operations or mental sets. In the WCST, participants view cards containing objects that vary in color, shape, and number. Participants must sort the cards according to a sorting rule (e.g. color only), but this rule is unknown to them and changes over the course of the task. Neuroanatomical studies have shown that the WCST activates a wide network of brain regions across all of the lobes of the brain (Graham et al., 2009; Nyhus & Barcelo, 2009). The WCST has long been thought of as the standard for assessing executive function, but the degree to which the test can distinguish patients with frontal lesions from those with more rostral lesions is debatable (Nyhus & Barcelo, 2009), underscoring the distinction between frontal and executive function (Stuss & Alexander, 2000). For this analysis, we used participants' perseverative error scores (i.e. failure to shift sets and sort cards on a different dimension when the rule changes), with higher scores indicating greater difficulty in set-shifting.

Go-Nogo—A Go-Nogo task (Leland, Arce, Miller, & Paulus, 2008) was chosen to measure the third EF component, inhibition, or the ability to deliberately suppress a dominant or automatic response (Miyake, et al., 2000). In a Go-Nogo task, the participant learns a prepotent response (e.g. press the space bar when you see the letter "A") and then is required to selectively inhibit that response (e.g. press the space bar when you see "AB," but do not press the space bar when you see "AC"). The "go" stimulus is presented approximately 80% of the time, increasing the difficulty of response inhibition. Within the frontal lobes, successful inhibition of nogo stimuli have been localized to the right hemisphere, and include the insula, and the middle and inferior frontal gyri with greater activation associated with faster responding on the go trials (Garavan, Ross, & Stein, 1999; Konishi et al., 1999). Final scores for this study consist of the number of false alarms (i.e. failures of response inhibition), with higher scored indicating poorer performance.

Iowa Gambling Task (IGT)—Finally, the IGT and its variant were selected to measure reward processing. The IGT (Bechara & Damasio, 2002) is a test of judgment and decision-making designed to identify patients with lesions of VM prefrontal cortex, which consistently demonstrates sensitivity to neurocognitive deficits among SDI (Bechara, 2003; Bechara, Dolan, & Hindes, 2002). The IGT requires participants to choose cards from a computer display of four card decks, with each selection resulting in a win and/or loss of money. Two of the decks yield high rewards, but also incur high penalties, resulting in an overall loss of money (bad decks). The other two decks yield smaller rewards, but confer smaller penalties, resulting in an overall monetary gain (good decks). The decks are rigged so that it is almost impossible to consciously predict or calculate the relative rewards/penalties of the different decks; however, most individuals without neurocognitive impairment “learn” to avoid the high-reward/high-penalty decks and maximize their winnings. Individuals who are impaired on the IGT are considered “hypersensitive to reward,” because they are unable to avoid the high-reward decks, even though these decks result in overall monetary loss. Studies using lesion methods have shown that those with VM prefrontal cortex lesions consistently perform poorly on the IGT, while damage to the dorsolateral prefrontal cortex has yielded more equivocal results (Bechara, 2003; Bechara & Damasio, 2002; Fellows & Farah, 2005; Manes et al., 2002). Studies of activation using PET and fMRI have shown frontal lobe activity when completing the IGT (Golin et al., 2010; Lin, Chiu, Cheng, & Hsieh, 2008), with regions such as the medial orbital frontal cortex (Bolla et al., 2003) and the medial and superior frontal gyri being correlated with performance (Tucker et al., 2004). Final scores on the IGT are calculated by subtracting the number of cards selected from the bad decks from the number of cards selected from the good decks across all five blocks, with higher scores indicating better performance.

IGT variant—The IGT variant (IGTv; Bechara, Tranel, & Damasio, 2000) is almost identical to the IGT, except that reward and punishment schedules are inverted. In the IGT variant, participants must learn to select cards from decks that administer high penalties, but will eventually result in larger gains. Those impaired on the IGT variant can be considered “hypersensitive to punishment,” because they are unable to choose the high-penalty decks, even though these decks would result in an overall monetary gain. Many individuals are impaired on the IGT basic but not on the variant, i.e. they never learn to avoid the high-reward decks in the IGT basic, but learn to choose the high-punishment decks in the IGT variant in order to maximize their long-term gain (Bechara, 2003; Bechara, et al., 2002). Final scores on the IGT variant are calculated in the same manner as the IGT, with higher scores on the IGT variant indicate better performance on the task. Few studies have examined the neuroanatomical correlates of this variant. In their original work with the variant, Bechara, Tranel and Damasio (2000) demonstrated that those with VM prefrontal cortex lesions performed poorly on the task. The IGT variant was selected as a fifth task in order to more fully explore the associations among the other three aspects of EF – updating, shifting, and inhibiting. The IGT and the IGT variant have been used extensively to characterize different subgroups of individuals with substance dependence (c.f. Bechara, 2003; Bechara, Dolan, & Hindes, 2002; Noel, et al., 2007; Wardle, et al., 2010).

Behavioral Measures

The timeline followback (TLFB) semi-structured interview (Sobell & Sobell, 1993), modified for the assessment of sexual risk behavior and substance use (Carey, Carey, Maisto, Gordon, & Weinhardt, 2001; Irwin, et al., 2006), was used to collect data for the previous 30 days. The TLFB has demonstrated good test-retest reliability, convergent validity, and agreement with collateral reports for sexual behavior and substance use (Fals-Stewart, O'Farrell, Freitas, McFarlin, & Rutigliano, 2000; Weinhardt et al., 1998). In the TLFB, interviewers asked participants to report sexual activity, substance use, and their

combination on each of the preceding 30 days. In this study, assessment of substance use focused on six “club drugs,” so called because of their association with dance clubs catering to GBM (Halkitis, Palamar, & Mukherjee, 2007). The majority of club drug use involves stimulants (i.e., cocaine, methamphetamine, and ecstasy); other classes of drugs are less frequently used but are also included (e.g. ketamine, gamma-hydroxybutyrate, and amyl nitrates). The rationale for recruiting club drug using GBM and assessing club drug use rather than restricting the sample to a specific class of drugs stems from the strong association between club drug use and HIV risk behaviors among GBM (Rudy et al., 2009; Schwarcz et al., 2007). Club drugs are the drugs most commonly used by GBM in sexual contexts (Pappas & Halkitis, 2011), and as such are most relevant to the association between substance use and sexual behavior in this population. For these analyses, substance use variables included: number of drug use days for each of the six club drugs as well as total number of drug use days (number of days on which at least one of these drugs was used). Sexual behavior variables included: total number of anal sex acts, number of high-risk sex acts (defined as any unprotected anal sex with a casual partner or sero-discordant main partner), and number of high-risk sex acts that occurred under the influence of alcohol or drugs. In the case of three extreme outliers on sexual behavior data, the distribution was truncated by assigning scores that were successively one unit higher than the highest score within 2.5 standard deviations of the mean (Tabachnick & Fidell, 2001).

