Personality and Risk-Taking: Common Biosocial Factors

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ABSTRACT The first part of this article describes a study of the relationships between personality and risk-taking in six areas: smoking, drinking, drugs, sex, driving, and gambling. The participants, 260 college students, were given self-report measures of risky behaviors in each of the six areas and the Zuckerman-Kuhlman five-factor personality questionnaire. Generalized risk-taking (across all six areas) was related to scales for impulsive sensation seeking, aggression, and sociability, but not to scales for neuroticism or activity. Gender differences on risk-taking were mediated by differences on impulsive sensation seeking. The second part discusses biological traits associated with both risk-taking and personality, particularly sensation seeking, such as the D4 dopamine receptor gene, the enzyme monoamine oxidase, and augmenting or reducing of the cortical evoked potential. Comparative studies show relationships between biological markers shared with other species and correlated behaviors similar to sensation seeking in humans. A biosocial model of the traits underlying risk-taking is presented.

Many of life's decisions involve a balance between anticipated reward and risk. The wild rodent venturing into an open field balances the possibility of finding food against the chance of being devoured by a predator on the ground or from the sky. The married man or woman who

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is charmed by an attractive stranger weighs the threat to his or her valued marital relationship and the possibilities of contracting a sexually transmitted disease against the possibility of a thrilling sexual encounter. The smoker weighs the postponed risk of lung and heart disease and social disapproval (from an increasing majority of nonsmokers) against the stimulation of nicotine. The drug abuser may consider the possibilities of addiction, overdose, arrest, and loss of social relationships and job against the next ecstatic "high." Of course when we say "weigh," "consider," or "think about," we are really talking about the early stages of risk-taking activities. Once the pattern of gratification becomes habitual there is rarely much deliberation between opportunity, approach, and consummation. The decision-making process may be reinstituted after a risk leads to punishment. For some, a negative outcome is enough to finish risk-taking in that area, whereas others never seem to learn from experience.

Some personality traits, such as sensation seeking and impulsivity, are of obvious relevance to the general risk-taking disposition, if there is such a trait. The most recent definition of sensation seeking is: ". . . a trait defined by the seeking of varied, novel, complex, and intense sensations and experiences, and the willingness to take physical, social, legal, and financial risks for the sake of such experience" (Zuckerman, 1994a). Impulsivity has been defined in many ways, but a definition incorporating its several elements is: the tendency to enter into situations, or rapidly respond to cues for potential reward, without much planning or deliberation and without consideration of potential punishment or loss of reward. Impulsivity also can be considered as a deficit in the capacity for inhibition of dangerous reward-seeking behavior. Sensation seeking and impulsivity have recently been combined in a supertrait called *impulsive sensation seeking* (Zuckerman, 1994b).

Sensation seeking and impulsivity represent the approach aspect of the reward/risk conflict. Rationally, one might expect trait anxiety/neuroticism or harm-avoidance to be traits determining the strength of the risk component of the conflict. These traits are associated with behavioral inhibition in novel situations, particularly those of a social nature (Kagan, Reznick, & Snidman, 1988). A problem with some measures of neuroticism is that they include impulsivity and hostility, traits that are associated with expression rather than inhibition of behavior. For instance, impulsivity and hostility are included as facets of the broader trait of neuroticism in the NEO (Costa & McCrae, 1992).

Sensation seeking has been associated with participation in a number of risky activities (Zuckerman, 1979a; 1994a) including: potentially risky experiments, sports, vocations, criminal activities, sexual behavior, smoking, heavy drinking, drug use and abuse, reckless driving and driving under the influence of alcohol, and gambling. Findings in most of these areas have been replicated many times, in different decades, and in different countries. High sensation seekers tend to appraise risk as lower than do low sensation seekers even for activities that they have never tried (Horvath & Zuckerman, 1993; Zuckerman, 1979b), and they anticipate experiencing less anxiety than low sensation seekers if they were in these situations. These expectations increase the likelihood of high sensation seekers engaging in such activities given the opportunity to do so. The approach gradient is higher and the avoidance gradient (anticipated anxiety) is lower in high sensation seekers than in low sensation seekers over the range of novel risk-taking activities (Zuckerman, 1979b).

Until recently, the main focus of our research has been on the single trait of sensation seeking. With the development of our broader five-factor personality questionnaire (ZKPQ; Zuckerman, Kuhlman, Joireman, Teta, & Kraft, 1993), which includes a scale for impulsive sensation seeking (ImpSS), however, we have begun to investigate the role of other personality factors in risk-taking behavior. For instance, a group of prostitutes working in a particularly risky environment showed elevated scores on ImpSS and aggression relative to matched controls and college students (O'Sullivan, Zuckerman, & Kraft, 1996). The prostitutes who were cocaine abusers had even higher ImpSS than those who were not cocaine users.

Eysenck (1976) found that both extraversion (E) and psychoticism (P) in his "big three" were related to risky behaviors such as "promiscuity." E is most highly related to sociability and P to ImpSS in the ZKPQ. Drinking and sexual activity often begin in parties of the type enjoyed by extraverted and impulsive sensation seekers more than introverted and controlled low sensation seekers. But there is a complicating factor in that extraversion, particularly in the earlier scale versions, included impulsivity and activity in addition to sociability. Our scales separate the factors because impulsivity is combined with sensation seeking in one factor, whereas the extraversion factor is just sociability. Activity constitutes a separate factor independent of the other four.

Recent studies using other test instruments have confirmed the relationships of sensation seeking and related traits to sexual risk-taking among HIV positive persons (Wulfert, Safren, Brown, & Wan, 1999), risky driving (Vavrik, 1997; Zimbardo, Keough, & Boyd, 1997), and risk for injuries (Cherpitel, 1999). Some of these studies found that impulsivity and aggression are also related to risky behavior. A few studies examined risk-taking in several forms of risky behaviors in the same subjects. Arnett (1996), using his own SSS, found that sensation seeking predicted reckless behaviors in driving, sex, illegal drug use, vandalism, and a composite index of these behaviors.

A study by Caspi et al. (1997) was distinctive in using a broad range of personality traits assessed at 18 years of age to predict four types of risky behaviors at 21 years of age, including alcohol dependence, violent offenses, risky sexual behavior, and dangerous driving habits. All three scales from the constraint factor (traditionalism, harm avoidance, control) of the Multidimensional Personality Questionnaire (MPQ; Tellegen, 1985) were negatively related to all four types of risky behavior. Aggression was positively related and social closeness was negatively related to all risky behaviors. Alienation was related to drinking and violent behavior, and stress reaction only to drinking. A composite risk-taking score that included all four types of risky behaviors was negatively related to traditionalism, harm-avoidance, control, and social closeness, and positively related to aggression and alienation.

The Caspi et al. study showed little prediction of risky behavior from the stress reaction scale, the one most clearly related to neuroticism-anxiety. Many have assumed that neuroticism plays a major role in risk-taking behavior on the assumption that alcohol and drugs are widely used for self-medication in anxious and depressed persons. Studies of persons in substance abuse programs typically show elevated scores on neuroticism and anxiety types of scales when these persons enter such programs. Much of their anxiety and depression, however, is a function of the stress that is a direct consequence of their substance abuse. Scores on neuroticism scales rapidly fall after 3 to 6 months in the programs in contrast to psychopathic deviate and hypomania scales that remain elevated (Zuckerman, Sola, Masterson, & Angelone, 1975). The resultant MMPI profile is the same as one found in a longitudinal study in men who later became alcoholics (Loper, Kammeier, & Hoffman, 1973). Other longitudinal studies suggest that neuroticism is not a prominent trait in male alcoholics during childhood and adolescence (Cloninger,

Sigvardsson, & Bohman, 1988; Jones, 1968, 1971). Concurrent studies of personality and drinking (Forsyth & Hundleby, 1987; Ratliff and Burkhart, 1984; Schwarz, Burkhart, & Green, 1978), marijuana use (Brill, Crumpton, & Grayson, 1971), and other drugs (Khavari, Humes, & Mabry, 1977) in young adults show a strong predictability of substance use from sensation seeking but practically no correlation with anxiety or neuroticism.

