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SENSATION SEEKING

> Only such "true believers" as expect from science a substitute for the religion they have relinquished will take it amiss if the investigator develops his views further or even transforms them.
>
> —Sigmund Freud, *Beyond the Pleasure Principle*

The theory of sensation seeking has evolved and changed over time. As Freud said, it is in the nature of scientific theory to change as new findings bring old ideas into question and suggest new interpretations of old data. This is particularly true for personality constructs. Even taxonomic theories like the Big Five (Costa & McCrae, 1992a; Goldberg, 1990) begin with a theoretical assumption, that is, that all the basic dimensions of human personality are expressed in the language, or the lexicon, and factor analyses of the relationships between these words as used to describe self or others will reveal the basic structure. Different assumptions are used by temperament theories built on observations of infant's and children's behaviors. I belong to a group of theorists who believe that basic personality traits have their roots in genes and biological mechanisms and their persisting interactions with the environment. There is an evolutionary history to basic behavioral traits, and therefore comparative studies using animal models should complement studies of humans. The question of what can be predicted from animals to humans, a "bottom-up" approach, is reversed in a "top-down" approach. What can we predict in animal behavior using biological markers shared by both species to identify the correlates?

Top-down theories of adult personality are usually operationalized in a questionnaire measure and then modified in view of the findings used to define the construct. This "bootstrap" approach may result in changes in the theory underlying the test or the test itself.

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Sensation Seeking and Risky Behavior, by M. Zuckerman

CONSTRUCT VALIDITY

Construct validity represents a two-way process between research and theory (Cronbach & Meehl, 1955). This is the path taken in the development of the Sensation Seeking Scales (SSS) from a theory of sensation seeking (Zuckerman, 1994). In this chapter, I describe the evolution of the theory and alternative tests developed either as shorter versions of the SSS or as versions based on other theories of the construct. The results relating sensation seeking to risky behaviors are dealt with in the subsequent chapters. Only the results related to the definition of the basic construct and its biological bases are treated in this chapter. Broader accounts can be found in previous volumes on the topic (Zuckerman, 1979a, 1994) and a more personal, autobiographical version (Zuckerman, 2004).

ORIGINS IN SENSORY DEPRIVATION RESEARCH

The idea for sensation seeking literally began in the dark. That is to say it began in the dark and silence of a sensory deprivation (SD) isolation chamber. In the decade between 1958 and 1968, my colleagues and I studied the experimental and subject variables affecting reactions to SD (Zuckerman, 1969b). There are wide individual reactions to this experimental situation in which subjects volunteer to spend anywhere from 1 hour to 2 weeks in environments in which visual and auditory sensory input is either reduced to a minimum or made invariant (as in a ganzfeld). Reactions included anxiety, boredom, hallucinations, and cognitive inefficiency. Most standard personality tests did not do a good job at predicting responses to this situation, characterized as a "walk-in inkblot" (Goldberger, 1961). Actually, one of the few successful predictors was a measure of "tolerance for primary process thinking" derived from the Rorschach inkblot test.

Optimal-Level Theories

We decided to use the optimal level of stimulation (OLS) and optimal level of arousal (OLA) theories as the basis for a questionnaire measure of individual differences in these constructs (Zuckerman, Kolin, Price, & Zoob, 1964). The OLS theory can be traced back to Wilhelm Wundt (1893), the founder of experimental psychology. Wundt noted that along a continuum of intensity of stimulation and sensation, there was an optimal point at which the stimulus was regarded as most pleasurable, but below or beyond this point, it was judged as less pleasurable or even aversive. Wundt's investigations were primarily concerned with the bitter and sweet dimensions

of taste, not surprising because his research was subsidized by beer manufacturers.

One of the first OLA theories was formulated by Freud (Breuer & Freud, 1895/1955). He called it the "constancy principle," suggesting that there is an optimal level of "intracerebral tonic excitement" for different individuals: "On this level of tonic excitement the brain is accessible to all external stimuli" (Breuer & Freud, 1895/1955, p. 143). Some people (e.g., torpid types) felt best at low levels of excitement, whereas others (e.g., the vivacious types) needed higher levels. This early biological theory was later replaced by a drive reduction theory suggesting that all persons seek a state of low excitement, even though this desire is periodically upset by the drives of the life instinct toward appetitive pleasures, primarily sexual ones. The death instinct opposed the life drive, leading to a search for the ultimate reduction of all sensation (Freud, 1920/1955).

In the 1950s, a neurological basis for the OLA was furnished by the discovery of the role of the reticular activating system (RAS) in the regulation of cortical arousal. External or internal stimulation was thought to activate this system. The ascending RAS running from the brain stem to the cortex produces a nonspecific arousal of the cortex. A descending system from the cortex to the RAS dampens arousal if the cortex is overloaded. The entire system functions as a homeostat to keep cortical arousal at some optimal level given task demands and point in the diurnal cycle. Hebb (1955) presented an OLA inverted-U-shaped curve to describe the relationship between the arousal function and cue function (see Figure 1.1). The latter refers to the organism's ability to use cues for discrimination, learning, and performance. Emotions are also affected, with unpleasant emotions like boredom at the low end below the OLA and anxiety at the high end beyond the OLA. Positive emotions are localized at or close to the OLA. Hebb did not discuss the possibility of individual differences in the OLA.

Sensory deprivation is an extreme situation far below the OLA of nearly all persons in a waking state but is further below the OLA for some individuals than for others. I hypothesized that high sensation seekers were persons with a high OLA and therefore should be more stressed by SD than low sensation seekers (Zuckerman, 1969a). Sensation seekers were thought to seek more novel and intense forms of sensation to reach a higher OLA, at which they felt and functioned better. Low sensation seekers were closer to their OLA in situations with less change in stimulation and therefore should be less stressed in SD. Although I tied sensation seeking to individual differences in the OLS and OLA (Zuckerman, 1969a, Postulate III, pp. 429–430), there was another possibility. Although high and low sensation seekers might not differ in their OLAs, they might differ in their normal levels of arousal in the nonstimulated state. High sensation seekers might be more chronically underaroused and therefore need more stimulation to