Assessment of Substance Dependence

The Substance Use Disorders Module of the Structured Clinical Interview for DSM Disorders (SCID: First, Spitzer, Gibbon, & Williams, 2002) is an interviewer-administered questionnaire that assesses for the presence or absence of substance use disorders based on the diagnostic criteria from the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR: American Psychiatric Association. & American Psychiatric Association. Task Force on DSM-IV., 2000). For this study, the SCID was conducted asking participants about the last 12-months of problematic drug use. Drugs assessed were restricted to the five club drugs that were the focus of the larger study. Based on DSM-IV-TR criteria (First, et al., 2002), participants were coded as meeting criteria for dependence, abuse, or neither for each of the drugs of interest. In the analyses below, participants were considered substance dependent if they met criteria for dependence on any of the drugs assessed.

Procedures

Participants were recruited through a multimethod approach, using techniques previously effective in the recruitment and enrollment of substance-using GBM (Groß, Bux, Parsons, & Morgenstern, 2009). Participants in the larger study (the Men’s Health Project) were invited to participate in a neuropsychological assessment battery in a separate study visit, and these data were matched with their sexual behavior, substance use data, and current dependence on the SCID. Computerized versions of all five tasks were administered to participants by masters-level research assistants. Research assistants were trained to assess for intoxication or other substance-related impairment, and participants were told that they could not participate in study visits if they were drunk or high. In addition, participants provided urine to be screened for the club drugs assessed in the study. Thirty participants tested positive for recent (i.e., past three days) club drug use. However, there were no differences between participants by urine screen results on any of the neuropsychological assessment tasks, or on the EF subtypes identified in the analyses below. As such, there is little reason to believe that residual drug levels influenced results. All procedures were reviewed and approved by the Hunter College institutional review board for the protection of human subjects.

Analysis Plan

The first goal of this analysis was to examine whether subgroups of EF performance exist in our sample of substance-using GBM, and evaluate the extent to which these subgroups might conform to past research in this area. The second goal was to investigate whether EF subtypes differentially predict behavior, as hypothesized. To examine potential subgroups of EF performance, we conducted a two-stage clustering procedure using SPSS version 17.0 (Aldenderfer & Blashfield, 1984; Norušis, 2010). The cluster analysis utilized all five neuropsychological measures, and allowed us to examine the extent to which groups of participants in our sample could be characterized in terms of their relative performance across EF areas, rather than looking at the role of each EF area on behavior individually. Because variables with larger ranges may have a disproportionate influence on cluster solutions (Aldenderfer & Blashfield, 1984), variables were transformed to standard z-scores and outliers were examined to insure that variables were comparable in range. Four individuals were dropped from the analysis due to univariate or multivariate outlier status. In the first stage of our analysis, hierarchical clustering was used to determine the number of clusters present in the dataset. Second, cluster centers derived from the hierarchical analysis were then used as starting points for iterative (i.e., K-means) analysis. Although these two procedures may be used independently, (e.g., Clark, Cornelius, Kirisci, & Tarter, 2005; Peretti-Watel, Spire, Lert, Obadia, & Group, 2006), the use of a two-stage exploratory clustering procedure has become common because it capitalizes on the individual strengths of both methods (e.g., Beitchman et al., 2001; Peretti-Watel, et al., 2006; Starks, Golub, Kelly, & Parsons, 2010; Vida et al., 2009).

Following identification of a solution that best fit the data, the internal validity of identified subtypes were evaluated by examining between-group differences on neuropsychological variables (Aldenderfer & Blashfield, 1984). This procedure also allowed for testing hypotheses regarding the EF components likely to distinguish among subgroups; in other words, identify which EF areas were driving subgroup differences. Finally, regression models were used to examine behavioral differences between identified EF subgroups on both substance use and sexual risk-taking.

Results

Identification of EF Subtypes

Using the cluster analytic procedure described above, a three-group solution was supported by the agglomerative schedule. Following K-means clustering, groups were suitable in size to support between group comparisons. Figure 1 depicts standardized means for each cluster on the five measures of EF used in the cluster analysis. A series of one-way ANOVAs were conducted to evaluate the cluster solution. Table 1 contains the results of these analyses.

Individuals in Cluster 1 (labeled “High-Performing”) demonstrated the best average performance across all neuropsychological measures. In contrast, individuals in Cluster 2 (labeled “Low-Performing”) constituted a group who performed poorly compared to those in Cluster 1 on every task. Cluster 3 (labeled the “Poor IGT-Performance”) was characterized by low scores on the IGT and extremely low scores on the IGT-variant. However, individuals in the Poor IGT-Performance subtype did not differ significantly from High-Performing individuals in scores on the Go/No-go, and performed significantly better than Low-Performing individuals on both the Counting Span and WCST.

Demographic comparisons by cluster are also presented in Table 1. There were no differences between the three clusters in any of the demographic variables examined, including: age, race/ethnicity, sexual identity, education, income, or partnership status.

Differences in Substance Use and Dependence by EF Subtype

Participants reported an average of 9.94 drug use days in the past 30 (range 0–30, median = 7, $SD = 8.94$). In analysis of variance (ANOVA) analyses, the three subtypes did not differ in total number of drug use days ($p = .23$) or in number of drug use days for any of the six individual drugs assessed (ps ranging from .23 to .53). Overall, 47 participants (47%) met criteria for substance dependence. The percentage of participants who met criteria for dependence was highest among those in the Low-Performing subtype (58%), and this percentage was significantly higher than the High-Performing subtype (28%), $\chi^2(2) = 6.03$, $p < .05$. An even 50% of individuals in the Poor IGT-Performance subtype met criteria for dependence, but this percentage did not differ significantly from either of the other subtypes. Because of the observed difference in dependence between subtypes, we examined differences in each of the individual neuropsychological variables by dependence. The only difference between participants was in Counting Span scores, with substance-dependent participants demonstrating significantly poorer Counting Span performance ($M = 32.77$, $SD = 21.14$) compared to those who did not meet criteria for dependence ($M = 47.56$, $SD = 24.31$), $t(1,95) = 3.19$, $p < .01$.