There may be subgroups of substance abusers who do use drugs to self-medicate their anxiety and depression. Forsyth and Hundleby (1987) found interactions between the situational factors in drinking and personality traits. High sensation seekers desired to drink in boring situations, whereas subjects high in neuroticism reported more desire to drink in stress and social situations. Cloninger (1987b) developed a classification of alcoholics into two types: Type 1 consists of both men and women with a late onset of alcoholism often related to reactions to some major stress or loss in their lives. Type 2 is primarily found in males who have an early onset and show more alcoholism in their families and more antisocial behavior associated with their alcoholism. Sensation seeking is associated with Type 2 and neuroticism may be prominent in Type 1.

A Study of Risk-Taking and Personality

The research described next is a study of six types of risk-taking intended to answer several questions. The first is the generality of risk-taking behaviors across the six kinds of risk-taking in young college students: drinking, smoking, drugs, sex, driving, and gambling. Previous studies of high school and college students have shown significant relationships between cigarette, alcohol, marijuana, and hard-drug use (Donovan & Jessor, 1985; Hayes, Stacy, & DiMatteo,1984; Hayes, Widamen, DiMatteo, & Stacy, 1987; McGee & Newcomb, 1992). Donovan and Jessor and McGee and Newcomb also found that these forms of substance abuse were related to delinquent and criminal behaviors such as theft, vandalism, and truancy, and Donovan and Jessor also found that sexual experience was part of this interrelated complex.

Horvath and Zuckerman (1993) examined the correlations between risk appraisal and risky behaviors across four areas of risk obtained from factor analysis of a general risk-taking scale: criminal, minor rule-violations (such as traffic offenses), financial (including gambling), and sports risks. All of the correlations across these areas were significant

although low to moderate in size. Caspi et al. (1997) found significant correlations among all four of the risky behaviors they studied.

The second question addresses the relationships between the five factors in the ZKPQ and the individual types of risk and a general risk factor, if such a factor is revealed in the intercorrelations among the six risky behavior measures. From all of the previous work, we would expect ImpSS to be strongly related to risk-taking in all of these areas. From the Caspi et al. (1997) study and others, we would also expect aggression and sociability to be related to risk-taking. Based on most of the previous literature, we would not expect neuroticism-anxiety to be strongly related to any of the risk behaviors, although the literature on this is not clear due to the use of neuroticism measures confounded with impulsivity and hostility in some of the previous work. There is no reason to predict any relationship between activity need and risk-taking.

A third question involves possible interactions between gender, personality, and risk-taking. Women score higher than men on neuroticism and sociability, and men score higher on impulsive sensation seeking and aggression-hostility. Men usually show more risk-taking in the six areas of risk in this study. The relationship between personality traits and risk-taking might be mediated by gender or the converse could be true.

METHODS

Personality

The Zuckerman-Kuhlman Personality Questionnaire (ZKPQ; Zuckerman et al., 1993) was used to assess five basic personality traits: Impulsive Sensation Seeking (ImpSS), Neuroticism-Anxiety (N-Anx), Aggression-Hostility (Agg-Hos), Activity, and Sociability (Soc). These scales were developed from factor analyses of older scales, item analyses of items derived from these scales, and factor analyses of the selected items to insure that they were correctly assigned to the factor scales and had a content validity that was significantly greater than their correlations with a social desirability scale. In our normative sample of nearly 3,000 college students we found high alpha internal reliabilities for all of the ZKPQ scales ranging from .74 to .82 for males and .76 to .84 for females (Zuckerman & Kuhlman, 1998). In the current study, we retested part of our sample (n = 124, retest inverval = 2 months) on the ZKPQ and found high retest reliabilities ranging from .82 to .87 for the five scales.

Life Experiences Questionnaire

The Life Experiences Questionnaire (LEQ) was developed to measure self-reported behavior in the six areas of risk.

Drinking. Two items assessed extent of drinking. Participants were asked how many drinks they had in a typical week during the past 12 months and what was the most drinks they had in any 1 day. Responses were made on 5-point scales ranging from *none* to *10 or more* for weekly drinks and *6 or more* on maximum for a day.

Smoking. Three items were used to measure extent of smoking on 5-point scales. The first was smoking history: *never smoked, used to smoke but quit, currently smoking but intend to quit, tried to quit and failed, currently smoking and intend to continue.* The second item was how much smoked on a typical day, and the third item was how often one inhaled, ranging from *never* to *most or nearly all of the time.*

Drugs. Three items were used to assess drug use on 5-point scales. The first asked about extent of marijuana or hashish use during the past year. The second rated use of other illegal drugs during the past year. The third asked how many different kinds of illegal drugs participants had tried at least once.

Sexual behavior. Four items assessed extent of risky sexual behavior. The first item asked with how many different persons participants had ever had sexual intercourse, ranging from *none* to *four or more*. The second item asked how many different persons the participant had had sexual intercourse with in the last 12 months. The third asked how many times they had had sex in a typical week when they had a sexual partner. The fourth asked how often they or their partners used some method of birth control. The fourth item also asked how often they or their partner used a condom during penetrative sexual intercourse.

Driving habits. This five-item scale was introduced by an item asking if the subject was a driver or not. The remaining five items asked about typical driving speeds, behavior in responses to the appearance of the yellow caution light in traffic light changes, typical distance maintained behind cars moving at fast speeds, and passing cautions.

Gambling. This scale was preceded by an item asking subjects if they ever gambled for money. The remaining 12 items in this scale asked about extent of frequency of gambling in 10 different forms of gambling (e.g., cards, horse races, slot machines) and the largest amounts of money won and lost on any given day.

Participants

The participants were obtained from introductory psychology classes and tested in large groups. They were told in advance about the types of information which would be asked for in the LEQ and given the opportunity to decline participation if they objected to these kinds of questions. They did not identify themselves by name but only by Social Security ID numbers and they were assured anonymity. Only a few participants refused to participate.

The first item in each scale asked if the participant had ever engaged in that particular activity and the remaining items asked about frequencies and forms of expression. Item means were used as scores for the risk scales. Participants who indicated that they never engaged in the activity received a minimum score of 1.0. Participants who had any experience were given their item means on all answered items (Each item had a range from 1 to 5 in the degree of response). The values for the six risk scales were averaged to give a composite measure of risk-taking. The alpha reliabilities for this measure (based on the six individual means) were .66 for males, .62 for females, and .65 for the combined genders. There were a total of 260 subjects, 101 males and 159 females.

RESULTS

Correlations Among Risk Scales

Table 1 shows the correlations among the six risk measures for male and female subjects. Drinking, smoking, drug use, and sexual experience scales were all significantly and substantially intercorrelated for both genders. Correlations among these four risk scales ranged from .31 to .51 for males and .23 to .44 for females.

Driving and gambling scales were less consistently correlated with the other four. Gambling correlated significantly with drinking and sexual experience for males, but did not correlate with any of the other risk scales in females. Risky driving habits correlated significantly only with drinking in both men and women.

Correlations Between Personality and Risk Scales

Table 1 also shows the correlations between the five ZKPQ personality scales and the six individual risk scales. N-Anxiety and Activity did not correlate significantly with any of the risk measures. ImpSS, Agg-Hos, and Sociability all correlated significantly with the composite risk measure

Table 1
Correlations Among Risk Scales and Between Personality and Risk Scales

	Drinking	Smoking	Drugs	Sex	Driving	Gambling
RISK SCALES#						
Drinking	1.00	.32***	.31***	.35***	.25*	.37***
Smoking	.44***	1.00	.51***	.31***	–.02	.13
Drugs	.35***	.43***	1.00	.40***	.04	.18
Sex	.33***	.29***	.23**	1.00	.08	.29**
Driving	.27***	.11	.09	.11	1.00	.16
Gambling	.07	–.02	–.02	–.02	.06	1.00
ZKPQ-MALES						
ImpSS	.25**	.26**	.26**	.20*	.10	.08
N-Anxiety	.04	–.07	–.03	–.01	–.18	–.09
Agg-Hos	.35***	.04	.04	.17	.25*	.15
Activity	.07	–.02	–.05	.04	.07	.15
Sociability	.47***	.10	.24*	.22*	.17	.37***
ZKPQ-FEMALES						
ImpSS	.43***	.29***	.30***	.18*	.13	.06
N-Anxiety	.01	.08	–.11	.11	–.04	.08

Table 1 (cont.)