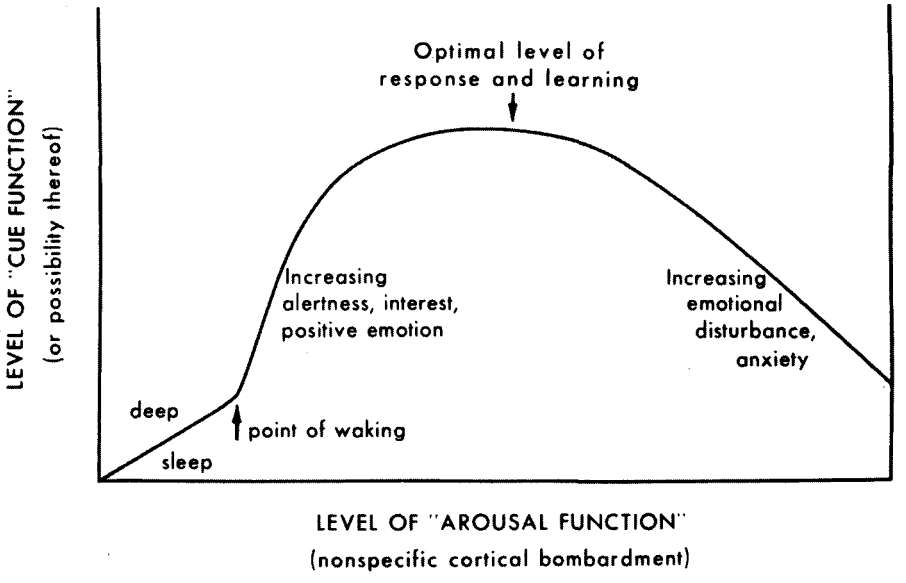


Figure 1.1. The relationship between arousal and cue function (response and learning). From "Drives and the CNS (Conceptual Nervous System)," by D. O. Hebb, 1955, *Psychological Review, 62*, p. 250. Copyright 1955 by the American Psychological Association.

reach their OLA. This is the hypothesis that H. J. Eysenck (1967) used to explain the biological basis for the difference between extraverts and introverts. H. J. Eysenck's hypothesis depended on stimulus intensity, not novelty, and looked primarily to EEG research to determine levels of arousal in introverts and extraverts with and without stimulation (Zuckerman, 1991).

In the early 1960s, we began writing items for a general SSS based on the OLS–OLA theory (Zuckerman et al., 1964). But translating theory into questionnaire items referring to behavioral preferences, intentions, and values is not an obvious task.

We approached it by thinking of prototypes among friends and figures in public life and how they thought and behaved. They drank heavily and were attracted to adventurous and risky activities (like Ernest Hemingway); used drugs that provided unusual sensations and experiences (like Timothy Leary); sought variety in sexual partners and activities (like Norman Mailer); liked to travel and experience new and exotic places and cultures; and were easily bored by conventional people, preferring the company of unconventional and nonconforming groups like artists, "hippies," and "gays." Some of our items were put in the form of intentions, for instance, "I would like to . . ." rather than actual experiences because many of the exotic sports, like mountain climbing and scuba diving, and psychedelic drug use were uncommon at that time. We reasoned that those who were already doing

those things would respond positively, as would those who would like to or intended to do them at some time in the future. The items were put into a forced-choice rather than a true–false form because of the big furor over the role of social desirability as a determinant of item response in true–false forms. We tried to word the two choices for an item in forms that were equally socially desirable or undesirable. Although some critics feared that the forced-choice form would make the items unpalatable to test takers, some studies of test reactions showed that, with the exception of a few people with obsessive–compulsive disorder, most subjects were not put off by the need to make a choice between two statements, neither of which precisely expressed their preferences. The test instructions anticipated this problem by telling them to pick the closest choice even if not precisely the expression of their behavior or preferences.

Investigators who stop test development at this point, depending on *face validity* (which should be called *faith* validity) of the content and not concerning themselves with reliability and construct validity, may have a test suitable for popular magazines or newspapers, but not for scientific studies. Our first question was whether there was a general factor running through the diverse kinds of item content (Zuckerman et al., 1964). Item–total correlations and a subsequent factor analysis revealed that there was a general factor that included most of the items we had written. There were some indications of additional factors after rotation, but we did not have enough items to define these with any precision, so we constructed the first SSS Form II (SSS–II) on the basis of an unrotated general factor common to both men and women (Zuckerman et al., 1964).

The SSS–II was developed primarily with a narrow construct validity in mind, namely, prediction of responses to SD. But the theory seemed to suggest a wider applicability to behavior in many other situations. Almost immediately, we noticed something that posed a challenge to the theory, which suggested that the deprivation of stimulation in SD would be particularly threatening and stressful for high sensation seekers. The subjects for SD experiments were chosen by putting ads in the college newspapers in the Philadelphia vicinity offering money for participation in the experiment. The experimental conditions were fully described to them. We thought that offering money would attract a random sample of the college population. On the basis of appearance alone, we had the impression that we were attracting primarily high sensation seekers. Long hair on men (still unfashionable in the early 1960s), motorcycle helmets, and unusual styles of dress suggested a selective factor. When we scored the SSS–II later, we confirmed our hunch. The experiment was attracting more high than low sensation seekers, based on general college norms.

Why would high sensation seekers, presumably with a high OLS, be more attracted to a situation in which they would be isolated and deprived

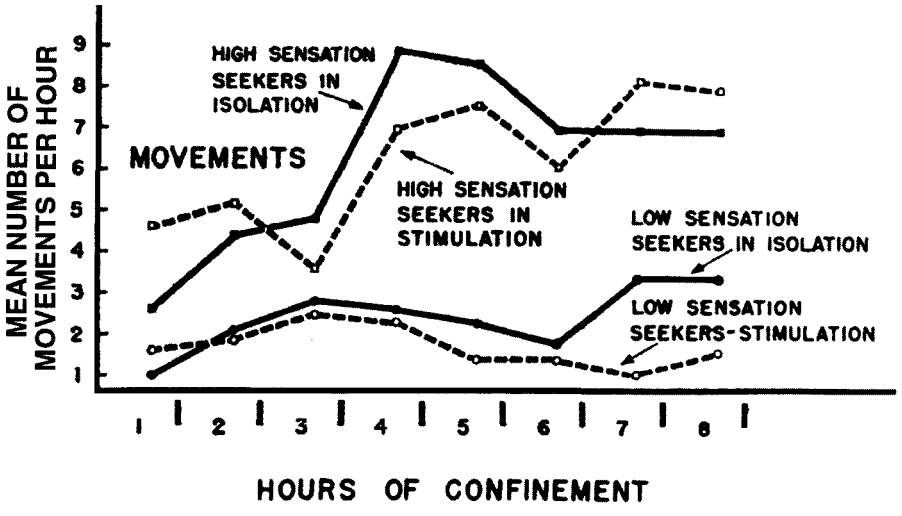


Figure 1.2. Restless movements by high and low sensation seekers in conditions of sensory deprivation and confinement in social isolation with some stimulation. From "Comparison of Stress Effects of Perceptual and Social Isolation," by M. Zuckerman et al., 1966, *Archives of General Psychiatry, 14*, p. 362. Copyright 1966 by the American Medical Association. Reprinted with permission.

of stimulation? We began to question them after the experiment. There had been some sensationalism of the SD experiments in the media and even in a movie in which one got the impression that deprivation of stimulation could produce a kind of temporary insanity with hallucinations and delusions. The high sensation seekers actually anticipated some kind of interesting and exciting "trip" without drugs. Most were disappointed because complex hallucinations are not common in the durations of experiments we were doing. The low sensation seekers anticipated a stressful experience but needed the money. We realized that sensation seeking involved more than simple intensity of stimulation. The desire for novel experiences was more important for the high sensation seekers, outweighing the risk portrayed in the media.