Difference in Sexual Behavior by EF

Participants reported an average of 12.06 anal sex acts in the past 30 days (median = 7, IQR 3–12.25). Of these, participants reported an average of 8.39 high-risk sex acts (median = 2, IQR = 1–8) and an average of 5.70 high-risk sex acts under the influence of drugs (median = 1, IQR = 0–4). We then examined differences in sexual behavior by EF subtype. Because of the highly skewed nature of sexual behavior data, we first used a Poisson regression approach, appropriate for count data (Long, 1997), but examination of the dispersion parameters suggested that significant over-dispersion was present, and indicated the superiority of a negative binomial approach for all three variables (deviance/df ranged from 5.95 to 18.04).

Estimated marginal means associated with binomial regression analyses on each of the sexual behavior variables are presented in Table 2. Individuals in the Low-Performing subtype reported a significantly higher number of total sex acts compared to both the High-Performing and Poor IGT-Performance subtypes, which did not differ significantly from each other. Individuals in the Low-Performing subtype also reported a significantly greater number of high-risk sex acts and high-risk acts under the influence compared to those in the Poor IGT-Performance subtype, but High-Performing individuals did not differ significantly on these variables from either of the other two subtypes.

Because of observed differences in sexual behavior among subtypes, we examined the bivariate associations (using Spearman's rho, because of the non-normal distribution of data) between each individual neuropsychological assessment task and sexual behavior. Scores on the Go-Nogo were significantly correlated with number of anal sex acts, $\rho = .29$, $p < .01$, number of high-risk sex acts, $\rho = .26$, $p < .02$, and number of high-risk sex acts under the influence $\rho = .23$, $p < .05$. There were no other statistically significant relationships among neuropsychological variables and any of three sexual behavior variables.

Differences in Global and Event-Level Associations between Substance Use and Sexual Behavior

The identification of differences between the Low-Performing and Poor IGT-Performance subtypes in the number of high-risk sex acts under the influence of drugs suggests a strong event-level association for this group of individuals. However, the fact that a similar pattern of behavioral differences was identified for sex acts and high-risk sex acts *in general* suggests that this association may be an artifact, rather than a true phenomenon. To better

understand both global- and event-level associations across subtypes, we undertook two further analyses. First, we examined global associations between number of drug use days and high-risk sexual behavior separately for each EF subtype. Second, we calculated the percentage of under the influence sex acts that were high-risk and the percentage of sober sex acts that were high-risk for each subtype, and examined differences using ANOVA. This analysis was designed to examine event-level associations between substance use and sexual risk-taking. A strong event-level association would be supported by data indicating a high percentage of under the influence acts that were high-risk and a low percentage of sober acts that were high risk.

Number of drug use days was significantly positively correlated with number of high-risk sex acts for individuals in the Low-Performance subtype, $\rho = .44$, $p < .01$, i.e., as the number of drug use days increases, the number of high-risk sex acts also increases for individuals in this subgroup. However, this association was not significant for those in Poor IGT-Performing, $\rho = .25$, $p = .26$, or High-Performing subtypes, $\rho = -.30$, $p = .15$, indicating that more drug use days were not necessarily associated with more high-risk sex acts among these participants.

Data on event-level associations between substance use and high-risk sex across subtypes are presented in Table 3. Forty-one participants (41%) reported no sober sex in the past 30 days (42% in the Low-Performance subtype, 45% in the Poor-IGT Performance subtype, and 34% in the High-Performing subtype); these participants were excluded from analyses of the percent of sober sex that was high-risk. There were no differences between subtypes in the percentage of under the influence acts that were high risk; across the three subtypes, participants reported that between 44% and 52% of their sex acts that occurred under the influence were also high-risk (i.e. unprotected). However differences did emerge between subtypes in percent of *sober* acts that were high-risk. High-Performing individuals reported the lowest percentage of sober acts that were high risk (19%), i.e. they were the least likely to have unprotected sex when they were sober. Post-hoc analyses indicate that this percentage is significantly lower than that reported by both Low-Performing individuals (48.28%, $p < .05$) and Poor IGT-Performing individuals (48.38%, $p = .06$).

Discussion

The primary goal of this investigation was to examine the role of EF on sexual risk among substance users by exploring the presence of distinct EF subtypes that might be associated with different patterns of sexual behavior and substance use. Building on past research, we set out to identify whether certain subtypes would be characterized by an asymmetrical relationship between working memory performance and myopic reward processing, as measured by the IGT (Bechara & Martin, 2004; Noel, et al., 2007). However, our design expanded upon past findings by considering this asymmetrical relationship in the context of a more comprehensive triadic model of EF, which includes not only working memory (referred to in the model as “updating”), but also two additional functions -- set-shifting and inhibiting (Miyake, et al., 2000). Cluster analysis identified three distinct subtypes in our sample: a High-Performing subtype that performed relatively well on all five EF tasks; a Low-Performing subtype that performed relatively poorly on all five tasks; and a Poor-IGT Performance subtype that performed relatively well on all three measures of the triadic EF model (i.e., the Counting Span (updating), WCST (shifting), and the GoNogo (inhibiting)), but scored poorly on both measures of reward processing (i.e., the IGT and the IGT variant).

These findings are in line with our initial hypothesis, and support previous research about the asymmetrical relationship between working memory (i.e., updating) and reward processing. In addition, these finding suggest that the asymmetrical relationship found in

previous studies may extend not only to working memory, but to other EF areas as well. Individuals who scored poorly on tasks measuring all three EF areas – updating, shifting, and inhibiting -- appear to demonstrate myopia in reward processing that translates into poor IGT performance. However, there was a group of individuals who scored poorly on the IGT without demonstrating poor performance on any of the other EF tasks. The emergence of these three subtypes is supported by other research indicating that some substance users are impaired on decision-making tasks, while other cognitive functions are preserved (Toplak, Sorge, Benoit, West, & Stanovich, 2010). These findings appear consistent with suggestions that decision making may be dissociable from other executive functions on a neuroanatomical level (Bechara, et al., 1998).