Agg-Hos	.38***	.31***	.09	.23**	.12	.12
Activity	–.07	–.16	–.12	.06	–.05	–.05
Sociability	.45***	.22**	.11	.02	.09	.07

Note. ZKPQ = Zuckerman-Kuhlman Personality Questionnaire; ImpSS = Impulsive Sensation Seeking; N-Anxiety = Neuroticism-Anxiety; Agg-Hos = Aggression-Hostility.
Males (n = 101) above diagonal, females (n = 159) below diagonal.
*p < .05. **p < .01. ***p < .001.

(*r*s: ImpSS =.33, .44; Agg-Hos = .26, .39; Sociability = .42, .32, for men and women respectively) and some of its component scales.

Gender Differences

Males scored higher than females on drug use ($t = 3.39$, $p < .001$), risky driving ($t = 2.24$, $p < .05$), and gambling risk ($t = 8.37$, $p < .0001$) scales and on the composite risk measure ($t = 2.24$, $p < .05$). The difference on the gambling scale was very strong, accounting for 22% of the variance on this scale. Males scored significantly higher on the ImpSS scale ($t = 4.78$, $p < .0001$) and women scored significantly higher than men on the N-Anx ($t = 4.20$, $p < .0001$) and Sociability ($t = 2.42$, $p < .05$) ZKPQ scales.

Prediction of Composite Risk Score From Gender and Personality Variables

Table 2 shows the results of the multiple regression of gender and personality scales on the composite risk score. Even though there were significant gender effects on some of the risk scores, as noted above, gender was not significant when controlling for the effects of ImpSS through sequential regressions. If gender was entered first and ImpSS second, the *F* for gender was highly significant ($p < .005$). But if ImpSS was entered first and gender second, then gender was no longer significant ($p = .51$). None of the other four personality scales showed this effect on gender differences. In other words, the gender differences on risk-taking were mediated entirely by Imp-SS. None of the interactions between gender and the five personality scales were significant and they accounted for trivial parts of the variance.

ImpSS, Agg-Hos, and Sociability were all significantly and independently related to the composite risk measure, whereas N-Anx and Activity had no predictive value for the measure. ImpSS and Sociability each accounted for about 6% of the variance, and Agg-Hos acounted for another 5%. All variables taken together (R^2) accounted for 26% of the variance of the general risk-taking measure.

Table 3 shows the results of multiple regression in prediction of each of the separate risk measures from gender and the scores on the five ZKPQ scales. Gender was not independently predictive of any of the risk areas, the reasons for which were discussed in the preceding analysis

Table 2
Tests of Significance for Multiple Regression of ZKPQ Scales on Composite Risk Score Using Unique Sums of Squares

	Mean Square	*F* (d.f. = 1/248)	eta
Gender	0.0	0.0	0.0
Impulsive-SS	3.54	15.76*	5.98%
N-Anxiety	0.0	0.0	0.0
Aggression-Hos	2.89	12.85*	4.93%
Activity	0.56	2.51	1.00%
Sociability	3.62	16.10*	6.10%
Gender × Imp-SS	.06	.28	0.11%
Gender × N-Anxiety	0.0	0.0	0.0
Gender × Agg-Hos	.30	1.33	0.53%
Gender × Activity	0.01	.06	0.02%
Gender × Sociability	0.78	3.47	1.38%
Error	0.22		
(Model)	9.21	9.21* (d.f. = 11)	
(Total)	.30	d.f. = 259	
R-Squared = .29			
Adjusted *R*-Squared = .26			

* $p < .001$.

(mediation by ImpSS). Drinking was predicted by Sociability, Agg-Hos, and ImpSS; the strongest predictor was clearly Sociability. Smoking and drug risks were significantly predicted only by ImpSS. Sexual risk was predicted by both ImpSS and Agg-Hos. Reckless driving was predicted by Agg-Hos and a barely significant negative relationship with N-Anx. In other words, reckless drivers tended to be high on aggression and low on anxiety. Gambling was only predicted from sociability.

Participants were divided into high, medium, and low general risk-takers on the basis of the distribution on the composite risk-taking score, using thirds of the distribution to define the three groups. Figure 1 shows the mean *T* scores of the three female groups plotted as a profile in which the score of 50 is based on the normative college group of nearly 3,000 subjects from the same university. The middle risk-taking group is close

Table 3
Univariate and Multivariate Results for the Six Separate Risk Measures Predicted From Subject's Gender and the Five ZKPQ Scales

		Gender	Soc	N-Anx	Agg-Host	ImpSS	Activity
DRINKING	coeff	–.01	.14***	.01	.10***	.04*	–.03
	eta	.00%	13.39%	.12%	7.83%	2.05%	.75%
SMOKING	coeff	.19	.02	.00	.03	.06***	–.03
	eta	.16%	.32%	.01%	.99%	5.08%	1.02%
DRUGS	coeff	–.15	.03	–.01	.00	.06***	–.03
	eta	.16%	1.02%	.08%	.02%	5.54%	1.31%
SEX	coeff	–.14	.01	.01	.04*	.03*	.00
	eta	.14%	.12%	.19%	2.08%	1.87%	.02%
DRIVING	coeff	.04	.01	–.01*	.02**	.00	.00
	eta	.03%	.39%	1.63%	2.81%	.04%	.03%
GAMBLING	coeff	.06	.03***	.00	.00	.00	.00
	eta	.17%	5.27%	.06%	.58%	.20%	.05%
Mutivariate *F*		.38	7.92***	.97	4.69***	3.62**	.98

Notes. For each univariate effect, the row labelled "coeff" is the value of the regression coefficient for each of the six predictions. The eta row shows the value of the default effect size estimate (partial eta-squared) computed by SPSS-MANOVA.
* $p < .05$. ** $p < .01$. *** $p < .001$.

to the norm on all scales. The high risk-takers peak on ImpSS, Agg-Hos and Sociability and the lower risk takers are low on these scales. Figure 2 shows the profiles for high, medium, and low risk-takers among the males. The same differences on ImpSS, Agg-Hos, and Sociability can be seen, but in the males ImpSS is the most salient peak in the profile. Both high and middle male risk-takers are average on Agg-Hos and it is the low scores of the low risk-takers which account for the significant overall difference. In other words, it is not that high risk-takers are more aggressive, but that low risk-takers are more agreeable. A similar finding can be seen for sociability, where high risk-takers are only a little above average on this trait, but low risk-takers are very much more introverted or unsociable.

DISCUSSION

The first question to be answered concerns the generality of risk-taking across the six areas studied: drinking, smoking, drugs, sex, driving, and gambling. The first four of these do show a substantial degree of intercorrelation. The first three all involve substance use or abuse. Risky sexual behavior is part of this complex, which is not surprising in a college population where parties involving heavy drinking and/or drugs are the places where sexual encounters often originate. The disinhibiting effects of alcohol and drugs probably play a major role in risky sexual behavior, such as having unprotected sex with persons of short acquaintance. Risky driving and gambling were only peripherally related to the substance-sex core of the risk-taking factor. Risky driving was only associated with drinking, which also may be a function of the disinhibiting effects of alcohol. Gambling was not related to any of the other risk-taking areas among women, but among men it was related to drinking and risky sex.

Three of the ZKPQ personality scales were significantly related to general risk-taking: ImpSS, Agg-Hos, and Sociability. N-Anxiety and Activity showed little or no relationship to the composite risk-taking score or any of the specific areas of risk-taking. The involvement of sensation seeking and impulsivity in risky behaviors was predictable from all of the previous research. The results of Caspi et al. (1997) also showed the role of aggression and alienation (hostility) in predicting risky behavior at age 21 from personality scores at age 18. These two scales are part of the MPQ supertrait called "Negative Emotionality." Only the

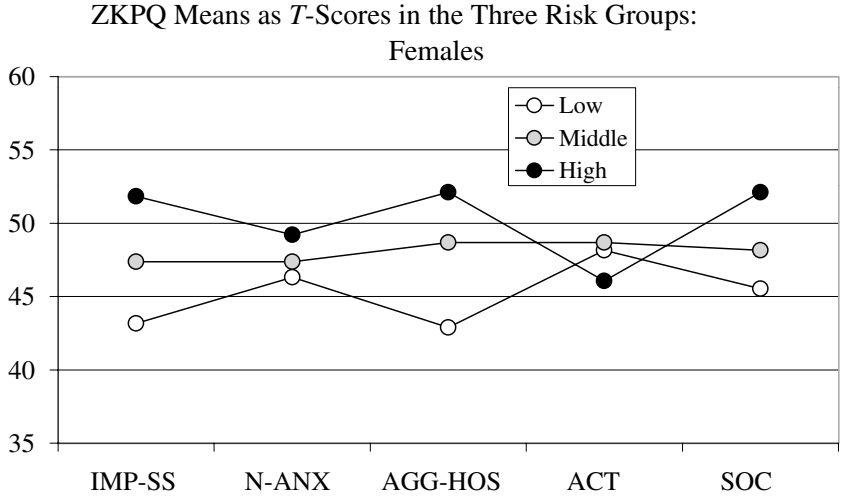

Figure 1
Female ZKPQ scale means (*T*-scores) for high, medium, and low risk-taking groups on the composite risk score.