Restlessness is one expression of boredom. The subjects were confined to a bed in the dark, sound-proof room except when they had to use the toilet or eat sandwiches provided for lunch (Zuckerman et al., 1966). The bed had an inflated air mattress attached to a pressure transducer so that any movements while on the bed were recorded. Figure 1.2 shows the movements of high and low sensation seekers in two conditions. One was the complete SD condition. In the other, called a stimulation condition, the lights in the room remained on and some minimal stimulation was provided with music played into the room. In retrospect, this latter condition

was not a very stimulating one if *stimulation* is defined in terms of stimulus change. Most subjects found it as boring as the complete SD situation, although somewhat less anxiety provoking.

The movements for the first 3 hours of confinement in both conditions were not very different in high and low sensation seekers. However, after that, the restless movements increased steadily over the remaining hours in the high sensation seekers but remained fairly low and stable in the low sensation seekers. The two groups did not differ in anxiety increase over time in the experiment. We subsequently discovered that anxiety in SD is related to measures of neuroticism or trait anxiety, particularly when there has been no prior experience in the SD room under stimulation conditions (Zuckerman, Persky, Link, & Basu, 1968). In other words, the novelty of the experience interacted with the trait of neuroticism to produce anxiety. Some of these subjects panicked and asked to be let out after only a few minutes in the dark room. Many correlation and factor analytic studies have shown that there is no relationship between neuroticism or trait anxiety and sensation seeking (Zuckerman, 1979a, 1994).

Boredom and anxiety are aversive states and are one result of SD. Another prediction from an OLS theory is that given the option of responding to produce stimulation, the high sensation seekers will respond more for the reward of stimulation and the reduction of stimulus deprivation. A. Jones (1964, 1969), in a series of SD studies that allowed such response, found that subjects responded particularly for series of stimuli, which provided maximum information (random, unpredictable sequences). Lambert and Levy (1972) allowed subjects to press a bar that rewarded them with visual stimulation (slides) and found that high sensation seekers responded more over time than low sensation seekers.

Both intense and novel stimuli produced more arousal than weak or familiar stimuli, so we had written items based on the need for both intensity and novelty of stimuli, but the items reflecting a desire for novel and changing experiences were more related to the broad general factor than those reflecting intensity of experience (Zuckerman et al., 1964). One expression of a need for novelty is in design preferences. In an early study using the SSS–II, we used the Barron–Welsh Preference for Designs (Barron & Welsh, 1952) test to compare the preferences of high and low sensation seekers (Zuckerman, Bone, Neary, Mangelsdorf, & Brustman, 1972). Figure 1.3 shows designs liked more by high sensation seekers, and Figure 1.4 shows designs liked more by low sensation seekers.

There are clear differences in design preferences. Low sensation seekers like designs that are simple, symmetrical, and familiar, whereas high sensation seekers like those that are asymetrical, novel, and complex. High sensation seekers scored high on Barron's (1953) design scale, Preference for Complexity.

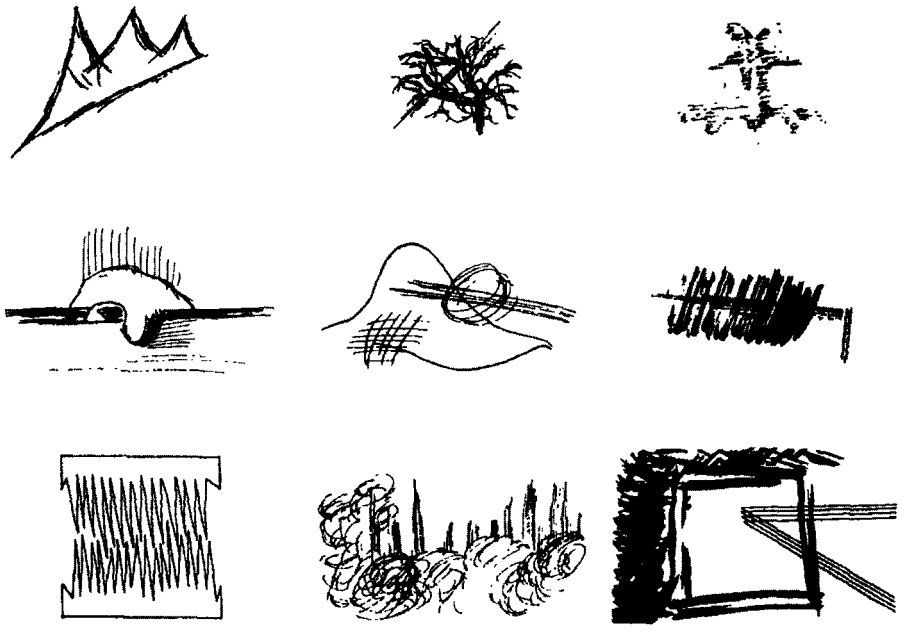


Figure 1.3. Designs liked more by high sensation seekers. From "What Is the Sensation Seeker? Personality Trait and Experience Correlates of the Sensation Seeking Scales," by M. Zuckerman, R. N. Bone, R. Neary, R. Mangelsdorf, and B. Brustman, 1972, *Journal of Consulting and Clinical Psychology, 39,* p. 317. Copyright 1972 by the American Psychological Association.

Interest and attention are expressed in behavioral and physiological responses called *orienting reflexes* (ORs). Animals or humans cease their ongoing activity and turn their head and sensory organs in the direction of the stimulus and show a phasic increase in physiological arousal, such as an increase in skin conductance (SC) or a deceleration of heart rate (HR). If the stimulus is very intense or threatening, a defensive reflex (DR) may be seen. If the stimulus is unexpected and intense, a startle reflex (SR) may occur. The OR may be differentiated from the DR in HR changes: The OR is a deceleratory HR over the first few seconds after stimulus presentation, whereas the DR is an acceleratory response (Graham, 1979). The OR maximizes information intake. In fact, Pavlov called it the "What is it?" reflex. It habituates quickly when the stimulus is repeated and information is fully extracted. The DR is an emergency response preparing for action (fight or flight). The SR is a fast protective reflex involving contraction of flexor muscles (flinching).