In contrast with past research, substance use variables, i.e., number of drug use days, did not distinguish between EF subtypes. However, individuals in the Low-Performing subtype were most likely to meet criteria for substance dependence, compared to the other two subtypes. Follow-up analyses indicated that substance dependent individuals evinced significantly lower Counting Span scores (i.e., poorer working memory), compared to those who did not meet criteria for dependence. No other individual EF task was significantly associated with dependence. Again, these findings are in line with theoretical models that consider working memory to be a central component of EF (Engle, 2002; Hofmann, Gschwendner, Friese, Wiers, & Schmitt, 2008), and suggest that working memory may be largely responsible for the differences between the Low Performing subtype and the other two subtypes.

Sexual risk behavior was highest among those in the Low-Performing subtype, with these individuals reporting the greatest number of sex acts, high-risk sex acts, and high-risk sex acts under the influence. These data are consistent with past research suggesting that global EF impairment increases risk-taking, and supports our hypotheses about the critical role of EF in behavioral control of sexual activity as well as substance use. However, it is important to note that those in the Poor IGT-Performance subtype reported the *lowest* number of sex acts in each category. On the surface, these data appear to be counterintuitive, as we would hypothesize that any type of EF deficits – especially impairment in reward processing -- would be positively associated with sexual risk. Indeed, this finding ran counter to our initial hypotheses, in which we expected EF deficits to be associated with greater risk-taking regardless of subtype. The most striking difference between the Poor IGT-Performance subtype and the other two subtypes were their scores on the IGT variant. Dissociation between scores on the IGT and its variant is consistent with a bivariate framework of affective reactivity in which individuals are impacted by two separate motivational systems – one associated with reactivity to positive events, the other associated with reactivity to negative effects (Gray, 1982). The IGT variant was designed to invert the reward and punishment schedules of the original IGT, requiring individuals to make choices that result in higher initial losses, but greater long-term rewards. Some research suggests that poor performance on the IGT variant is indeed associated with strong reactivity to negative events (Peters & Slovic, 2000), or a strong asymmetry between reactivity to positive or negative events (Desmeules, Bechara, & Dube, 2008).

Our findings suggest that – in the context of good EF performance in other areas – strong reactivity to negative events, i.e., loss aversion, may actually be protective against sexual risk-taking. Individuals in the Poor IGT Performing subtype reported the least amount of sexual activity, as well as the lowest rates of sexual risk. It is possible that the risk associated with sexual behavior is more salient to individuals in this cluster than its rewards. These individuals may lack confidence in their ability to use condoms when confronted with a sexual situation, and therefore may avoid sex in general in order to minimize the potential for punishment (e.g., HIV infection or some other negative consequence of unprotected sex).

Importantly, these protective effects appear unique to the domain of sexual behavior, as individuals in the Poor IGT-Performing subtype reported similar rates of substance use as those in the other two subtypes. More research is needed into the dimensions of affective reactivity in a sexual context, and their implications for decision-making.

Our findings have complex implications for the role of myopia in the relationship between substance use and risky sex in this sample. Individuals in the Low Performing and High Performing subtypes did not differ significantly in their total number of high-risk sex acts or number of high-risk sex acts under the influence in the past 30 days. However, further investigation of global and event-level associations between substance use and sexual behavior tells a more nuanced story. The global association, i.e., correlation, between substance use and sexual risk was present only for individuals in the Low Performing subtype, such that individuals who reported a greater number of substance use days also reported a greater number of high-risk sex acts. This association was not statistically significant for the Low-Performing or Poor IGT-Performance subtypes, suggesting that substance use and sexual risk may not covary in the same way for these individuals. At the event level, all three subtypes reported similar percentages of high-risk sex acts while under the influence (ranging from 44% to 52%), but only 19% of those in the High-Performing subtype reported high-risk sex while sober, compared to 48% in both the Low-Performing and Poor IGT-Performing subtypes. Taken together these results suggest that the Low-Performing subtype is most likely to engage in risk-taking behavior in general, but the association between substance use and sexual risk may be driven by the fact that the riskiest members of this subtype are risky across domains. Support for this interpretation is found in the fact that the same percentage of under the influence acts and sober acts were high risk in this subgroup (52% and 48%, respectively) suggesting that their sexual risk-taking occurs independent of substance use. Similarly, although individuals in the Poor IGT-Performing subtype appear to lower rates of risky sex by avoiding sexual behavior, but when they do engage in risk, it also appears to be equally likely to be under the influence or sober. In contrast, a substance-driven myopia appears best supported by data for the High-Performing subtype. The subtype is much more likely to engage in risky sex when they are under the influence, compared to when they are sober. The lack of a global association between number of substance use days and number of high risk sex acts in this subtype indicates that this impact occurs at the event-level, i.e., for individuals in this subtype, a sex event that includes substance use is more likely to be risky, but individuals who use drugs on more days over the course of a month do not necessarily engage in more high-risk sex acts. These data suggest different patterns of association between substance use and sexual risk among EF subtypes.

Some limitations of the study should be mentioned. First, all behavioral variables were assessed via self-report, which may have led to inaccurate- or under-reporting. However, there is little evidence to suggest that scores on the EF tasks would result in differential *patterns* of inaccurate reporting, lending confidence to our analysis of differences among EF groups. Second, three of the five neuropsychological tasks used in this study lack standardized norms that would have allowed comparison of performance within EF subtypes to established means. Future research should attempt to replicate these data using measures with norms that would allow for more equivalent comparison. Third, a larger sample size would have increased confidence in our cluster solution, and would increase statistical power to examine differences among groups. Fourth, this sample included participants who reported “club drug use,” rather than restricting eligibility to a particular class of drugs or distinguishing between users of different substances. This lack of differentiation may have impacted results, and further research should examine EF subtypes in more discrete or highly differentiated populations. However, it has been noted that it is often difficult to discern the extent to which individual drugs or drug classes are associated with EF, as

individuals often use multiple substances on a regular basis (Fals-Stewart & Bates, 2003). Relatedly, our sample included both individuals who met criteria for dependence and those who did not. Although this diversity may have facilitated the identification of distinct patterns of EF performance not seen in past research, this level of heterogeneity may also have contributed error variance that complicated analysis. And finally, further research is needed into these patterns of association with larger and more diverse samples, and into the mechanisms of association between substance use and sexual risk that may differentially impact individuals with different types of neuropsychological impairment.