Note: IMP-SS = Impulsive Sensation Seeking; N-ANX = Neuroticism-Anxiety; AGG-HOS =Aggression-Hostility; ACT = Activity; SOC = Sociability.

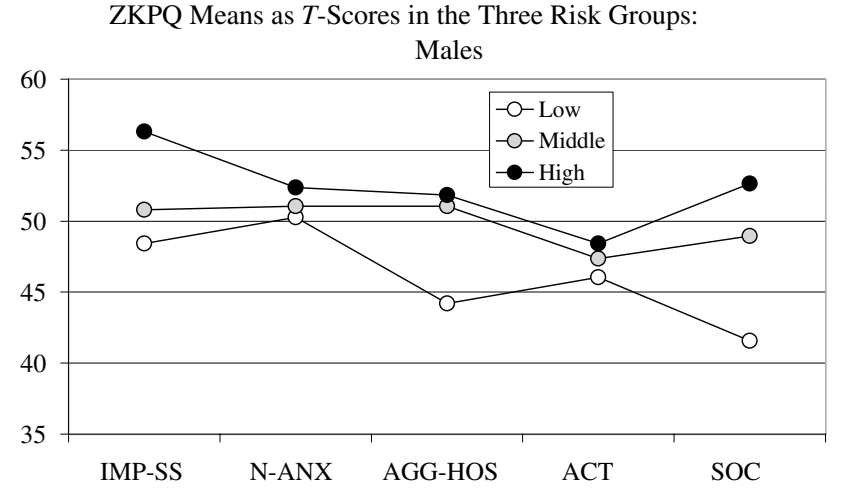

Figure 2
Male ZKPQ scale means (*T*-scores) for high, medium, and low risk-taking groups on the composite risk score.

Note: IMP-SS = Impulsive Sensation Seeking; N-ANX = Neuroticism-Anxiety; AGG-HOS =Aggression-Hostility; ACT = Activity; SOC = Sociability.

third factor in this triad, however, stress reaction, is clearly a measure of conventional neuroticism, which has anxiety at its core. This scale was only related to the alcohol risk-taking factor in their study and was not related to the composite risk-taking measure. Achievement, the closest equivalent to the ZKPQ activity factor, was not at all related to risk-taking in the study by Caspi et al.

With one exception, the results of our study resemble the results of Caspi et al.'s (1997) study. The exception was sociability. In their study social closeness, equivalent to our sociability, was *negatively* related to all four types of risk-taking and the composite score, but in our study sociability was positively related to the composite score and strongly related to drinking in particular. This difference in results may be due to the different populations in the two studies. Caspi et al. used a general population in New Zealand, whereas our sample consisted entirely of college students at our university. The age range at the time of initial testing is fairly close, at 18 in Caspi et al.'s study and 18 to 19 in our study. In a small college town like Newark, Delaware, however, much of the social life centers around drinking and, therefore, the more sociable students are likely to do more drinking. But in a larger population like that of New Zealand, it may be that the people who drink and take drugs are introverts who use substances and sex as ways to establish relationships.

Our results are clear-cut but based only on concurrent personality and self-reported risk-taking behavior. With the exception of the finding of the positive relationship between sociability and risk-taking they are compatible with previous predictive, studies like the one by Caspi et al. (1997). But whether concurrent or predictive, such studies tell us little about the basis for the relationships. To understand why personality predicts risky behavior, we must investigate the sources of the three relevant personality traits themselves. In the remainder of this article we will discuss the psychobiology of personality and risk-taking, looking for common influences at the genetic, neuropsychological, psychopharmacological, and psychophysiological levels.

Psychobiology of Risk-Taking

Genetics

Given the definition of sensation seeking as the seeking of novel situations and the willingness to take risks for the sake of such stimulation, our species of hominids is highly sensation seeking. About 100,000 years ago, they emerged from Africa and, in a relatively short time-span, by evolutionary standards, they spread over the entire world from Arctic tundras to tropical jungles. Before the advent of agriculture they existed in hunting-gathering groups and when they exhausted the resources in one area they moved on to another. Moving out of one's territory entails great risks so that in the conflict between explorative migration and dangers from unknown environments they elected to take the chances. The history of hunting is much longer than that of agriculture and hunting large animals is risky business, but people have always found a certain pleasure in taking these risks to the benefit of the community.

But within the species variation in this trait has persisted. Perhaps this is a function of the high level of assortative mating based on sensation seeking (Farley & Davis, 1977; Farley & Mueller, 1978; Lesnick-Oberstein & Cohen, 1984). Such assortative mating is unusual for personality traits where the correlations of traits between husbands and wives rarely exceeds zero (Eysenck, 1990).

Biometric studies of sensation seeking of twins raised together in their families yielded a heritability for the broad trait of .58 with the remaining variance due to specific (but not shared) environment and error of measurement (Fulker, Eysenck, & Zuckerman, 1980). A study done with twins who were separated at birth and raised in different environments (Hur & Bouchard, 1997) yielded nearly the same heritability (59%) and correlation between identical twins, whether raised together (r = .59) or apart (r = .54). There was no effect of shared family environment, a common finding with regard to most personality traits. To the extent that children resemble their parents in this trait, their similarity is primarily due to genetic reasons, not social modeling and reinforcement. Kraft and Zuckerman (1999) examined correlations between personality variables in young adult students and their ratings of the child rearing attitudes and practices of their parents. Whereas neuroticism had many correlations with the parenting they claim they received in intact and stepfather families, sociability showed some few significant correlations, and ImpSS and Agg-Hos showed no correlations at all in intact families and

few in the stepfamilies. The specific environment, as in the influence of peers and others outside of the home, is of some importance in shaping this trait. The social environment is somewhat influenced, however, by genetic factors (Plomin & Bergeman, 1991). This paradox is due to the fact that outside of the family we tend to create our own environments. We choose our peer groups and friends, and these in turn may reinforce the trait expressions that we share with them and that were the basis on which we chose them to begin with.

The heritability of sensation seeking is at the high end of what is found for most personality traits, which range from .3 to .6, with the mean around .4 (Bouchard, 1994). The results for extraversion are also around .4. Aggressiveness is not usually measured directly in the major adult personality tests like the "Big Five," but is considered to be at the opposite pole of agreeableness. One may be disagreeable, however, without being aggressive. Eley (1997) did a twin study of aggressive antisocial behavior in children and found that genetic factors accounted for about 65% of the variance in this type of behavior with nearly all of the remainder due to nonshared environment. Thus, at least two of the three personality factors that influence risk-taking have a high degree of genetic influence and little evidence of an influence of shared environment.

The science of behavior genetics has moved to the molecular level with the development of methods for identifying loci on the DNA and specific genes associated with forms of psychopathology and personality traits. The first discovery of an association between a gene and a personality trait was that found between the D4 dopamine receptor (D4DR) exon III and the trait of "novelty seeking" (Ebstein et al., 1996) Although there have been some failures to replicate this finding, four out of seven studies have done so (Ebstein & Belmaker, 1997). Novelty seeking, as measured by Tridimensional Personality Questionnaire (Cloninger, 1987a) is highly correlated (r = .68) with the Impulsive Sensation Seeking scale from the ZKPQ (Zuckerman & Cloninger, 1996). Three studies comparing heroin addicts with matched controls all found a significant excess of the form of the gene associated with the trait of novelty seeking in the heroin addicts. Only two of four studies found a greater incidence of this allele in alcoholics.

The form of the D4DR that was found to be associated with sensation seeking and heroin abuse has also been found to be more characteristic of men with bisexual experience than those who are exclusively heterosexual or homosexual (Hamer & Copeland, 1998). The gene is also

associated with pathological gambling (Castro, Ibanez, Torres, Sáiz-Ruiz, & Fernández-Piqueras, 1997).