Neary and Zuckerman (1976) used the SSS–II to investigate the SC response (SCR) to a simple visual stimulus, followed by a more complex one (see Figure 1.5). The high sensation seekers showed a stronger response

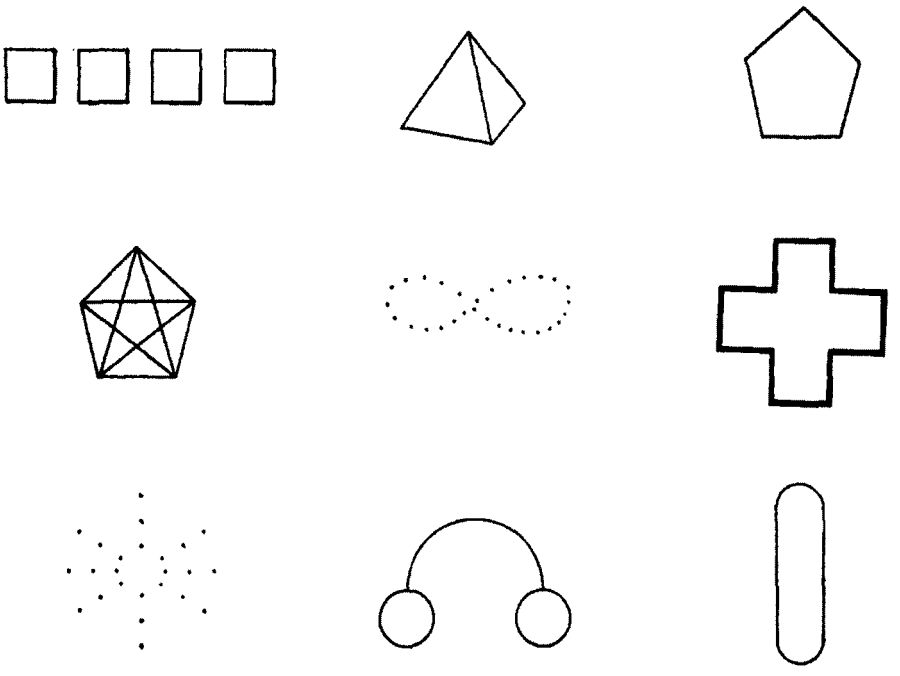


Figure 1.4. Designs liked more by low sensation seekers. From "What Is the Sensation Seeker? Personality Trait and Experience Correlates of the Sensation Seeking Scales," by M. Zuckerman, R. N. Bone, R. Neary, R. Mangelsdor, and B. Brustman, 1972, *Journal of Consulting and Clinical Psychology, 39,* p. 318. Copyright 1972 by the American Psychological Association.

than the low sensation seekers to the first trial presentation of the simple stimulus when it was novel. But on the second trial, the high sensation seekers dropped to the habituated level of the low sensation seekers and continued to habituate over the next 8 trials at the level of the lows. When a new stimulus was presented, the stronger OR in the high sensation seekers was again seen. There were no differences in basal levels of arousal prior to stimulus presentation. The OR responses of the high sensation seekers differed from those of the low sensation seekers only in response to a novel stimulus.

Early replication attempts yielded mixed results. However, B. D. Smith, Perlstein, Davidson, and Michael (1986) had success using visual and auditory stimuli with content of interest to high sensation seekers. B. D. Smith, Davidson, Smith, Goldstein, and Perlstein (1989) also investigated the influence of emotional intensity by using words graded in intensity of meanings. High sensation seekers showed stronger SCRs than low sensation seekers to loaded stimuli and to high-intensity words, particularly on the first trial presentations of the stimuli, when they were novel. There were no differences in response to neutral stimuli.

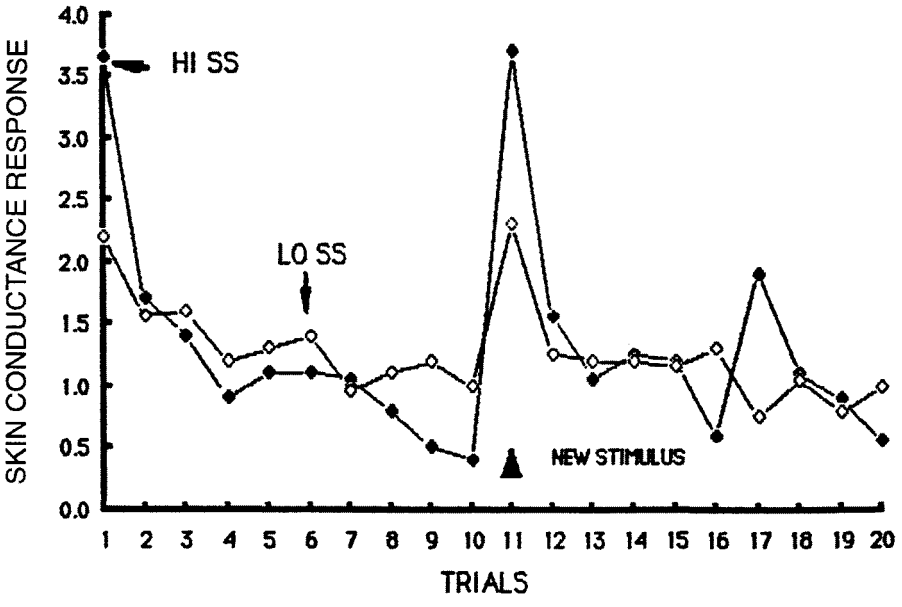


Figure 1.5. Skin conductance responses to a simple (Trials 1–10) and a complex (Trials 11–20) visual stimulus. Hi = high; lo = low; SS = sensation seekers. From "Sensation Seeking, Trait and State Anxiety, and the Electrodermal Orienting Reflex," by R. S. Neary and M. Zuckerman, 1976, *Psychophysiology," 13,* p. 207. Copyright 1976 by Blackwell. Reprinted with permission.

The SSS General Scale was also related to sexual experience, drinking, and drug use of college students, but these studies will be discussed in the subsequent chapters on risk taking (Zuckerman, Bone, Neary, Mangelsdorf, & Brustman, 1972).

Development of Sensation Seeking Scale Forms IV and V

As mentioned previously, the SSS–II General Scale showed some evidence of subfactors among the item content (Farley, 1967). To investigate this possibility, additional items that might represent these factors were added. Originally it was thought that the factors might be grouped by sensory modalities (i.e., visual, auditory, olfactory, somesthetic, kinesthetic). However, the factors resulting from the analyses were quite different from what was expected (Zuckerman, 1971). Four factors emerged, which have proven quite robust across nations and translations of the SSS (Zuckerman, 1994). These four factors are described in the list that follows in terms of their item content. Subsequent work with the SSS has shown the greater relevance of some of the subscales than others in predicting specific behavioral phenomena and biological correlates.