Despite these limitations, this paper makes a significant contribution to the literature on the relationship between substance use and sexual risk, suggesting that theoretical models that focus on event-level myopia may be most applicable to populations with intact EF. For those who perform more poorly on EF tasks, the link between substance use and sexual risk may be driven by a propensity toward risk-taking in general, rather than by a specific substance use-sex link. These findings underscore the importance of identifying difference EF subtypes – rather than simply examining specific EF tasks individuals – in the development of interventions to reduce risk behavior among substance users. Individuals in both the High-Performing and Poor IGT-Performing subtypes evinced good performance on working memory, inhibition, and set-shifting tasks, however, our findings indicate that the role of substance use in sexual risk may differ significantly between the two. Similarly, both the Low-Performing and Poor IGT-Performance subtypes demonstrated poor performance on the decision-making tasks, but the loss aversion evinced by the Poor IGT-Performance subtype may be protective against sexual risk, albeit independent of substance use. Further investigation into EF subtypes has the potential to improve HIV prevention strategies in three ways. First, a better understanding of the ways in which EF deficits may impact risk may lead to the development of intervention strategies focusing on these elements. Low-Performing individuals may benefit from training in concrete strategies for avoidance of risky situations, as it may be difficult for them to exercise the cognitive control needed for self-regulation. Second, HIV prevention interventions targeting substance users must consider the extent to which their target population may include individuals from different EF subtypes, and should modify intervention strategies accordingly. For example, harm reduction strategies of reducing substance use in sexual contexts in order to reduce risky sexual behavior may be effective for High-Performing individuals, but may not reduce risk among individuals in other subtypes. And third, a better understanding of the role of EF in risk behavior might lead to the modification of existing interventions to include components that better meet the particular needs of subtypes. Future studies should further investigate the existence of EF profiles among GBM and others, and explore their utility in the prediction of risk behaviors and targeting of HIV prevention efforts.

Acknowledgments

Funding for this study was provided by the Foundation for AIDS Research (amfAR) grant 106963-43-RGBR (S.A. Golub, PI) and NIDA grant R01DA020366 (J.T. Parsons, PI). The content is solely the responsibility of the authors and does not necessarily represent the official views of NIDA, NIH or amfAR.

References

- Aldenderfer, MS.; Blashfield, RK. Cluster Analysis. Vol. Vol. 44. Newbury Park, CA: Sage Publications Inc.; 1984.
- American Psychiatric Association., & American Psychiatric Association. Task Force on DSM-IV. Diagnostic and statistical manual of mental disorders : DSM-IV-TR. 4th ed.. Washington, DC: American Psychiatric Association; 2000.
- Anand P, Springer SA, Copenhaver MM, Altice FL. Neurocognitive impairment and HIV risk factors: a reciprocal relationship. *AIDS and Behavior*. 2010; 14(6):1213–1226. [PubMed: 20232242]

- Bates ME. Utility of component-process approaches for understanding complex alcohol-related behavior within an executive functioning framework: comment on Giancola (2000). *Experimental and Clinical Psychopharmacol.* 2000; 8(4):598–600.
- Bechara A. Risky business: emotion, decision-making, and addiction. *Journal of Gambling Studies.* 2003; 19(1):23–51. [PubMed: 12635539]
- Bechara A, Damasio H. Decision-making and addiction (part I): impaired activation of somatic states in substance dependent individuals when pondering decisions with negative future consequences. *Neuropsychologia.* 2002; 40(10):1675–1689. [PubMed: 11992656]
- Bechara A, Damasio H, Tranel D, Anderson SW. Dissociation of working memory from decision making within the human prefrontal cortex. *The Journal of Neuroscience.* 1998; 18(1):428. [PubMed: 9412519]
- Bechara A, Dolan S, Hindes A. Decision-making and addiction (part II): myopia for the future or hypersensitivity to reward? *Neuropsychologia.* 2002; 40(10):1690–1705. [PubMed: 11992657]
- Bechara A, Martin EM. Impaired Decision Making Related to Working Memory Deficits in Individuals With Substance Addictions. *Neuropsychology.* 2004; 18(1):152. [PubMed: 14744198]
- Bechara A, Tranel D, Damasio H. Characterization of the decision-making deficit of patients with ventromedial prefrontal cortex lesions. *Brain.* 2000; 123(11):2189. [PubMed: 11050020]
- Beitchman J, Beitchman JH, Adlaf EM, Douglas L, Atkinson L, Young AJ, et al. Comorbidity of psychiatric and substance abuse disorders in late adolescence: A cluster analytic approach. *The American Journal of Drug and Alcohol Abuse.* 2001; 27(3):421–440. [PubMed: 11506260]
- Berman S, O'Neill J, Fears S, Bartzokis G, London ED. Abuse of amphetamines and structural abnormalities in the brain. *Annals of the New York Academy of Science.* 2008; 1141:195–220.
- Bolla K, Eldreth D, London E, Kiehl K, Mouratidis M, Contoreggi C, et al. Orbitofrontal cortex dysfunction in abstinent cocaine abusers performing a decision-making task. *Neuroimage.* 2003; 19(3):1085–1094. [PubMed: 12880834]
- Brewer DD, Golden MR, Handsfield HH. Unsafe sexual behavior and correlates of risk in a probability sample of men who have sex with men in the era of highly active antiretroviral therapy. *Sexually Transmitted Diseases.* 2006; 33(4):250–255. [PubMed: 16505748]
- Buchbinder SP, Vittinghoff E, Heagerty PJ, Celum CL, Seage GR 3rd, Judson FN, et al. Sexual risk, nitrite inhalant use, and lack of circumcision associated with HIV seroconversion in men who have sex with men in the United States. *Journal of Acquired Immune Deficiency Syndrome.* 2005; 39(1):82–89.
- Carey MP, Carey KB, Maisto SA, Gordon CM, Weinhardt LS. Assessing sexual risk behaviour with the Timeline Followback (TLFB) approach: continued development and psychometric evaluation with psychiatric outpatients. *International Journal of STD AIDS.* 2001; 12(6):365–375. [PubMed: 11368817]
- Celentano DD, Valleroy LA, Sifakis F, MacKellar DA, Hylton J, Thiede H, et al. Associations between substance use and sexual risk among very young men who have sex with men. *Sexually Transmitted Diseases.* 2006; 33(4):265–271. [PubMed: 16434886]
- Clark DB, Cornelius JR, Kirisci L, Tarter RE. Childhood risk categories for adolescent substance involvement: A general liability typology. *Drug and Alcohol Dependence.* 2005; 77:13–21. [PubMed: 15607837]
- Conway AR, Kane MJ, Bunting MF, Hambrick DZ, Wilhelm O, Engle RW. Working memory span tasks: A methodological review and user's guide. *Psychon Bull Rev.* 2005; 12(5):769–786. [PubMed: 16523997]
- Desmeules R, Bechara A, Dube L. Subjective valuation and asymmetrical motivational systems: Implications of scope insensitivity for decision making. *Journal of Behavioral Decision Making.* 2008; 21:211–224.
- Drumright LN, Gorbach PM, Little SJ, Strathdee SA. Associations between substance use, erectile dysfunction medication and recent HIV infection among men who have sex with men. *AIDS and Behavior.* 2009; 13(2):328–336. [PubMed: 18064558]
- Drumright LN, Patterson TL, Strathdee SA. Club drugs as causal risk factors for HIV acquisition among men who have sex with men: a review. *Substance Use and Misuse.* 2006; 41(10–12):1551–1601. [PubMed: 17002993]

