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THE RELATIONSHIP OF NEUROPSYCHOLOGICAL FUNCTIONING TO MEASURES OF SUBSTANCE USE IN AN ADOLESCENT DRUG ABUSING SAMPLE*

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The purpose of this research was to investigate the relationship between recent and long term substance use on adolescents' neuropsychological functioning. Subjects were 77 adolescents who were referred for outpatient treatment for drug and conduct problems. Subjects were administered the Luria-Nebraska Neuropsychological Battery-III, structured interviews to assess substance use, and urine tests. Subjects were divided into neuropsychologically impaired and nonimpaired groups. Results indicated no significant group differences for: self-reports of lifetime use of alcohol, cannabis, and hard drugs; self or collateral reports of recent (past 30 days) use of alcohol, cannabis, and hard drugs; or urinalysis detection of alcohol, cannabis, and hard drugs. Correlations between these dependent measures of substance use and neuropsychological functioning were also non-significant (all *ps* > .05). Although neuropsychological impairment was observed for some subjects in this sample, it was unrelated to their cannabis, hard drug, or alcohol use. These results are consistent with those found in the adult literature, given the relatively short period of time that these youth have used such substances. However, given the severity of their absolute levels of substance usage, they may be at greater risk for developing future neuropsychological problems, related directly to the ingestion of alcohol and illicit drugs, and to their secondary effects (*e.g.*, head traumas, malnutrition).

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There has been an exponential increase in the number of publications specific to the study of substance abuse. However, relatively few studies have been published that report on the neuropsychological functioning of alcohol and drug abusers, particularly among adolescent substance abusers. Neuropsychological studies that have been conducted with these substance abusing populations strongly suggest that the chronic long-term abuse of alcohol is associated with a number of brain impairments. These impairments may be attributed directly to the ingestion of alcohol, or perhaps more commonly, to its secondary effects such as malnutrition, head traumas, cerebrovascular insults, and other neuropathological disease processes (Adams and Victor, 1993). Studies have indicated cerebral atrophy in persons who have consumed alcohol excessively for greater than 15 years (Lishman, 1995). Although studies have demonstrated reversibility of cerebral atrophy and ventricular enlargement after only one month of abstinence (*e.g.*, Zipursky, Lim and Pfefferbaum, 1989; Schroth, Naegele and Klose, 1988), recovery is often incomplete as cerebral deficits have been documented after extended periods of abstinence (Carlen *et al.*, 1994; Di Sclafani *et al.*, 1995; Lishman, Jacobson and Acker, 1987). Moreover, when significant recovery to the cortex has occurred, resumption of drinking after a short period of abstinence has been demonstrated to result rapidly in loss of white matter and increases in third ventricular volume (Pfefferbaum, Sullivan, Mathalon, Shear, Rosenbloom and Lim, 1995).

The neuropsychological consequences of chronic alcohol abuse vary depending on the nature of the disease process. Such deficits range from a profound amnesic syndrome that is characterized by anterograde and retrograde memory deficits, ocular dysfunction, apathy, and a general decline in higher order cognitive abilities as in Korsakoff's syndrome (Victor and Banker, 1977), executive dysfunction as demonstrated in cases of cerebral atrophy (Courville, 1967; Davila, Shear, Lane, Sullivan and Pfefferbaum, 1994), and abnormal stance, gait, and ataxia of the limbs resulting from cerebellar atrophy

(Fals-Stewart, Schafer, Lucente, Rustine and Brown, 1994; Victor and Adams, 1993). Research investigating the neurological and neuropsychological correlates of alcohol abuse in adolescent populations is notably absent.