1. *Thrill and Adventure Seeking (TAS).* The items in this subscale indicate the desire to engage in physical activities that provide unusual sensations and experiences, such as mountain climbing, skydiving, or scuba diving. Most of these activities are perceived as moderately risky, which is what deters lower sensation seekers from engaging in them. It is the sensation rewards that attract the high sensation seekers, not the risk.
2. *Experience Seeking (ES).* This subscale describes seeking sensation and new experiences through the mind and the senses (music, art, travel) and through a nonconforming general lifestyle with like-minded friends. In the 1970s, we informally called it the "hippie factor," and even used the term *hippie* in one of the items. In the 1980s, we discovered that the term *hippie* no longer had relevance to the younger generations, so we substituted the term *punk.* One should really anticipate anachronisms when devising a test that may have continued use through more than 1 decade and one generation.
3. *Disinhibition (Dis).* Dis items refer to seeking sensation through other people, a hedonistic lifestyle, "wild" parties, sexual variety, and drinking to disinhibit. It is an ancient form of sensation seeking, finding social acceptance in bacchanals and carnivals; shows few if any relationships to education, race, or class; and is the subscale most highly related to certain of the biological correlates of sensation seeking such as the HR OR, gonadal hormones, and augmenting of the cortical evoked potential (EP). It is also the subscale that best differentiates psychopathic personalities from nonpsychopathic criminals and normals. However, taken alone, a high score on Dis is normal. It becomes more likely to be a sign of psychopathy when combined with an aggression scale (not included in the SSS Form V [SSS–V]).
4. *Boredom Susceptibility (BS).* This subscale represents the fourth factor, the weakest one to emerge from factor analyses. It is less internally reliable than the other three subscales. The items represent an aversion to any kind of monotonous conditions and restlessness when confined to such conditions. There is a dislike of people who are not exciting or interesting, even if they are reliable. It is most highly related to the Dis subscale and like Dis is high in psychopathic personalities.

SSS Form IV (SSS–IV; Zuckerman, 1971), included 72 items, unevenly distributed among the four subfactor scales and including the SSS–II General Scale. The correlations among the subscales were moderate

(*Mdn rs* = .30–.58). The SSS–V (Zuckerman, Eysenck, & Eysenck, 1978) represented an attempt to shorten the test by selecting items with the highest loadings on one of the subscales relative to the other three subscales. Ten best items were selected for each of the four subscales. Instead of a separate SSS General Scale, the SSS Total score for all 40 items was used as an overall measure of sensation seeking. The mode of selecting items guaranteed that the correlations between subscales would be lower than in the SSS–IV, although nearly all were still significant (*Mdn rs* = .14–.41). Some have questioned the existence of a broad general factor because of the low correlations among some of the subscales in SSS–V, but it should be recognized that this was the result of a deliberate attempt to sharpen the discriminant validity of the subscales going from SSS–IV to SSS–V.

Demographic Studies

The two most significant demographic factors affecting the SSS are gender and age (Zuckerman, 1979a, 1994; Zuckerman & Neeb, 1980). Men score higher than women on all subscales except ES, and this is generally the finding in many different cultures. The largest gender differences are on TAS and Dis. SS scores increase with age in children's scales (Russo et al., 1993) but in adult populations they peak in late adolescence and steadily decline with age thereafter (L. Ball, Farnill, & Wangeman, 1983; Zuckerman et al., 1978). Similar findings on the Venturesomeness scale were reported by S. B. G. Eysenck, Pearson, Easting, and Allsopp (1985). By age 60, the total score on SSS–V is about half of that obtained from subjects in their late adolescence. The age decline is most marked on TAS and Dis but is less in ES, and BS shows no age change. It is tragic that whereas the forms of sensation seeking expressed in TAS, Dis, and ES decline with age, the capacity to be bored (BS) does not.

Socioeconomic factors have a weaker effect on the SSS and are largely confined to women on the ES scale (Zuckerman & Neeb, 1980). Blacks score lower on the subscales except on Dis, in which there is no race difference (Zuckerman, 1994). TAS and ES scales represent activities and interests, such as extreme sports and art preferences, which may be of less interest in the larger African American culture. In contrast, Dis and BS represent more universal and cross-cultural modes of sensation seeking.

Construct Validity Research Using the Sensation Seeking Scale Forms IV and V

The use of subscales enabled researchers to show which scales were most highly related to specific phenomena and physiological and hormonal

functions. As might be expected, art and design preferences are most highly related to the ES subscale, and engagement in extreme sports, to the TAS subscale. However, in most cases there are also significant correlations with the Total score and at least one other of the subscales. In musical preferences, all of the subscales were related to a preference for rock music, but ES was also related to preferences for folk and jazz, reflecting the greater openness to experience of experience seekers and their greater exposure to other kinds of music (Litle & Zuckerman, 1986).

PSYCHOPHYSIOLOGICAL STUDIES

Orienting and Defensive Reflexes

By the time HR was used as a measure of OR, the new forms (SSS–IV and SSS–V) had been developed. HR, unlike SCR, had the advantage of being able to detect DRs and SRs as well as ORs. Low to moderate intensities of stimuli tend to elicit ORs, whereas more intense stimuli tend to produce DRs, or SRs if unexpected. Orlebeke and Feij (1979) did the first study of sensation seeking using HR. In response to a moderate tone of 80 dB, high and low scorers on the Dis subscale demonstrated striking differences between their responses. Those high on Dis typically showed an OR (HR deceleration), whereas those low on Dis usually had a DR (HR acceleration).

Ridgeway and Hare (1981) found similar results, which were stronger for the Dis subscale than for the Total score. Zuckerman, Simons, and Como (1988) found similar differences with the Dis subscale, but in this study the OR and DR differences were found using different stimulus intensities. A less intense stimulus (60 dB) produced greater HR deceleration in high Dis than in low Dis subjects, whereas an intense stimulus (100 dB) elicited more HR acceleration in the low Dis than in the high Dis subjects.

This research confirms the importance of intensity as well as novelty of stimulation in the construct of sensation seeking. The differences in HR response of high and low sensation seekers described previously occurred only on the first presentations of the stimuli in a series of trials and therefore represent a combination of the influences of novelty and intensity. ORs and DRs may be viewed as opposite modes of reacting to the intensity dimension of stimuli. High Dis subjects are more accessible or attentive to such stimuli, whereas low Dis types show more of a defensive emotional reaction. The next topic concerns a more direct measure of cortical reactivity and one simply related to the intensity dimension of stimulation rather than an interaction of intensity and novelty.

The Cortical Evoked Potential

Buchsbaum and Silverman (1968) developed a method for analyzing the cortical response to intensity of stimulation using the cortical EP method. The EP represents responses of different parts of the brain, subcortical and cortical, to a brief stimulus like a flash of light, a tone, or a somesthetic electrical stimulus. For visual stimulation, they used the P1–N1 component of the EP occurring at about 100 to 140 milliseconds after the stimulus. This component usually represents the first impact of stimulus intensity on the cortex. Earlier components represent subcortical reactions, and later components represent more processed information such as stimulus familiarity or novelty.

Measuring the response to increasing intensities of stimulation, Buchsbaum and Silverman (1968) found wide individual differences in the slopes of the stimulus-intensity/EP correlation. Some individuals showed what might be expected in all subjects if this were a simple psychophysiological reaction, namely, a positive slope indicating a cortical response in proportion to the intensity of the stimulus. Many subjects did show this type of reaction to varying degrees, but others showed little increase of EP amplitude over intensity or even a significant decrease at the highest intensities. They called the first type of reactors "augmenters" and the latter type "reducers," although they used a continuous distribution of slopes to make these distinctions.