Biochemistry

Because of the difficulty of accessing neurochemical reactions in the human brain and the ethical prohibition against procedures that would cause permanent changes in neurotransmitter status, research in human psychopharmacology is largely correlational and must rely on peripheral indices of neurochemical brain activity. Another source of knowledge comes from studies of psychopathology. Experimental studies of normals use short acting neurotransmitter agonists or antagonists. Only work with other species, most commonly rats, allows direct experimentation on central neurochemical functions by selective chemical or neural lesioning, electrical or chemical stimulation of selected brain areas, and measurement of response in these areas. The psychobiology of personality can only be understood by a synthesis of findings from the human correlational, experimental, and psychopathology research, and experimental and correlational studies of other species using animal models for human personality traits and psychopathology (Zuckerman, 1984, 1991).

Monoamine Oxidase

Monoamine oxidase (MAO) is an enzyme that is involved in the catabolic degradation of the monoamine neurotransmitters. By breaking down the neurotransmitter before it can be stored in the neuoron or in the synaptic space, MAO regulates the levels of neurotransmitter in a balance between production and disposal. MAO is found in two forms: A and B. The human brain contains a predominance of the B type, but most studies of humans rely on MAO-B derived from blood platelets. Direct correlations between platelet and brain MAO have not been found, although drugs that inhibit MAO-B in the brain also inhibit platelet MAO.

Despite the absence of direct correlation between brain and peripheral MAO, a vast amount of research links platelet MAO-B to personality, psychopathology, and risky behavior. Nine of 13 studies have found significant negative correlations between MAO-B and sensation seeking and many other studies have found similar relationships with extraversion (Zuckerman, 1994a). MAO-B is a very reliable biological trait changing only slowly as a function of age. Inversely mirroring the

relation of sensation seeking to age, MAO is lowest in adolescence and rises with age in brain and platelets. MAO is higher in women than in men at all ages, just as sensation seeking is higher in men than women.

Many studies conducted in different countries have linked low MAO-B levels with tobacco, drug, and alcohol use and criminal offenses (see Zuckerman, 1994a). Over a third of male students in the low end of the MAO distribution admitted convictions for offenses more serious than traffic violations, compared to only 6% of those in the high MAO group (Coursey, Buchsbaum, & Murphy, 1979).

Table 4 shows the areas of psychopathology associated with low MAO levels. All of these are disorders characterized by disinhibition, with the possible exception of schizophrenia. In this group, however, the more chronic patients characterized by behavioral retardation had higher MAO levels in contrast to those with paranoid schizophrenia, who had lower levels of MAO. Among alcoholics low MAO is more characteristic in Type 2 alcoholism, which is characterized by early onset, a large predominance of males, and an association of alcoholism with antisocial and

Table 4
Psychopathology and Monoamine Oxidase (MAO)

Low MAO-B is found in:	Study by:
High sensation seekers	Zuckerman (1994a 9/13 studies sig. *r*s
Attention Deficit-Hyperactivity Disorder	Shekim et al. (1986)
Antisocial Personality Disorder	Lidberg et al. (1985)
Chronic Criminality	Klinteberg (1996)
Borderline Personality Disorder	Reist et al. (1990)
Alcoholism	Major & Murphy (1978)
Relatives of alcoholics	Schukit (1994); Sher (1993)
Drug abuse	Von Knorring et al. (1987)
Pathological Gambling Disorder	Blanco et al. (1996)
Bipolar Mood Disorder	Murphy & Weiss (1972)
Relatives of bipolar disorders	Leckman et al. (1977)
Pathological Gambling Disorder	Blanco et al. (1996)
Paranoid Schizophrenic Disorder	Zureik & Meltzer (1988)

impulsive behavior patterns. It is interesting that low MAO levels are found in the relatives of alcoholics and those with bipolar disorders who do not manifest these disorders themselves. This suggests that low MAO levels are genetically linked to the disorder rather than a state-dependent reaction to the disorder or the drugs used to treat it. MAO levels in bipolars do not change with the clinical phase of the disorder. MAO-B is under complete genetic determination and a gene has been found underlying the enzyme.

Comparative correlational results from an MAO study of monkeys observed in a colony living in a natural island environment parallel many of the human personality and behavioral results (Redmond, Murphy, & Baulu, 1979). Low MAO monkeys of both sexes were more active and social and spent more time in play than high MAO monkeys. Low MAO male monkeys were also more aggressive, dominant, and sexually active.

Personality, psychopathology, and comparative behavioral studies are consistent in linking low MAO-B levels with sensation seeking, sociability, disinhibition, and impulsivity. Human risk-taking behavior in several areas is also related to low MAO levels. MAO is not active itself, however, but influences behavior through its enzymatic actions on the monoamine neurotransmitters. But which neurotransmitters are implicated and how might they affect risk-taking behavior?

Monoamines

Beginning with the work of Gray (1982), several theories (Cloninger, 1987a; Depue & Collins, 1999; Zuckerman, 1979a, 1984, 1991; Zuckerman, Ballenger, & Post, 1984) have suggested that the brain monoamines, dopamine, norepinephrine, and serotonin underlie behavioral mechanisms such as approach, inhibition, and arousal and personality traits like sensation or novelty seeking, impulsivity versus constraint, neuroticism or anxiety. There are significant differences in the details of these theories: in what are considered the basic dimensions of personality, and the relationships between specific monoamines and behavioral and personality dimensions.

I have developed a biochemical model that includes the traits implicated in risky behavior: sociability and impulsive unsocialized sensation seeking (Zuckerman, 1995). Actually this model is an evolvement of the elaborate model in "Psychobiology of Personality" (Zuckerman, 1991, p. 407), but focused on neurotransmitters, hormones, and enzymes and

omitting the intermediate levels of psychophysiology, emotions, and cognitive-behavioral traits.

Simplifying a vast comparative literature on the functions of the brain monoamine systems led to the definition of three basic behavioral mechanisms and their underlying biological bases: (1) an approach mechanism based on the mesolimbic dopamine system; (2) a behavioral inhibition mechanism mediated by the serotonergic system originating in the medial raphe nucleus and ascending to limbic and neocortical brain structures; and (3) an arousal system as a function of the dorsal tegmental noradrenergic system originating in the locus coeruleus and ascending to the structures of the limbic system and virtually the entire neocortex. The approach mechanism is also potentiated by gonadal hormones and indirectly inhibited through the catabolic action of MAO-B on dopamine. Research with selective MAO-inhibitors has suggested that MAO-B may be more closely tied to the regulation of dopamine whereas MAO-A may be more involved in the regulation of serotonin and norepinephrine (Murphy, Aulakh, Garrick, & Sunderland, 1987). The dorsal ascending norepinephrine system is inhibited by endorphins and gamma-aminobutyric acid (GABA) and potentiated by the enzyme dopamine-beta-hydroxylase (DBH). Sociability is suggested to be a pure function of the strength of the approach mechanism, anxiety a function of the arousal mechanism, and impulsive unsocialized sensation seeking a combination of a strong approach and weak inhibition and arousal systems. The model also indicates interactions between the basic behavioral mechanisms and the three neurotransmitters systems at both levels.

Correlational studies between metabolites of the monoamines found in cerebrospinal fluid (CSF), plasma, or urine and personality in nonpatients have been few and the results from these studies have not been impressive. Negative correlations were found between sensation seeking and norepinephrine in the CSF and DBH in plasma (Ballenger et al., 1983). Eysenck's psychoticism (P) scale, a marker for the ImpSS dimension of personality, correlated negatively with CSF 5-HIAA, the metabolite of serotonin, consistent with the idea that serotonin mediates capacity for inhibition and impulsive sensation seeking tendency is related to a deficit in this neurotransmitter (Schalling, Åsberg, & Edman, unpublished manuscript, 1984). Schalling (personal communication, September 24, 1990) later said that she was unable to replicate these findings. Better evidence of the deficit in inhibitory control as a function of weak serotonergic systems comes from studies of psychopathology in

which low levels of serotonin or its metabolite 5-HIAA have been found in the CSF of those with antisocial and impulsive personality disorders among adults (Virkkunen et al., 1994) and children (Kruesi et al., 1990) and those who commit violent and impulsive murders or suicide attempts (Lidberg et al., 1985). To better understand the psychobiology of personality and behavior, we must turn to the more direct animal experiments in the comparative literature.