In adult populations, the acute effects of marijuana use on cognitive functions include poor memory, difficulty tracking stimuli, delays in visual processing, distorted time perception (Lezak, 1995), and problems with selective attention (Solowij, Michie and Fox, 1991). Preliminary findings of a group of adolescent marijuana abusers with conduct problems ($N = 15$) suggested short-term verbal memory deficits (Millsaps, Azrin and Mittenberg, 1994), albeit similar patterns of deficits have been noted in related populations such as adolescent delinquents (*e.g.*, Denno, 1990; Moffitt, 1988). Most controlled studies have generally found no negative long-term neuropsychological consequences resulting from marijuana use (see Bruhn and Maage, 1975; Carlin and Trupin, 1977; Carlin, 1986), although other investigations have found residual memory impairments in chronic long-term cannabis users (Singh Mendhiratta, Wig and Verma, 1978; Page, Fletcher and True, 1988). All investigations relating these variables were conducted with adults only.

In contrast, the immediate and long-term neuropsychological effects of "hard" drug use are more pronounced, at least in adult populations. Benzodiazepine abuse can contribute to learning and memory difficulties (see Pagliaro and Pagliaro, 1996 for a comprehensive review). In general, long-term chronic abuse of opiates does not result in permanent negative neuropsychological consequences (see Fields and Fullerton, 1975), although chronic opiate users have been observed to exhibit mild impairment on tests of visuospatial and visuomotor functions (Grant *et al.*, 1978). Many studies have indicated neuropsychological deficits among chronic cocaine abusers (O'Malley and Gawin, 1990), including memory and concentration problems (Mittenberg and Motta, 1993), sleep disturbances, lack of orientation (Lezak, 1995), deficits to executive functions and verbal memory even after full detoxification (Rosselli and Ardila, 1996), and strokes resulting from overstimulation to the central nervous system (Brust, 1993).

Polydrug use in chronic abusing populations is common as such individuals rarely use illicit drugs in isolation. Grant and his colleagues

(Grant *et al.*, 1978) examined the long-term neuropsychological consequences of polydrug use in an adult population. In this study, screens for illicit substance use, medical histories, and neuropsychological assessments were obtained from three samples (*i.e.*, polydrug users, psychiatric patients, nonpatient controls), including a 10-year history of drug use frequency for seven drugs. Results indicated that polydrug users (37%) and psychiatric patients (26%) exhibited greater neuropsychological impairment than nonpatient controls (8%). Cumulative drug use was associated with neuropsychological impairment, and polydrug abusers performed poorly on tests of verbal fluency, abstraction, and problem solving, as compared to the other two groups. Polydrug users and psychiatric patients demonstrated deficits in perceptual-motor abilities, as compared to control subjects. Findings were replicated three months after the initial study was conducted.

A recent investigation of 183 subjects in their mid-20s (*i.e.*, 3 groups: poly-drug dependent, cocaine dependent, nondrug using controls) also demonstrated neuropsychological deficits in poly-drug users (Rosselli and Ardila, 1996). All substance abusers were assessed to have used their respective drugs for about 10 years prior to receiving 2 months of inpatient substance abuse treatment. Subjects with a prior history of neurological problems were excluded from the study. Results indicated that polydrug abusing groups exhibited poorer scores for most verbal memory (and some visual memory) subtests, as compared to controls.

In summary, studies have clearly indicated that in adult samples, neuropsychological impairments are associated with the chronic abuse of alcohol and some hard drugs. Additionally, most controlled adult studies have failed to demonstrate a link between the long-term abuse of marijuana and cognitive functioning, although a few uncontrolled investigations have suggested that the chronic use of marijuana may result in residual memory difficulties. As stated, these conclusions are almost entirely based on the adult literature. Thus, because adolescent substance abuse is reaching epidemic proportions in the United States (see U.S. Department of Health and Human Services, Public Health Service, 1994) and the current state of knowledge regarding neuropsychological functioning in this population is limited, there is a need to examine the effects of substance use/abuse on cerebral functions.