The use of the augmenting–reducing terms was, in retrospect, an unfortunate one. Petrie (1967) used these terms to describe a kinesthetic–somaethetic sensory discrimination response involving estimates of the width of a block of wood before and after stimulating the fingers by rubbing another larger block of wood. Those who increased their estimates were called "augmenters," and those who decreased them were called "reducers." This was said to be a measure of brain function, although its claim to be so is questionable (Zuckerman, 1986a). The Kinesthetic Aftereffect (KAE) has no retest reliability as one should demand for a physiological trait. The behavioral and personality characteristics associated with EP augmenting tend to be associated with KAE reducing (Davis, Cowles, & Kohn, 1983). No direct correlation is generally found between the methods. The choice is between an actual measure of brain reactivity, the EP, and one based on a peripheral psychophysical measure. Another problem is that the KAE uses kinesthetic stimulation, whereas the EP method, which is most related to personality, uses visual or auditory stimulation. I use the terms *augmenting* and *reducing* strictly in relation to the EP method.

Buchsbaum (1971) suggested that there might be a relationship between augmenting–reducing and sensation seeking. Zuckerman, Murtaugh, and Siegel (1974) put this to the test using a range of intensities of visual

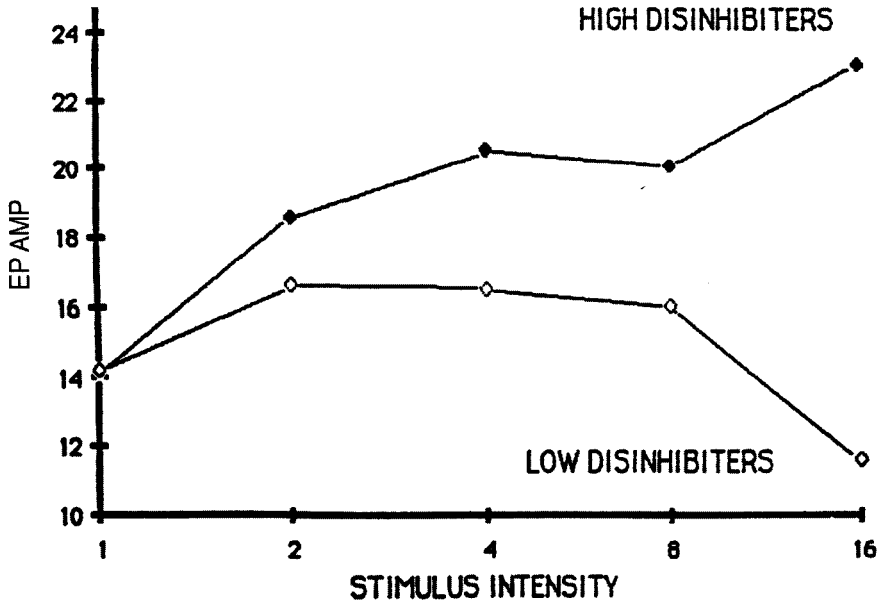


Figure 1.6. Visual evoked potentials (EPs) of high and low scorers on the Disinhibition subscale of the Sensation Seeking Scale as a function of stimulus intensity. AMP = amplitude. From "Sensation Seeking and Cortical Augmenting–Reducing," by M. Zuckerman, T. T. Murtaugh, and J. Siegel, 1974, *Psychophysiology, 11*, p. 539. Copyright 1974 by Blackwell. Reprinted with permission.

stimulation (flashes) on subjects who had taken the SSS. They found a significant relationship only with the Dis subscale. Figure 1.6 shows the relationship, plotting the mean EPs for subjects above and below the median on Dis. High Dis subjects showed an augmenting pattern of response, whereas low Dis subjects showed a reducing pattern, with a significant decrease in cortical responses to the brightest light flashes. These were not a function of artifacts like blinking and therefore represented some kind of cortical inhibition in response to intense stimulation. The actual correlation between Dis and the EP slope was .59.

Zuckerman, Simons, and Como (1988) demonstrated the same relationship for the auditory EP, again with the Dis subscale only. Their results are shown in Figure 1.7. Zuckerman (1990) summarized the results for both visual and auditory EP studies done subsequent to the 1974 study. Replication of the results, particularly in relation to Dis, have been good, especially for the auditory EP (8 of 10 studies), and additional replications have appeared since 1990 (e.g., Brocke, Beauducel, John, Debener, & Heileman, 2000).

I have advocated a comparative approach to sensation seeking (Zuckerman, 1984b). Sensation seeking is not a uniquely human trait. Most species of mammals demonstrate individual differences, which might be called

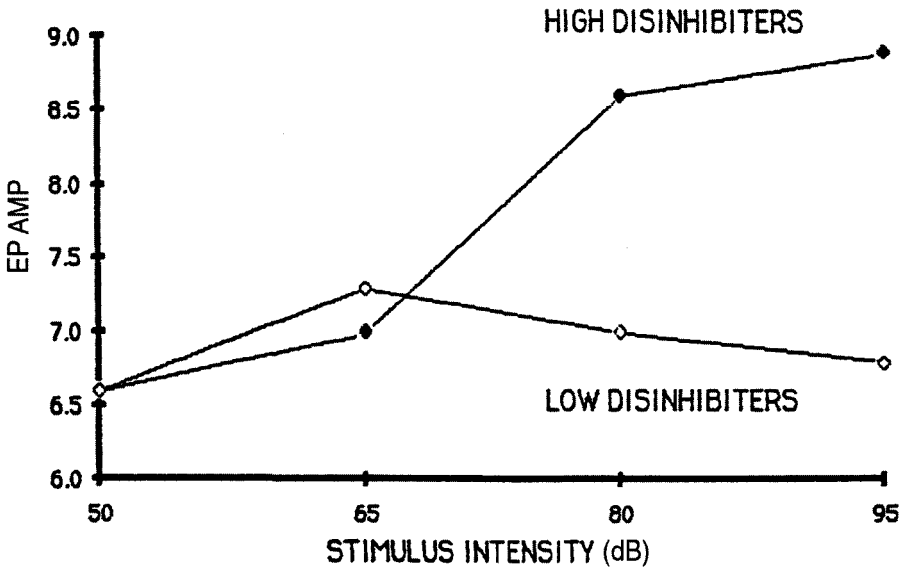


Figure 1.7. Auditory evoked potentials (EPs) of high and low scorers on the Disinhibition subscale of the Sensation Seeking Scale as a function of stimulus intensity for the short interstimulus interval condition (2 seconds). AMP = amplitude. From "Sensation Seeking and Stimulus Intensity as Modulators of Cortical, Cardiovascular, and Electrodermal Response: A Cross-Modality Study," by M. Zuckerman, R. F. Simons, and P. G. Como, 1988, *Personality and Individual Differences, 9*, p. 368. Copyright 1988 by Elsevier Science. Reprinted with permission.