Soubrié (1986), summarizing the comparative literature on serotonin, says that serotonin depletion in rats increases predatory and shock-induced aggression and makes all organisms more prone to react impulsively and ignore threats of punishment in the pursuit of rewards.

If serotonin is the brakes, dopamine is the accelerator in the drive to risky behavior, particularly in the area of drug use and abuse. Novelty seeking is the core of the definition of sensation seeking. This trait can be identified by behavioral criteria in rats such as exploration activity in open areas or choices of novel areas in a maze. Marked differences between inbred strains and within subspecies are found in exploratory or novelty seeking behaviors in mice suggesting genetic control of this trait (Henderson, 1967). A number of investigators have suggested that this behavioral trait may serve as an animal model for sensation seeking trait in humans (Bardo, Donohew, & Harrington, 1996; Dellu, Piazza, Mayo, LeMoal, & Simon, 1996; Zuckerman, 1984). Similar species and individual differences are found in susceptibility to the reinforcement of drugs such as alcohol, amphetamines, nicotine, and cocaine (Meliska, Bartke, McGlacken, & Jensen, 1995). The investigators cited above (Bardo et al. and Dellu et al.) attempted to answer two questions: (1) Is there a relationship between sensation seeking and susceptibility to drug reinforcement? (2) Do novel stimulation and drugs act through the same biological reward mechanism?

Dellu et al. (1996) showed that rats that were "high responders" to novelty were also more susceptible to reinforcement from drugs of abuse. They more rapidly acquired a drug self-administration habit than did the "low responders to novelty."

All drugs of abuse, including amphetamine, cocaine, nicotine, morphine, and alcohol, increase extracellular levels of dopamine in the nucleus accumbens (NA) and some other areas within the mesolimbic dopamine system (Bardo et al., 1996). Dopamine antagonists block novelty seeking behavior in rodents, and destruction of the mesolimbic dopamine system disrupts novelty-seeking behavior. Exposure to novelty

also causes brief increases in dopamine release from the NA suggesting that both novel situations and stimuli and drugs are rewarding, because they act through a common biological mechanism.

Dellu et al. (1996) found that their high novelty reactive rats had high levels of dopamine activity in the NA both under basal conditions and during either novel or stressful stimulation. The release of dopamine during stressful conditions may represent an adaptive response that leads to active avoidance rather than passive avoidance or immobilization in the face of stress.

This connection is seen in another animal model. Augmenting or reducing of the cortical evoked potential (EP) in response to increased levels of stimulus intensity has been one of the best replicated results related to sensation seeking in humans (Zuckerman, 1990, 1991, 1994a). Augmenting and reducing represent two poles of a continuum of cortical EP reactions. In some individuals, the amplitude of the EP increases markedly as a direct linear function of the intensity of visual, auditory, or somesthetic stimulation. Other individuals either show little change with increasing intensities of stimulation or show a marked decrease of EP at the highest intensities. Well-replicated results have shown that *augmenters* tend to be high sensation seekers (particularly of the disinhibitory type), whereas *reducers* tend to be low sensation seekers (Zuckerman, 1990). Augmenting is also related to impulsivity.

This paradigm was extended to cats and EP-augmenter cats were found to be more exploratory, active, aggressive, and likely to approach novel stimuli than reducers (Lukas & Siegel, 1977; Saxton, Siegel, & Lukas, 1987). Saxton et al. also tested their cats in two experimental paradigms and found that augmenters responded more vigorously for food reward on a fixed interval bar-pressing task, but were less effective in learning to modulate their response rate on a differential reinforcement for a low rate of response. Behaviorally, augmenting cats resemble impulsive sensation seekers.

Siegel, Sisson, and Driscoll (1993) extended the augmenting-reducing paradigm to rats in order to study the common genetic basis of the psychophysiological and behavioral phenomena. They used two strains of rats: the Roman High Avoidance (RHA) and the Roman Low Avoidance (RLA). These two strains were selectively inbred based on their ability to learn how to avoid punishment (shock avoidance). RHA rats are active in the situation and therefore learn the avoidance response

quickly, whereas the RLA rats tend to be passive and immobilized and therefore learn avoidance slowly or not at all.

Nearly all of the RHA rats were moderate to strong EP augmenters and nearly all of the RLA rats were reducers or weak augmenters. Thus, a marker for sensation seeking in humans was highly related to the strain differences in rats. All members of a strain are almost like identical twins or clones so that a strong difference between strains on one trait is likely to be associated with differences on other traits. Apart from the difference for which they were bred, the RLA (reducers) show less exploration and more emotionality (defecation) in the open-field, less shock-induced aggression, more aversion to alcohol, and little tolerance for barbiturates than the RHA (augmenters) rats. The female RLA rats are more maternal, that is, they spend more time in the nests with their pups, than the RHA females. The RHA rats are more exploratory, more aggressive, less nurturing, and more likely to learn to like alcohol and barbiturates.

With electrodes planted in the reward center in the lateral hypothalamus the RHA rats are less sensitive than the RLAs to low intensities of stimulation, but self-stimulate avidly to high intensities of stimulation. By contrast, the RLAs tend to avoid stimulation by high intensities.

The neurochemical stress effects are relevant to hypotheses about the role of neurotransmitters and hormones in impulsive sensation seeking. Under stress, the RLAs (reducers) show increases in serotonin and corticotropin-releasing-factor in the hypothalamus and increased adrenocorticotropic hormone (ACTH) from the pituitary. This pattern describes activation of the hypothothalamic-pituitary-adrenocortical stress pathway. In contrast the RHA rats show less of these stress hormone reactions but more increased dopamine release from the prefrontal cortex. Perhaps it is their dopamine reactivity that accounts for their capacity to exhibit active avoidance behavior rather than immobilization in the face of stress. It may also be what makes them more impulsive and less reactive to the risk of punishment in the pursuit of immediate reward.

SUMMARY

Our study of the relationship between personality and risk-taking has shown that there is some generalization across risk-taking in different areas, particularly in use of different kinds of risky substances (alcohol, nicotine, and various other drugs) and sexual risk-taking. Risky driving and gambling are more peripheral to a central risk-taking factor. Three

of the five personality traits measured by the ZKPQ are related to the general risk-taking factor: Impulsive Sensation Seeking, Aggression, and Sociability. Neuroticism-Anxiety and Activity are not related to risk-taking. Men engage in more overall risky behavior than women, but this difference is entirely mediated by the gender difference in the trait of ImpSS. ImpSS is the only trait that is independently predictive of smoking and drug use.

The personality traits associated with risk-taking have a moderate to strong heritability and the environmental influences are mostly not of the shared family environment type. One genetically determined characteristic is MAO. MAO is an enzyme that is low in high sensation seekers, various disinhibitory types of disorders, and persons who engage in many types of risky behaviors such as smoking, drinking, drug use, and criminal activity. The MAO findings indicate an involvement of the monoamine neurotransmitters, particularly dopamine, in risk-taking behavior and the personality traits related to it. The discovery of a dopamine receptor gene related to novelty (sensation) seeking indicates the likely involvement of this neurotransmitter. Whereas dopamine seems to mediate approach and impulsive tendencies in humans and other species, serotonin has primarily inhibitory effects on behavior. The balance between approach to reward and avoidance of punishment may depend on the interaction of these two neurotransmitters and enzymes like MAO.

The findings on humans, rats, and mice show that novelty seeking is a genetically influenced biological trait, related to susceptibity to drugs, and influenced by levels and reactivities of the mesolimbic dopaminergic system. Other animal models using markers found in humans as well as other species lead to similar conclusions.

Some personality psychologists balk when we cross the great species divide in search of animal models for personality. If we are to get beyond correlational studies using peripheral indicators of brain function in humans, however, we must turn to animals where we can experiment directly on the brain. Rats are not humans but we do share a great deal of DNA and basic emotions with them. Early hominids must have encountered similar survival problems when they emerged from their caves as rats still do when they emerge from their burrows. Foraging for food or mates was risky but necessary for survival. Those who enjoyed it had an advantage over those who only did it out of necessity. Modern forms of human sensation seeking such as drug abuse, reckless driving, mountain climbing and parachuting are not adaptive. They are merely a

testimony to the persistence of traits produced by the selective pressures of the distant evolutionary history of our species.