- Engle RW. Working memory capacity as executive attention. *Current Directions in Psychological Science*. 2002; 11(1):19–23.
- Fals-Stewart W, Bates ME. The neuropsychological test performance of drug-abusing patients: an examination of latent cognitive abilities and associated risk factors. *Experimental Clinical Psychopharmacology*. 2003; 11(1):34–45.
- Fals-Stewart W, O'Farrell TJ, Freitas TT, McFarlin SK, Rutigliano P. The timeline followback reports of psychoactive substance use by drug-abusing patients: psychometric properties. *Journal of Consulting and Clinical Psychology*. 2000; 68(1):134–144. [PubMed: 10710848]
- Fellows LK, Farah MJ. Different underlying impairments in decision-making following ventromedial and dorsolateral frontal lobe damage in humans. *Cerebral Cortex*. 2005; 15(1):58–63.
- First, MB.; Spitzer, RL.; Gibbon, M.; Williams, JBW. Structured Clinical Interview for DSM-IV-TR Axis I Disorders, Research Version. Non-patient Edition.. New York: Biometrics Research, New York State Psychiatric Institute; 2002.
- Garavan H, Ross TJ, Stein EA. Right hemispheric dominance of inhibitory control: an event-related functional MRI study. *Proceedings from the National Academy of Science U S A*. 1999; 96(14): 8301–8306.
- Giancola PR. Executive functioning: a conceptual framework for alcohol-related aggression. *Experimental and Clinical Psychopharmacology*. 2000; 8(4):576–597.
- Giancola PR, Godlaski AJ, Roth RM. Identifying component-processes of executive functioning that serve as risk factors for the alcohol-aggression relation. *Psychology of Addictive Behavior*. 2011
- Goldberg, E. The executive brain: Frontal lobes and the civilized mind. Oxford University Press, USA; 2002.
- Golub SA, Starks TJ, Payton G, Parsons JT. The Critical Role of Intimacy in the Sexual Risk Behaviors of Gay and Bisexual Men. *AIDS and Behavior*. (in press).
- Graham S, Phua E, Soon CS, Oh T, Au C, Shuter B, et al. Role of medial cortical, hippocampal and striatal interactions during cognitive set-shifting. *Neuroimage*. 2009; 45(4):1359–1367. [PubMed: 19162202]
- Gray, JA. The neuropsychology of anxiety: An enquiry into the functions of the septo-hippocampal system. New York: Oxford University Press; 1982.
- Grov C, Bux D, Parsons J, Morgenstern J. Recruiting hard-to-reach men who have sex with men into an intervention study: Lessons learned and implications for applied research. *Substance Use and Misuse*. 2009; 44:1603–1619.
- Halkitis PN, Palamar JJ, Mukherjee PP. Poly-club-drug use among gay and bisexual men: a longitudinal analysis. *Drug and Alcohol Dependence*. 2007; 89(2–3):153–160. [PubMed: 17267140]
- Hester R, Fassbender C, Garavan H. Individual differences in error processing: a review and reanalysis of three event-related fMRI studies using the GO/NOGO task. *Cerebral cortex*. 2004; 14(9):986–994. [PubMed: 15115734]
- Hofmann W, Gschwendner T, Friese M, Wiers RW, Schmitt M. Working memory capacity and self-regulatory behavior: toward an individual differences perspective on behavior determination by automatic versus controlled processes. *Journal of Personality and Social Psychology*. 2008; 95(4): 962–977.
- Irwin TW, Morgenstern J, Parsons JT, Wainberg M, Labouvie E. Alcohol and sexual HIV risk behavior among problem drinking men who have sex with men: An event level analysis of timeline followback data. *AIDS and Behavior*. 2006; 10(3):299–307. [PubMed: 16482407]
- Jonides, J.; Smith, EE. The architecture of working memory. In: Rugg, MD., editor. *Cognitive neuroscience*. Cambridge, MA: MIT Press; 1997. p. 243–276.
- Kane MJ, Engle RW. The role of prefrontal cortex in working-memory capacity, executive attention, and general fluid intelligence: an individual-differences perspective. *Psychon Bull Rev*. 2002; 9(4):637–671. [PubMed: 12613671]
- Kane MJ, Hambrick DZ, Tuholski SW, Wilhelm O, Payne TW, Engle RW. The generality of working memory capacity: a latent-variable approach to verbal and visuospatial memory span and reasoning. *Journal of Experimental Psychology General*. 2004; 133(2):189–217.