METHOD

Subjects

Subjects were 77 adolescents who were referred to a cognitive-behavioral substance abuse treatment program due to anti-social problems associated with their conduct and drug abuse. The mean age of subjects was 15.3 years ($SD = 1.2$), and their mean family income was \$40,897 ($SD = \$23,926$). Sixty (78%) were male, 62 (81%) were enrolled in school, 24 (32%) were involved in special education due to an academic disability, and 48 (62%) of the youths' primary caregivers were married/cohabitating. Forty-seven (61%) were Caucasian, 20 (26%) were Hispanic, and the remaining 10 (13%) were of other minority racial status. As indicated in Table I, most subjects (68%) were diagnosed with cannabis dependence (see description of SCID-IV in Measures section), and only 8% were identified to have abused other drugs. Table II presents information pertinent to the youth's drug and alcohol usage.

Procedure

Prior to participating in this study, a structured telephone screen was performed with the youth's legal guardian to determine if the youth

TABLE I DSM-IV diagnoses for the sample ($N = 77$)

DSM-IV Diagnosis		
Substance dependence		
Cannabis	53	(68.8)
Cocaine	5	(6.5)
Stimulant	4	(5.2)
Hallucinogen	3	(3.9)
Sedative	2	(2.9)
Poly-substance	2	(2.9)
Other	1	(1.3)
Substance abuse		
Cannabis	13	(16.9)
Cocaine	4	(5.2)
Stimulant	2	(2.6)
Hallucinogen	6	(7.8)
Sedative	5	(6.5)
Poly-substance	1	(1.3)

Note: Diagnoses of alcohol abuse and dependence were not assessed.

TABLE II Drug and alcohol use of the sample ($N=77$)

	Alcohol		*Cannabis*		*Hard drugs*	
	M	*SD*	*M*	*SD*	*M*	*SD*
Life time use (# days)	81.88	(224.08)	331.99	(475.18)	23.31	(109.61)
Recent use (# days during past 30 days)	2.13	(3.53)	6.56	(7.47)	.21	(.74)
Age when 1st used	12.08	(2.81)	12.78	(1.56)	14.07	(1.64)
% Urines positive	.35	(2.97)	52.98	(41.69)	8.08	(21.75)

met the following study inclusionary and exclusionary criteria: (1) a diagnosis of substance abuse and conduct disorder consistent with the Diagnostic and Statistical Manual of Mental Health Disorders (fourth edition; DSM-IV) (American Psychiatric Association, 1994), (2) between 13–18 years of age, (3) not currently receiving psychological intervention, (4) not diagnosed with mental retardation or a psychotic disorder. Parents and their youth were then scheduled to receive a battery of psychological and neuropsychological tests. Youths and their legal guardians were assessed in separate rooms. Assessment consisted of three sessions, approximately 2-hours each, and sessions were conducted approximately one week apart. All assessments were conducted by doctoral students enrolled in a clinical psychology program. Urine alcohol and drug screens were obtained at each of the assessment sessions.

Measures

Structured Clinical Interview for DSM-IV (SCID-IV)

The SCID-IV is a structured diagnostic interview that is consistent with the DSM-IV. The substance abuse module of the SCID-IV was utilized in this study to obtain diagnostic information pertinent to substance abuse and dependence (*i.e.*, consistent with the DSM-IV). Good estimates of validity and reliability of this measure have been reported elsewhere (see Spitzer, Williams, Gibbon and First, 1992).

Luria Nebraska Neuropsychological Battery-III (LNNB-III)

The LNNB-III is a neuropsychological testing battery that assesses academic achievement, general intellectual ability, executive, verbal,

visual-spatial, memory, somatosensory, and motor functions. The LNNB-III consists of 31 clinical subscales, yielding 35 scores. *T*-scores are derived to correct for age and educational attainment (see Freshwater and Teichner, 1998). For each scale, a *T*-score < 40 indicates compromised functioning for that functional skill. Initial studies of the LNNB-III indicate that its psychometric properties are excellent (Bradley, Teichner, Crum and Golden, in press; Crum, Bradley, Teichner and Golden, in press; Teichner, Golden, Bradley and Crum, 1999).