REFERENCES

Arnett, J. J. (1996). Sensation seeking, aggressivenesss, and adolescent reckless behavior. *Personality and Individual Differences,* **20,** 693–702.

Ballenger, J. C., Post, R. M., Jimerson, D. C., Lake, C. R., Murphy, D. L., Zuckerman, M., & Cronin, C. (1983). Biochemical correlates of personality traits in normals: An exploratory study. *Personality and Individual Differences,* **4,** 615–625.

Bardo, M. T., Donohew, R. L., & Harrington, N. G. (1996). Psychobiology of novelty seeking and drug seeking behavior. *Behavioural Brain Research,* **77,** 23–43.

Blanco, C., Orensanz-Munoz, L., Blanco-Jerez, C., & Sáiz-Ruiz (1996). Pathological gambling and platelet MAO activity: A psychobiological study. *American Journal of Psychiatry,* **153,** 119–121.

Bouchard, T. J., Jr. (1994). Genes, environment and personality. *Science,* **264,** 1700–1701.

Brill, N. Q., Crumpton, E., & Grayson, H. M. (1971). Personality factors in marijuana use. *Archives of General Psychiatry,* **24,** 163–165.

Caspi, A., Begg, D., Dickson, N., Harrington, H. L., Langley, J., Moffitt, T. E., & Silva, P. A. (1997). Personality differences predict health-risk behaviors in young adulthood: Evidence from a longitudinal study. *Journal of Personality and Social Psychology,* **73,** 1052–1063.

Castro, I. P., Ibanez, A., Torres, P., Sáiz-Ruiz, J., & Fernández-Piqueras, J. (1997). Genetic association study between pathological gambling and a functional DNA polymorphism at the D4 receptor gene. *Pharmacogenetics,* **7,** 345–348.

Cherpitel, C. J. (1999). Substance use, injury, and risk-taking dispositions in the general population. *Alcoholism: Clinical and Experimental Research,* **23,** 121–126.

Cloninger, C. R. (1987a). A systematic method for clinical description and classification of personality variants. *Archives of General Psychiatry,* **44,** 573–588.

Cloninger, C. R. (1987b). Neurogenic adaptive mechanisms in alcoholism. *Science,* **236,** 410–416.

Cloninger, C. R., Sigvardsson, S., & Bohman, M. (1988). Childhood personality predicts alcohol abuse in young adults. *Alcoholism: Clinical and Experimental Research,* **12,** 494–505.

Costa, P. T. Jr., & McCrae, R. R. (1992). *NEO-PI-R: Revised NEO Personality Inventory (NEO-PI-R)*. Odessa, FL: Psychological Assessment Resources.

Coursey, R. D., Buchsbaum, M. S., & Murphy, D. L. (1979). Platelet MAO activity and evoked potentials in the identification of subjects biologically at risk for psychiatric disorders. *British Journal of Psychiatry,* **134,** 372–381.

Dellu, F., Piazza, P.V., Mayo, W., LeMoal, M., & Simon, H. (1996). Novelty-seeking in rats—Biobehavioral characteristics and possible relationship with the sensation-seeking trait in man. *Neuropsychobiology,* **31,** 136–145.

Depue, R. A. & Collins, P. F. (1999). Neurobiology of the structure of personality: Dopamine, facilitation of incentive motivation, and extraversion. *Behavioral and Brain Sciences,* **22,** 491–569.

Donovan, J., & Jessor, R. (1985). Structure of problem behavior in adolescence and young adulthood. *Journal of Consulting and Clinical Psychology,* **53,** 890–904.

Ebstein, R. P., & Belmaker, R. H. (1997). Saga of an adventure gene: Novelty seeking, substance abuse and the dopamine D4 receptor (D4DR) exon III repeat polymorphism. *Molecular Psychiatry,* **2,** 381–384.

Ebstein, R. P., Novick, O., Umansky, R., Priel, B., Osher, Y., Blaine, D., Bennett, E. R., Nemanov, L., Katz, M, & Belmaker, R. H. (1996). Dopamine D4 receptor (D4DR) exon III polymorphism associated with the human personality trait novelty seeking. *Nature Genetics,* **12,** 78–80.

Eley, T. C. (1997). General genes: A new theme in developmental psychopathology. *Current Directions in Psychological Science,* **6,** 90–95.

Eysenck, H. J. (1976). *Sex and personality*. Austin: University of Texas Press.

Eysenck, H. J. (1990). Genetic and environmental contributions to individual differences: three major dimensions of personality. *Journal of Personality,* **58,** 245–261.

Farley, F. H., & Davis, S. A. (1977). Arousal, personality, and assortative mating in marriage. *Journal of Sex and Marital Therapy,* **3,** 122–127.

Farley, F. H., & Mueller, C. B. (1978). Arousal, personality and assortative mating in marriage: Generalizability and cross-cultural factors. *Journal of Sex and Marital Therapy,* **4,** 50–53.

Forsyth, G., & Hundelby, J. D. (1987). Personality and situation as determinants of desire to drink in young adults. *International Journal of the Addictions,* **22,** 653–669.

Fulker, D. W., Eysenck, S. B. G., & Zuckerman, M. (1980). The genetics of sensation seeking. *Journal of Personality Research,* **14,** 261–281.

Gray, J. A. (1982). *The neuropsychology of anxiety: An enquiry into the functions of the septo-hippocampal system*. New York: Oxford University Press.

Hamer, D., & Copeland, P. (1998). *Living with our genes.* New York: Doubleday.

Hayes, R., Stacy, A. W., & DiMatteo, M. R. (1984). Covariation among health-related behaviors. *Addictive Behaviors,* **9,** 315–318.

Hayes, R. D., Widaman, K. F., DiMatteo, M. R., & Stacy, A. W. (1987). Structural equation models of current drug use: Are appropriate models so simple(x)? *Journal of Personality and Social Psychology,* **52,** 134–144.

Henderson, N. D. (1967). Prior treatment effects on open field behavior of mice: A genetic analysis. *Animal Behaviour,* **15,** 365–376.

Horvath, P., & Zuckerman, M. (1993). Sensation seeking, risk appraisal and risky behavior. *Personality and Individual Differences,* **14,** 41–52.

Hur, Y-M, & Bouchard, T. J., Jr. (1997). The genetic correlation between impulsivity and sensation seeking traits. *Behavior Genetics,* **27,** 455–463.

Jones, M. C. (1968). Personality correlates and antecedents of drinking patterns in adult males. *Journal of Consulting and Clinical Psychology,* **32,** 2–12.

Jones, M. C. (1971). Personality antecedents and correlates of drinking patterns in women. *Journal of Consulting and Clinical Psychology,* **36,** 61–69.

Kagan, J., Reznick, J. S., & Snidman, N. (1988). Biological bases of childhood shyness. *Science,* **240,** 167–171.

Khavari, K. A., Humes, M., & Mabry, E. (1977). Personality correlates of hallucinogenic drug use. *Journal of Abnormal Psychology,* **86,** 172–178.

Klinteberg, B. (1996). Biology, norms, and personality: A developmental perspective. *Neuropsychobiology,* **34,** 146–154.

Kraft, M. R. Jr., & Zuckerman, M. (1999). Parental behavior and attitudes of their parents reported by young adults from intact and stepparent families and relationships between perceived parenting and personality. *Personality and Individual Differences,* **27,** 453–476.

Kruesi, M. J. P., Rapaport, J. L., Hamburger, S., Hibbs, E., Potter, W. Z., Lename, M., & Brown, G. L. (1990). Cerebrospinal fluid monoamine metabolites, aggression, and impulsivity in behavior disorders of children and adolescents. *Archives of General Psychiatry,* **47,** 419–426.

Leckman, J. F., Gershon, E. S., Nichols, A. S., & Murphy, D. L. (1977). Reduced MAO activity in first degree relatives of individuals with bipolar affective disorders. *Archives of General Psychiatry,* **34,** 601–606.

Lesnick-Oberstein, M., & Cohen, L. (1984). Cognitive style, sensation seeking, and assortative mating. *Journal of Personality and Social Psychology,* **46,** 112–117.

Lidberg, L., Modlin, I., Oreland, L., Tuck, J. R., & Gillner, A. (1985). Platelet monoamine oxidase activity and psychopathy. *Psychiatry Research,* **16,** 339–343.