"boldness," "approach behavior," or "exploratiVeness," in unfamiliar environments or in response to novel stimuli. In many nonhuman species, particularly primates, boldness is also related to dominance and aggressiveness.

My colleague Jerome Siegel used the augmenting–reducing paradigm, in a top-down approach, to identify similar EP differences in cats and rats and to relate these to behavioral trait differences in these species. Cats were classified as augmenters or reducers using the visual cortical EP. Their contrasts in behavior from studies by Lukas and Siegel (1977) and P. M. Saxton, Siegel, and Lukas (1987) are shown in Table 1.1.

In behavioral reactions to novel stimuli, augmenter cats were more active, exploratory, and aggressive, whereas reducer cats were more fearful and tended to withdraw rather than approach the object. In an experimental situation in which the cats were put into an unfamiliar box with a lever that produced food reinforcement on a fixed interval schedule, the augmenter cats were quick to habituate to the strange environment and learn the lever press that produced positive reinforcement. The reducer cats took longer to adjust to the unfamiliar environment (neophobia) and to learn the response, and they responded at a lower rate. However, when the cats were exposed to a different schedule, differential reinforcement for a low rate of

TABLE 1.1
Correlates of Augmenting–Reducing in Cats

Conditions	Reducers	Augmenters
Reactions to novel stimuli	Withdrawal Fearful	Approach Aggressive
Fixed interval reward schedule	Longer to habituate and learn the response	Quicker to habituate to experimental situation, learn response, make more responses
DRL reward schedule	Learned more quickly Made fewer errors	Learned more slowly Made more errors

Note. Based on data from studies by Lukas and Siegel (1977) and Saxton, Siegel, and Lukas (1987). DRL = differential reinforcement for a low rate of response.

response and loss of reinforcement if they exceeded that rate, the reducer rats were superior in performance. The augmenter cats were poor on this schedule because of their lack of restraint or inhibitory control in modulating their rate of response. This cat model is consistent with the latest trait version of sensation seeking, which combines impulsivity with sensation seeking ("Impulsive Sensation Seeking"; Zuckerman, 1996b).

Siegel, Sisson, and Driscoll (1993) used another species to study augmenting–reducing in two strains bred for behavioral characteristics. Both strains were selectively bred from the parent Wistar strain. The Roman high-avoidance (RHA) strain was bred for superior performance in learning an active avoidance response in a shock shuttle-box. The Roman low-avoidance (RLA) strain performed poorly because they tended to freeze and were slow to learn how to avoid the shock. The augmenting–reducing characteristics of the strains using a visual EP are shown in Figure 1.8.

Nearly all of the RHAs were EP augmenters, and almost all of the RLAs were reducers. The RHAs (augmenters) are more active and exploratory in the open-field test, are more aggressive in response to shock, are more ready to drink alcohol, have a high tolerance for barbiturates, and responded more for electrical brain stimulation reward in the lateral hypothalamus at high intensities. The female RHAs who had pups tended to be neglectful of them, spending less time on the nest. The RLAs are less exploratory and aggressive, less likely to drink alcohol, and have a low tolerance for barbiturates. The female RLAs are "good mothers," spending more time in the nest with the pups. They were more sensitive than the RHAs to low intensities of brain stimulation, but when the intensities were high they used an escape response to terminate the stimulation. The difference between RHAs and RLAs in behavioral response to brain stimulation is analogous to their reflexive defensive responses to high-intensity external stimulation.

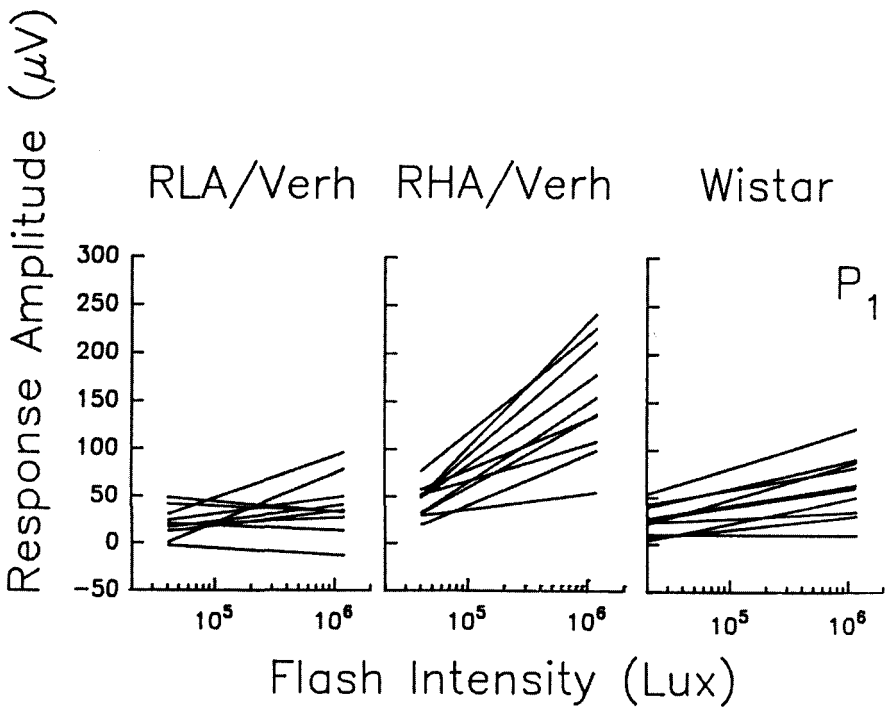


Figure 1.8. Visual evoked potentials as a function of stimulus intensity in Roman high-avoidance (RHA) rats and Roman low-avoidance (RLA) rats and the parental Wistar stock rats. P1 = first positive peak in evoked potential after the stimulus, Verh = first negative peak after the stimulus. From "Augmenting and Reducing of Visual Evoked Potentials in Roman High- and Low-Avoidance Rats," by J. Siegel, D. F. Sisson, and P. Driscoll, 1993, *Physiology and Behavior, 54*, p. 709. Copyright 1993 by Elsevier Science. Reprinted with permission.

When an animal model is used for a human trait in either a top-down or a bottom-up approach, the model assumes some equivalence of behavior in the two species. The assumptions may not be entirely correct. A rat's behavior in the empty open-field test, for instance, is said to be a measure of fearfulness or explorativeness, depending on whether the animal freezes or quickly moves to the center of the arena. Inhibited behavior is accompanied by defecation, a sign of emotionality in the rat. The behavior may be like the first time human sensation seekers try a new risky activity, like skydiving. Their anticipatory reactions are a mixture of pleasure in anticipating a new kind of experience and an inborn fear of falling from heights. If the fear is much greater, the adventurer will not jump. However, many sensation seeking situations do not involve any significant degree of fear, and fearfulness, or trait anxiety, is not related to sensation seeking. The rat model therefore involves two different traits that are independent in humans

but not in rats. The use of a common biological marker, like the EP paradigm here described, goes beyond mere analogy in behavior to confirm the model.