Time-line Follow-back Interview

Self-reports of the youth's frequency of days using illicit drugs and alcohol during the past 30 days were obtained from the youth and their legal guardian utilizing the "time-line follow back" method (Ehrman and Robbins, 1994; Sobell, Sobell, Klajner, Paven and Basian, 1986; Babor, Cooney and Lauerman, 1987). In this method, subjects construct a calendar of significant events (*e.g.*, birthdays, vacation days, holidays) and are then asked to report the frequency of days in which illicit drugs and alcohol were used during this time period. This standardized method has been found to correspond closely with official records and reports by collaterals, and test-retest reliability is good (Ehrman and Robbins, 1994; Sobell *et al.*, 1986). Each day of illicit drug use other than marijuana and alcohol (*e.g.*, stimulants, barbiturates, opiates) was classified as one day of "hard" drug use. Thus, use of cocaine and valium on the same day was recorded as 1 day of hard drug use.

Drug Use History Interview (DSUHI)

The DUHI is a structured interview that was developed in this study to assess the youth's lifetime frequency of days using alcohol, marijuana, and "hard" drugs (*i.e.*, cocaine, barbiturates, opiates, benzodiazepines, amphetamines, methadone, PCP), and to assess the youth's number of months using the aforementioned drugs. The following two questions from this interview were utilized in this study to assess severity and chronicity of drug use: (a) How many days have you used (the respective drug) in your lifetime? (b) How old were you when you first used (the respective drug)? The latter question permitted an

estimate of the number of months the youth reportedly had used the respective drug in his/her lifetime. If more than one hard drug was used by the youth during his/her lifetime, the hard drug that was most often consumed was utilized to estimate the youth's number of days using "hard" drugs. For instance, if the youth reported 50 days of cocaine use and 2 days of benzodiazepine use, the number of days using hard drugs would be "50." Similarly, the earliest onset of hard drug use was utilized to derive an estimate of the number of months using "hard" drugs.

Urine Drug Screens

A urine sample was obtained from each subject during each of the assessment sessions. Urine specimens were supervised by a research assistant of the same sex. Each sample was then screened by Redwood Toxicology Laboratory for the following illicit substances: ethanol (alcohol), THC (marijuana), cocaine, amphetamines, barbiturates, benzodiazepines, opiates, PCP, methaqualone. All positive immunoassay screens were verified using gas chromatography for ethanol and thin layer chromatography for all other substances. Conventional cutoffs at or above which the results are generally reported as positive in routine clinical laboratory work were utilized in this study. For each subject, a score was derived that indicated the percentage of urine tests that were positive for each drug during the month of assessment.

RESULTS

Subject LNNB-III raw scores were transformed to *T*-scores to correct for age and educational attainment. For each scale of the LNNB-III, subjects were divided into 2 groups; those scoring below the clinical cutoff ($T < 40$), and those scoring above the clinical cutoff ($T > = 40$). Subjects scoring below this clinical cutoff (*i.e.*, the "impaired" group) were compared to subjects scoring within the normal range, per clinical scale, on their extent of drug and alcohol use in order to determine the possible impact of substance use on neuropsychological functioning. Specifically, for each LNNB-III scale, independent

sample *t*-tests were conducted between impaired and nonimpaired groups on each of the measures of substance use (*i.e.*, # of months since first use of alcohol, marijuana, and hard drugs; lifetime number of days using alcohol, marijuana, hard drugs; # of days using alcohol, marijuana, and hard drugs during the 30 days of assessment; percentage of urine tests that were positive for alcohol, marijuana, and hard drugs during the 30 days of assessment). Results indicated that for all LNNB-III clinical scales, subjects who evinced neuropsychological impairment did not differ from those who did not in their recent and lifetime use of alcohol and illicit drugs (all $ps > .05$).