Loper, R. G., Kammeier, M. L., & Hoffman, H. (1973). MMPI characteristics of college males who later became alcoholics. *Journal of Abnormal Psychology,* **82,** 159–162.

Lukas, J. H., & Siegel, J. (1977). Cortical mechanisms that augment or reduce evoked potentials in cats. *Science,* **196,** 73–75.

Major, L. F., & Murphy, D. L. (1978). Platelet and plasma amine oxidase activity in alcoholic individuals. *British Journal of Psychiatry,* **132,** 548–554.

McGee, L., & Newcomb, M. D. (1992). General deviance syndrome: Expanded hierarchal evaluations at four ages from early adolescence to adulthood. *Journal of Consulting and Clinical Psychology,* **60,** 766–776.

Meliska, C. J., Bartke, A., McGlacken, G., & Jensen, R. A. (1995). Ethanol, nicotine, amphetamine and aspartame consumption and preferences in C57BL/6 and DBA/2 mice. *Pharmacology, Biochemistry, and Behavior,* **50,** 619–626.

Murphy, D. L., Aulakh, C. S., Garrick, N. A., & Sunderland, T. (1987). Monoamine oxidase inhibitors as antidepressants: Implications for the mechanism of action of antidepressants and the psychology of the affective disorders and some related disorders. In H. Y. Meltzer (Ed.), *Psychopharmacology: The third generation of progress* (pp. 545–552). New York: Raven Press.

Murphy, D. L., & Weiss, R. (1972). Reduced monoamine oxidase activity in blood platelets from bipolar depressed patients. *American Journal of Psychiatry,* **128,** 1351–1357.

O'Sullivan, D. M., Zuckerman, M., & Kraft, M. (1996). The personality of prostitutes. *Personality and Individual Difference,* **21,** 445–448.

Plomin, R., & Bergeman, C. S. (1991). The nature of nurture: Genetic influence on "environmental" measures. *Behavioral and Brain Sciences,* **14,** 373–427.

Ratliff, K. G., & Burkhart, B. R. (1984). Sex differences in motivations for and effects of drinking among college students. *Journal of Studies in Alcohol,* **45,** 26–32.

Redmond, D. E. Jr., Murphy, D. L., & Baulu, J. (1979). Platelet monoamine oxidase activity correlates with social affiliative and agonistic behaviors in normal rhesus monkeys. *Psychosomatic Medicine,* **41,** 87–100.

Reist, C., Haier, R. J., DeMet, E., & Cici-DeMet, A. (1990). Platelet MAO activity in personality disorders and normal controls. *Psychiatry Research,* **30,** 221–227.

Saxton, P. M., Siegel, J., & Lukas, J. H. (1987). Visual evoked potential augmenting-reducing slopes in cats—2. Correlations with behavior. *Personality and Individual Differences,* **8,** 511–519.

Schalling, D., Åsberg, M., & Edman, G. (1984). Personality and CSF monoamine metabolites. Unpublished manuscript.

Schukit, M. A. (1994). Familial alcoholism. In T. A. Widiger, A. J. Francis, H. A. Pincus, M. B. First, R. Ross, & W. Davis (Eds), *DSM IV-Sourcebook* (Vol. 1, pp. 159–167). Washington, DC: American Psychiatric Association.

Schwarz, R. M., Burkhart, B. R., & Green, S. B. (1978). Turning on or turning off: Sensation seeking on tension reduction as motivational determinants of alcohol use. *Journal of Consulting and Clinical Psychology,* **46,** 1144–1145.

Shekim, W. O., Bylund, D. B., Alexson, J., Glaser, R. D., Jones, S. B., Hodges, K., & Perdue, S. (1986). Platelet MAO and measures of attention and impulsivity in boys with attention disorder deficit and hyperactivity. *Psychiatry Research,* **18,** 179–188.

Sher, K. J. (1993). Children of alcoholics and the intergenerational transmission of alcoholism: A biosocial perspective. In J. S. Baer, A. Marlatt, & R. J. McMahon (Eds.), *Addictive behaviors across the life-span* (pp. 3–33). Newbury Park, NJ: Sage Publications.

Siegel, J., Sisson, D. F., & Driscoll, P. (1993). Augmenting and reducing of visual evoked potentials in Roman high- and low-avoidance rats. *Physiology and Behavior,* **54,** 707–711.

Soubrié, P. (1986). Reconciling the role of central serotonin neurons in human and animal behavior. *Behavioral and Brain Sciences,* **9,** 319–364.

Tellegen, A. (1985). Structures of mood and personality and their relevance to assessing anxiety, with an emphasis on self-report. In A. H. Tuma & J. D. Maser (Eds.), *Anxiety and the anxiety disorders* (pp. 681–706). Hillsdale, NJ: Erlbaum.

Vavrik, J. (1997). Personality and risk-taking: A brief report on adolescent male drivers. *Journal of Adolescence,* **20,** 461–465.

Virkkunen, M., Rawlings, R., Tokala, R., Poland, R. E., Gudidotti, A., Nemeroff, C., & Bissette, G. (1994). CSF biochemistries, glucose metabolism, and diurnal activity in alcoholic, violent offenders, fire setters, and health volunteers. *Archives of General Psychiatry,* **51,** 20–27.

Von Knorring, L., Oreland, L., & von Knorring, A. L. (1987). Personality traits and platelet MAO activity in alcohol and drug abusing teenage boys. *Acta Psychiatrica Scandinavica,* **75,** 307–314.

Wulfert, E., Safren, S. A., Brown, I., & Wan, C. K. (1999). Cognitive, behavioral and personality correlates of HIV-positive persons: Unsafe sexual behavior. *Journal of Applied Social Psychology,* **29,** 223–244.

Zimbardo, P. G., Keough, K. A., & Boyd, J. N. (1997). Present time perspective as a predictor of risky driving. *Personality and Individual Differences,* **23,** 1007–1023.

Zuckerman, M. (1979a). *Sensation seeking: Beyond the optimal level of arousal*. Hillsdale, NJ: Erlbaum.

Zuckerman, M. (1979b). Sensation seeking and risk-taking. In C. E. Izard (Ed.), *Emotions in personality and psychopathology* (pp. 163–197). New York: Plenum.

Zuckerman, M. (1984). Sensation seeking: A comparative approach to a human trait. *Behavioral and Brain Sciences,* **7,** 413–471.

Zuckerman, M. (1990). The psychophysiology of sensation seeking. *Journal of Personality,* **58,** 313–345.

Zuckerman, M. (1991). *Psychobiology of personality.* Cambridge, UK: Cambridge University Press.

Zuckerman, M. (1994a). *Behavioral expressions and biosocial bases of sensation seeking.* New York: Cambridge University Press.

Zuckerman, M. (1994b). Impulsive unsocialized sensation seeking: The biological foundations of a basic dimension of personality. In J. E. Bates & T. D. Wachs (Eds.), *Temperament: Individual differences at the interface of biology and behavior*. Washington, DC: American Psychological Association.

Zuckerman, M. (1995). Good and bad humors: Biochemical bases of personality and its disorders. *Psychological Science,* **6,** 325–332.

Zuckerman, M., Ballenger, J. C., & Post, R. M. (1984). The neurobiology of some dimensions of personality. In J. R. Smythies & R. J. Bradley (Eds.), *International review of neurobiology* (Vol. 25, pp. 392–436). New York: Academic Press.

Zuckerman, M., & Cloninger, C. R. (1996). Relationships between Cloninger's, Zuckerman's, and Eysenck's dimensions of personality. *Personality and Individual Differences,* **21,** 283–285.

Zuckerman, M., & Kuhlman, D. M. (1998). *Norms for the Zuckerman-Kuhlman Personality Questionnaire*. Unpublished manual.

Zuckerman, M., Kuhlman, D. M., Joireman, J., Teta, P., & Kraft, M. (1993). A comparison of three structural models for personality: The big three, the big five and the alternative five. *Journal of Personality and Social Psychology,* **65,** 757–768.

Zuckerman, M., Sola, S., Masterson, J., & Angelone, J. V. (1975). MMPI patterns in drug abusers before and after treatment in therapeutic communities. *Journal of Consulting and Clinical Psychology,* **43,** 286–296.

Zureik, J. L. & Meltzer, H. J. (1988). Platelet MAO activity in hallucinating and paranoid schizophrenics: A review and meta-analysis. *Biological Psychiatry,* **24,** 63–78.