- Koblin BA, Husnik MJ, Colfax G, Huang Y, Madison M, Mayer K, et al. Risk factors for HIV infection among men who have sex with men. *AIDS*. 2006; 20(5):731–739. [PubMed: 16514304]
- Konishi S, Nakajima K, Uchida I, Kikyo H, Kameyama M, Miyashita Y. Common inhibitory mechanism in human inferior prefrontal cortex revealed by event-related functional MRI. *Brain : a journal of neurology*. 1999; 122(Pt 5):981–991. [PubMed: 10355680]
- Leland DS, Arce E, Miller DA, Paulus MP. Anterior cingulate cortex and benefit of predictive cueing on response inhibition in stimulant dependent individuals. *Biological Psychiatry*. 2008; 63(2):184–190. [PubMed: 17707348]
- Lelutiu-Weinberger C, Pachankis JE, Walker JJ, Bamonte A, Golub SA, Parsons JT. Age cohort differences in the effects of gay-related stigma, anxiety and identification with the gay community on risky sex and substance use. *AIDS and Behavior*. (in press).
- Li X, Lu ZL, D'Argembeau A, Ng M, Bechara A. The Iowa Gambling Task in fMRI images. *Human brain mapping*. 2010; 31(3):410–423. [PubMed: 19777556]
- Lin CH, Chiu YC, Cheng CM, Hsieh JC. Brain maps of Iowa gambling task. *BMC Neuroscience*. 2008; 9:72. [PubMed: 18655719]
- Long, JS. *Regression Models for Categorical and Limited Dependent Variables*. Vol. (Vol. 7). Thousand Oaks, CA: Sage, Inc.; 1997.
- Manes F, Sahakian B, Clark L, Rogers R, Antoun N, Aitken M, et al. Decision-making processes following damage to the prefrontal cortex. *Brain*. 2002; 125(Pt 3):624–639. [PubMed: 11872618]
- Mathalon DH, Whitfield SL, Ford JM. Anatomy of an error: ERP and fMRI. *Biological psychology*. 2003; 64(1–2):119–141. [PubMed: 14602358]
- McKirnan DJ, Ostrow DG, Hope B. Sex, drugs and escape: a psychological model of HIV-risk sexual behaviours. *AIDS Care*. 1996; 8(6):655–669. [PubMed: 8993716]
- Miyake A, Friedman NP, Emerson MJ, Witzki AH, Howerter A, Wager TD. The unity and diversity of executive functions and their contributions to complex. *Cognitive psychology*. 2000; 41(1):49–100. [PubMed: 10945922]
- Mustanski B. Moderating effects of age on the alcohol and sexual risk taking association: an online daily diary study of men who have sex with men. *AIDS and Behavior*. 2008; 12(1):118–126. [PubMed: 18034298]
- Noel X, Bechara A, Dan B, Hanak C, Verbanck P. Response inhibition deficit is involved in poor decision making under risk in nonamnesic individuals with alcoholism. *Neuropsychology*. 2007; 21(6):778–786. [PubMed: 17983291]
- Norušis, MJ. *PASW Statistics 18 Statistical Procedures Companion*. Chicago, IL: SPSS Inc.; 2010.
- Nyhus E, Barcelo F. The Wisconsin Card Sorting Test and the cognitive assessment of prefrontal executive functions: a critical update. *Brain and Cognition*. 2009; 71(3):437–451. [PubMed: 19375839]
- Pappas MK, Halkitis PN. Sexual risk taking and club drug use across three age cohorts of HIV-positive gay and bisexual men in New York City. *AIDS Care*. 2011; 23(11):1410–1416. [PubMed: 22022849]
- Paulus MP, Hozack NE, Zauscher BE, Frank L, Brown GG, Braff DL, et al. Behavioral and functional neuroimaging evidence for prefrontal dysfunction in methamphetamine-dependent subjects. *Neuropsychopharmacology*. 2002; 26(1):53–63. [PubMed: 11751032]
- Peretti-Watel P, Spire B, Lert F, Obadia Y, Group V. Drug use patterns and adherence to treatment among HIV-positive patients: Evidence from a large sample of French outpatients. *Drug and Alcohol Dependence*. 2006; 82(Suppl. 1):S71–S79. [PubMed: 16769450]
- Peters E, Slovic P. The springs of action: Affective and analytical information processing in choice. *Personality and Social Psychology Bulletin*. 2000; 26(12):1465–1475.
- Prejean J, Song R, Hernandez A, Ziebell R, Green T, Walker F, et al. Estimated HIV incidence in the United States, 2006–2009. *PLoS One*. 2011; 6(8):e17502. [PubMed: 21826193]
- Rapeli P, Kivisaari R, Autti T, Kahkonen S, Puuskari V, Jokela O, et al. Cognitive function during early abstinence from opioid dependence: a comparison to age, gender, and verbal intelligence matched controls. *BMC Psychiatry*. 2006; 6:9. [PubMed: 16504127]