Another way to assess the relationship between neuropsychological functioning and substance use is to correlate subjects' total number of days using alcohol, marijuana, and hard drugs during the assessment phase (according to percentage of urine tests that were positive, and youth and parent reports), and over the lifetime (youth and parent reports only) with each of the clinical scales of the LNNB-III. Pearson Product Moment Correlations were performed between the aforementioned measures of substance use and LNNB-III subscales. Results indicated no significant relationship between any of the alcohol or drug use measures and neuropsychological functioning, as all correlations were non-significant (all $ps > .05$).

DISCUSSION

The present study was the first to examine the neuropsychological consequences of substance use using a variety of drug use measures in an adolescent population. Results indicated that regardless of substance (*i.e.*, alcohol, marijuana, and hard drug use), method used to determine substance use (*i.e.*, urine analysis, self-reports, collateral report), and extent of substance use (total # of days using substance in lifetime, total # of days using substance in past month), there was no relationship between substance use and neuropsychological functioning in this sample of adolescents. Given the relatively low chronicity and frequency of alcohol and hard drug use in this adolescent sample, the results suggest later neuropsychological impairments would be unlikely to develop if the use of these substances were discontinued. However, previous research (*e.g.*, Carlen *et al.*, 1994; Lishman, 1995)

suggests continued abuse of alcohol (*i.e.*, 10 years of chronic abuse) and some hard drugs (Grant *et al.*, 1978; Rosselli and Ardila, 1996) may lead to later neuropsychological impairments.

In regard to marijuana use, the findings are consistent with controlled adult studies which have generally failed to demonstrate a relationship between chronic cannabis use and neuropsychological functioning (*e.g.*, Bruhn and Maage, 1975; Carlin *et al.*, 1994). Millsaps *et al.* (1994) determined that their sample of adolescents had lower memory scores than expected given their level of intellectual functioning. However, the relationship of drug use and memory for these youths was not assessed. Relatedly, a subset of individuals in the current sample exhibited neuropsychological dysfunction, however, these impairments appear to be due to factors other than their use of substances. Indeed, similar neuropsychological results have been documented in delinquent adolescents (*e.g.*, Denno, 1990; Levine, Karniski, Palfrey, Meltzer and Fenton, 1985; Moffitt, 1988).

The results of this study indicate that drug and alcohol use were not associated with neuropsychological impairment in these youths. However, these youths may be at greater risk for future impairment due to the primary and secondary effects of these substances (*e.g.*, head injuries resulting from car accidents, physical fights, continued abuse) if interventions are not pursued. Additionally, continued substance abuse may negatively impact their social, educational, and vocational functioning. Future studies should address the relation between neuropsychological functioning and substance use in related adolescent samples, young adults, and other populations in order to further our understanding of the impact that alcohol and illicit drugs may have on cognitive functions. Such information may assist in developing optimal prevention and intervention initiatives which are desperately needed to address this growing societal problem.

References

Adams, R. D. & Victor, M. (1993) *Principles of neurology*, 5th edn. New York: McGraw-Hill.

Babor, T. F., Cooney, N. L. & Lauerman, R. J. (1987) The dependence syndrome concept as a psychological theory of relapse behavior: An empirical evaluation of alcoholic and opiate addicts. Special issue: Psychology and addiction. *British Journal of Addiction*, **82**, 393–405.

Bradley, J. D., Teichner, G., Crum, T. A. & Golden, C. J. (in press) Concurrent Validity and Analysis of Learning Curves on the Memory Scales of the Luria-Nebraska Neuropsychological Battery–Third edition. *International Journal of Neurosciences.*

Bruhn, P. & Maage, N. (1975) Intellectual and neuropsychological functions in young men with heavy and long-term patterns of drug abuse. *American Journal of Psychiatry*, **132**, 397–401.

Brust, J. C. (1993) *Neurological aspects of substance abuse*. Boston: Butterworth-Heinemann.

Carlin, A. S. & Trupin, E. W. (1977) The effect of long-term chronic marijuana use on neuropsychological functioning. *The International Journal of Addictions*, **12**, 617–624.

Carlin, A. S. (1986) Neuropsychological consequences of drug abuse. In: Grant, I. and Adams, K. M. (Eds.). *Neuropsychological assessment of neuropsychiatric disorders*. New York: Oxford University Press.

Carlen, P. L., McAndrews, M. P., Weiss, R. T., Dongier, M., Hill, J. M., Menzano, E., Farcnik, K., Abarbanel, J. & Eastwood, M. R. (1994) Alcohol-related dementia in the institutionalized elderly. *Alcoholism: Clinical and Experimental Research*, **18**(6), 1330–1334.

Courville, C. B. (1967) Intracranial tumors. Notes upon a series of three thousand verified cases with some current observations pertaining to their mortality. *Bulletin of the Los Angeles Neurological Society*, **32**, 1–80.

Crum, T., Bradley, J., Teichner, G. & Golden, C. J. (2000) Prediction of WAIS-R indices based on performance on the Luria-Nebraska Neuropsychological Battery – Third Edition, *International Journal of Neuroscience*, **101**, 157–163.

Davila, M. D., Shear, P. K., Lane, B., Sullivan, E. V. & Pfefferbaum, A. (1994) Mammillary Body and cerebellar shrinkage in chronic alcoholics: An MRI and neuropsychological study. *Neuropsychology*, **8**(3), 433–444.

Diagnostic and Statistical manual of mental disorders: Fourth edition – DSM-IV (1994) American Psychiatric Association: Washington, D.C.

Di Sclafani, V., Ezekiel, F., Meyerhoff, D. J., MacKay, S., Dillon, W. P., Weiner, M. W. & Fein, G. (1995) Brain atrophy and cognitive function in older abstinent alcoholic men. *Alcoholism: Clinical and Experimental Research*, **19**(5), 1121–1126.

Denno, D. W. (1990) *Biology and violence: From birth to adulthood*. New York, NY: Cambridge University Press.

Ehrman, R. N. & Robbins, S. J. (1994) Reliability and validity of 6-month reports of cocaine and heroin use in a methadone population. *Journal of Consulting and Clinical Psychology*, **62**, 843–850.

Fals-Stewart, Schafer, J., Lucente, S., Rustine, T. & Brown, L. (1994) Neurobehavioral consequences of prolonged alcohol and substance abuse: A review of findings and treatment implications. *Clinical Psychology Review*, **14**(8), 755–778.

Fields, S. & Fullerton, J. (1975) Influence of heroin addiction on neuropsychological functioning. *Journal of Consulting and Clinical Psychology*, **43**, 114.

Freshwater, S. & Teichner, G., The use of age and education corrected *T*-scores in the interpretation of the Luria Nebraska Neuropsychological Battery-III. *Poster Presentation at the 1st Annual Assessment Conference*, Orlando, FL, (April, 1998).

Grant, I., Adams, K., Carlin, A., Rennick, P. M., Judd, L. L. & Schooff, K. (1978) The collaborative neuropsychological study of polydrug users. *Archives of General Psychiatry*, **35**, 1063–1074.

Levine, M. D., Karniski, W. M., Palfrey, J. S., Meltzer, J. & Fenton, T. (1985) A study of risk factor complexes in early adolescent delinquency. *AJDC*, **139**, 50–56.

Lezak, M. D. (1995) *Neuropsychological Assessment* (3rd edn.). New York: Oxford University Press.

Lishman, W. A., Jacobson, R. R. & Acker, C. (1987) Brain shrinkage in chronic alcoholics: a pathological study. *Journal of Neurology, Neurosurgery, and Psychiatry*, **48**, 211–217.

Lishman, W. A. (1995) Psychiatry and neuropathology: the maturing of a relationship. *Journal of Neurology, Neurosurgery, and Psychiatry*, **58**, 284–292.