- Rudy ET, Shoptaw S, Lazzar M, Bolan RK, Tilekar SD, Kerndt PR. Methamphetamine use and other club drug use differ in relation to HIV status and risk behavior among gay and bisexual men. *Sexually Transmitted Diseases*. 2009; 36(11):693–695. [PubMed: 19704399]
- Schwarcz S, Scheer S, McFarland W, Katz M, Valleroy L, Chen S, et al. Prevalence of HIV infection and predictors of high-transmission sexual risk behaviors among men who have sex with men. *American Journal of Public Health*. 2007; 97(6):1067–1075. [PubMed: 17463384]
- Sim ME, Lyoo IK, Streeter CC, Covell J, Sarid-Segal O, Ciraulo DA, et al. Cerebellar gray matter volume correlates with duration of cocaine use in cocaine-dependent subjects. *Neuropsychopharmacology*. 2007; 32(10):2229–2237. [PubMed: 17299505]
- Simon SL, Domier C, Carnell J, Brethen P, Rawson R, Ling W. Cognitive impairment in individuals currently using methamphetamine. *American Journal of Addiction*. 2000; 9(3):222–231.
- Smith EE. Neural bases of human working memory. *Current Directions in Psychological Science*. 2000; 9:45–49.
- Smith EE, Jonides J. Storage and executive processes in the frontal lobes. *Science*. 1999; 283:1657–1661. [PubMed: 10073923]
- Smyth MM, Pelky PL. Short-term retention of spatial information. *British Journal of Psychology*. 1992; 83(Pt 3):359–374. [PubMed: 1393366]
- Sobell, MB.; Sobell, LC. Problem drinkers: Guided self-change treatment. New York: Guilford Press; 1993.
- Starks TJ, Golub SA, Kelly DK, Parsons JT. The problem of “just for fun”: Patterns of use situations among active club drug users. *Addictive Behaviors*. 2010; 24(3):487–497.
- Steele CM, Josephs RA. Alcohol myopia: Its prized and dangerous effects. *American Psychologist*. 1990; 45(8):921–933. [PubMed: 2221564]
- Stuss DT, Alexander MP. Executive functions and the frontal lobes: a conceptual view. *Psychological Research*. 2000; 63(3–4):289–298. [PubMed: 11004882]
- Tabachnick, B.; Fidell, L. Using Multivariate Statistics. 4th ed.. Boston: Allyn and Bacon; 2001.
- Toplak ME, Sorge GB, Benoit A, West RF, Stanovich KE. Decision-making and cognitive abilities: A review of associations between Iowa Gambling Task performance, executive functions, and intelligence. *Clinical psychology review*. 2010; 30(5):562–581. [PubMed: 20457481]
- Tucker KA, Potenza MN, Beauvais JE, Browndyke JN, Gottschalk PC, Kosten TR. Perfusion abnormalities and decision making in cocaine dependence. *Biological Psychiatry*. 2004; 56(7):527–530. [PubMed: 15450790]
- Verdejo-García A, Pérez-García M. Profile of executive deficits in cocaine and heroin polysubstance users: common and differential effects on separate executive components. *Psychopharmacology*. 2007; 190(4):517–530. [PubMed: 17136401]
- Vida R, Brownlie EB, Beitchman JH, Adlaf EM, Atkinson L, Escobar M, et al. Emerging Adult Outcomes of Adolescent Psychiatric and Substance Use Disorders. *Journal of Addictive Behaviors*. 2009; 34:800–805.
- Wardle MC, Gonzalez R, Bechara A, Martin-Thormeyer EM. Iowa Gambling Task performance and emotional distress interact to predict risky sexual behavior in individuals with dual substance and HIV diagnoses. *Journal of Clinical and Experimental Neuropsychology*. 2010; 32(10):1110–1121. [PubMed: 20480423]
- Weinhardt LS, Carey MP, Maisto SA, Carey KB, Cohen MM, Wickramasinghe SM. Reliability of the timeline follow-back sexual behavior interview. *Ann Behav Med*. 1998; 20(1):25–30. [PubMed: 9755348]
- Wells BE, Golub SA, Parsons JT. An integrated theoretical approach to substance use and risky sexual behavior among men who have sex with men. *AIDS and Behavior*. 2011; 15(3):509–520. [PubMed: 20677019]

Figure 1.
Standardized Means on Neuropsychological Assessments by Cluster

Table 1
Differences among EF Subtypes in Neuropsychological Assessment Scores and Demographics

Assessment Scores	High Performing (n = 26)		Low Performing (n = 52)		Poor IGT- Performance (n = 22)	
	M	(SD)	M	(SD)	M	(SD)
IGT	31.77 ^a	(24.3)	1.81 ^b	(24.6)	1.91 ^b	(27.8)
IGT Variant	56.23 ^a	(31.3)	22.35 ^b	(30.3)	-27.36 ^c	(36.5)
Counting Span	63.19 ^a	(22.1)	25.08 ^c	(16.0)	47.45 ^b	(15.5)
Go-Nogo	15.23 ^a	(10.8)	26.88 ^b	(17.3)	9.77 ^a	(6.6)
WCST	9.88 ^a	(5.4)	26.1 ^c	(11.1)	14.73 ^b	(8.3)
Demographic Differences						
	M	(SD)	M	(SD)	M	(SD)
Age	28.89	(6.9)	31.06	(7.7)	28.86	(7.3)
	n	%	n	%	n	%
Sexual Orientation						
Bisexual	5	19.2	5	9.6	2	9.1
Gay	21	80.8	47	90.4	20	90.9
Race						
White	13	50	15	28.8	10	45.5
NonWhite	13	50	37	71.2	12	54.5
Education						
Less than a B .A .	17	65.4	29	55.8	17	77.3
B .A .or more	9	34.6	23	44.2	5	22.7
Income						
<\$29,999	15	57.7	30	57.7	15	68.2
>\$30,000	11	42.3	22	42.3	7	31.8
Relationship status						
Partnered	7	26.9	17	32.7	6	27.3
Single	19	73.1	35	67.3	16	72.7

NOTE: Within rows, means with different superscripts differ significantly from each other at $p < .05$. IGT = Iowa Gambling Task. WCST = Wisconsin Card Sort Task.

*
 $p < .05$,
**
 $p < .01$.

\$watermark-text

\$watermark-text

\$watermark-text

Table 2
Negative Binomial Regression Models of Sexual Behavior Variables by EF Subtype

EF Subtype	Total Number of Sex Acts		Number of High Risk Sex Acts		Number of High Risk Sex Acts UI	
	EMM	(SE)	EMM	(SE)	EMM	(SE)
Low -Performing	16.17 ^a	(2.60)	11.83 ^a	(2.6)	9.83 ^a	(2.5)
High-Performing	9.46 ^b	(2.19)	6.13 ^{ab}	(1.9)	5.50 ^{ab}	(2.0)
Poor IGT-Performance	5.95 ^b	(1.48)	3.36 ^b	(1.1)	2.50 ^b	(.99)
Wald $\chi^2(2)$	11.81	**	9.53	**	8.21	*

NOTE: Within variables, estimated marginal means with different superscripts differ from each other significantly at the $p < .05$ level, based on pairwise comparisons following a significant omnibus Likelihood Ratio Chi-Square. EMM = Estimated Marginal Means. UI = Under the influence of drugs.

* $p < .05$.

** $p < .01$.

Table 3

One-way ANOVA Comparisons of Event-Level Variables by EF Subtype

EF Subtype	<u>Percent of UI Act that were High-Risk</u>		<u>Percent of Sober Acts that were High-Risk</u>	
	M	(SE)	M	(SE)
Low -Performing	51.79	(6.41)	48.28	(7.87)
High-Performing	43.75	(9.82)	19.61	(8.60)
Poor IGT-Performance	51.95	(8.34)	48.38	(10.68)
	F (2, 91) = .30		F(2, 56) = 3.13 *	

*
p = .05.