Millsaps, C. L., Azrin, R. L. & Mittenberg, W. (1994) Neuropsychological effects of chronic cannabis use on the memory and intelligence of adolescents. *Journal of Child and Adolescent Substance Abuse*, **3**, 47–55.

Mittenberg, W. & Motta, S. (1993) Effects of chronic cocaine abuse on memory and learning. *Archives of Clinical Neuropsychology*, **8**, 477–483.

Moffitt, T. E. (1988) Neuropsychology and self-reported early delinquency in an unselected birth cohort: A preliminary report from New Zealand. In: Moffitt, T. E. and Mednick, S. A. (Eds.). *Biological Contributions to Crime Causation*, pp. 93–117. Martinus Nijhoff Publishers: Boston.

O'Malley, S. S. & Gawin, F. H. (1990) Abstinence symptomotology and neuropsychological deficits in chronic cocaine abusers. In: Spencer, J. W. and Boren, J. J. (Eds.), *Residual effects of abused drugs on behavior*, National Institute on Drug Abuse Research Monograph, **101**, 179–190. Washington, D.C.: U.S. Government Printing Office.

Page, J. B., Fletcher, J. & True, W. R. (1988) Psychosocial perspectives on chronic cannabis use: the Costa Rican follow-up. *Journal of Psychoactive Drugs*, **20**, 57–65.

Pagliaro, A. M. & Pagliaro, L. A. (1996) *Substance use among children and adolescents: Its nature, extent, and effects from conception to adulthood.* New York: John Wiley & Sons, Inc.

Pfefferbaum, A., Sullivan, D. H., Mathalon, H., Shear, K., Rosenbloom, M. J. & Lim, K. O. (1995) Longitudinal changes in magnetic resonance imaging brain volumes in abstinent and relapsed alcoholics. *Alcoholism: Clinical and Experimental Research*, **19**(5), 1177–1191.

Rosselli, M. & Ardilla, A. (1996) Cognitive effects of cocaine and polydrug abuse. *Journal of Clinical and Experimental Neuropsychology*, **18**(1), 122–135.

Schroth, G., Naegele, T. & Klose, U. (1988) Reversible brain shrinkage in abstinent alcoholics, measured by MRI. *Neuroradiology*, **30**, 385–389.

Singh Mendhiratta, S., Wig, N. N. & Verma, S. K. (1978) Some psychological correlates of long-term heavy cannabis users. *British Journal of Psychiatry*, **132**, 482–486.

Sobell, M. B., Sobell, L. C., Klajner, F., Pavan, D. & Basian, E. (1986) The reliability of the timeline method of assessing normal drinker college students' recent drinking history: Utility for alcohol research. *Addictive Behaviors II*, pp. 149–162.

Solowij, N., Michie, P. T. & Fox, A. M. (1995) Differential impairments of selective attention due to frequency and duration of cannabis use. *Biological Psychiatry*, **37**, 731–739.

Spitzer, R. L., Williams, J. B., Gibbon, M. & First, M. B. (1992) The structured clinical interview for the DSM-III-R (SCID): I. History, rationale, and description. *Archives of General Psychiatry*, **49**, 624–629.

Teichner, G., Golden, C. J., Bradley, J. & Crum, T. (1999) Establishing the reliability and validity of the Luria-Nebraska Neuropsychological Battery-III. *International Journal of Neurosciences*, **98**, 141–152.

U.S. Department of Health and Human Services, Public Health Service (1994) *National Household Survey on Drug Abuse, Population Estimates, 1994.*

Victor, M. & Banker, B. Q. (1977) Alcohol dementia. In: Katzman, R., Terry, R. D. and Bick, K. L. (Eds.), *Alzheimer's disease. Senile dementia and related disorders. Aging*, Vol. 7. New York: Raven Press.

Zipursky, R. B., Lim, K. O. & Pfefferbaum, A. (1990) MRI study of brain changes with shortterm abstinence form alcohol. *Alcohol Clinical Experimental Research*, **13**, 664–670.