Thus far I have been largely speaking of psychophysiological methods for testing the sensation seeking construct. The RHAs and RLAs also differ on a number of biochemical measures, as I describe later in this chapter. First, let me discuss the biochemical findings on sensation seeking and the new theoretical models emerging from these.

BIOCHEMICAL STUDIES

Sex Hormones

The sex hormone testosterone is associated with aggression, sexuality, and exploratiVeness in other species. Castration reduces these activities in male animals. Such radical methods of reducing testosterone levels are clearly not ethical in humans, so that most of the data is correlational. However, a study of hypogonadal men with low testosterone levels found that they had low levels of sensation seeking (O'Carroll, 1984). Men with functional impotence but normal testosterone levels had normal levels of sensation seeking. Subsequent administration of testosterone to both groups increased their sex drive and interest, but it did not change their scores on the SSS. Sensation seeking is a trait that might have its origins in earlier prenatal testosterone levels, which affect the developing brain. However, testosterone does vary with gender and age, being markedly higher in men than in women and dropping with age after late adolescence. Sensation seeking shows the same gender and age differences so that it might reflect the influence of gradually changing levels of the hormonal substrate.

Daitzman, Zuckerman, Sammelwitz, and Ganjam (1978) found that androgens and estrogens in males were positively associated with the Dis subscale of the SSS. Daitzman and Zuckerman (1980), using more hormone-specific plasma measures, confirmed that male subjects scoring high on Dis were higher in testosterone and estradiol than subjects low on Dis. Estrogens in men are largely produced by conversion from testosterone and therefore have a different significance than the ovary-produced estrogen in women. In fact, the aromatization hypothesis suggests that androgens in males have their major motivational effects after conversion to estrogenic metabolites (Brain, 1983). The low Dis subjects were not low on testosterone compared with normal men of their age, but the high Dis subjects had unusually high testosterone levels. These findings were confirmed by Aluja and Torrubia (2004) and by Gerra et al. (1999), who found correlations between sensation seeking measures and plasma testosterone.

Monoamine Oxidase

Monoamine oxidase (MAO) is an enzyme that catabolizes monoamines after they are taken up in the presynaptic neuron, thereby regulating the level of the neurotransmitter. Type-A MAO (MAO-A) seems to be primarily involved in the regulation of serotonin and norepinephrine (NE), whereas dopamine (DA) in humans is oxidized by Type B (MAO-B; Glover, Sandler, Owen, & Riley, 1977). Mice with MAO-A gene knockout have elevated levels of serotonin, NE, and DA and are hyperaggressive, whereas mice with MAO-B gene knockout have elevated levels of phenylethylamine and the MAO-B inhibitor deprenyl and do not show increased aggressiveness (Shih, Chen, & Ridd, 1999). MAO-B is positively correlated with serotonergic activity in particular brain areas (Adolfsson, Gottfries, Oreland, Roos, & Winblad, 1978). These investigators have suggested that MAO-B and serotonin regulators are governed by the same set of genes. MAO-inhibiters have been used in the treatment of depression, and MAO-B inhibition potentiates the activity of DA (Deutch & Roth, 1999). MAO is negatively correlated with testosterone in men and estradiol in women (Briggs & Briggs, 1972)

MAO-B obtained from blood platelets was first related inversely to sensation seeking in studies by Murphy et al. (1977) and by Schooler, Zahn, Murphy, and Buchsbaum (1978). Since those early findings, many studies have been done attempting to replicate this interesting relationship. Significant negative correlations between MAO-B and the SSS General or Total score were found in 10 of the 15 groups in the studies. The median correlation was only .25. Significant or not, in 13 of the 15 groups, the relationship was in the negative direction. If the relationship was due to chance, half of the correlations would be negative and half would be positive. There were no significant correlations in the groups consisting entirely of females, possibly because estrogen influences MAO levels, and it is difficult to control for the phase of the estrus cycle in individual subjects. A reliable but weak relationship is not surprising because MAO-B only influences behavior through its effect on the monoamine it regulates, primarily DA.

In humans, MAO-B is also related to a number of disorders, as shown in Table 1.2. All of these disorders, with the possible exception of anorexia and paranoid schizophrenia, are characterized by high sensation seeking and impulsivity. The fact that low levels of MAO are found in the relatives, usually sons, of alcoholics and patients with bipolar disorder is evidence that the low levels are part of a genetic vulnerability to these disorders. Bipolar disorders in the manic phase are an expression of impulsive sensation seeking totally out of control. The Dis subscale comes closest to measuring their actual behavior in pursuit of parties, sex, drinking, drugs, and gambling. However, even when those with bipolar disorder are in a remitted or depressed phase, they still score high on the SSS describing their typical (trait)

TABLE 1.2
Psychopathology and Monoamine Oxidase (MAO)

Disorder or description of subjects with low MAO-B	Researcher(s)
Attention-deficit/hyperactivity disorder	Shekim et al. (1986)
Antisocial personality disorder	Lidberg et al. (1985); Sher et al. (1994)
Borderline personality disorder	Reist et al. (1990)
Criminality	Coursey et al. (1979); Garpenstrand et al. (2002); af Klinteberg (1996); Stalenheim (2004)
Alcoholism	Coccini et al. (2002); Hallman et al. (2001); La Grange et al. (1995); Major & Murphy (1978)
Well relatives of alcoholics	Schukit (1994); Sher (1993)
Drug abuse	L. von Knorring et al. (1987); Sher et al. (1994)
Pathological gambling	Blanco et al. (1996)
Bipolar mood disorder	Murphy & Weiss (1972)
Well relatives of people with bipolar mood disorders	Leckman et al. (1977)
Paranoid schizophrenia[a]	Zureik & Meltzer (1988)
Anorexia	Díaz-Marsá et al. (2000)

Note. MAO-B = Type-B MAO. [a]People with other types of schizophrenia have higher levels of MAO.

attitudes and behaviors (Cronin & Zuckerman, 1992). Even in unscreened college populations, low MAO is found in those who smoke, use drugs, and have a record of felonious criminal behavior (Coursey, Buchsbaum, & Murphy, 1979).

Descending to a lower level in the phylogenetic tree, monkeys with low MAO-B are more dominant, aggressive, sexually active, and sociable and spend more time in play than high MAO monkeys (Redmond, Murphy, & Baulu, 1979).

Because MAO is not a neutransmitter itself, it must exert its effect through the monoamine(s) it regulates. Some hint of the relationships that might exist between the monoamines and sensation seeking in studies of humans is derived from studies of biochemical correlates of EP augmenting–reducing.

MAO is low in EP augmenters and it is high in EP reducers (L. von Knorring & Perris, 1981). Augmenters among patients tend to have low levels of cerebrospinal fluid (CSF) serotonin, DA metabolites, and endorphins, and reducers have higher levels. This last finding on endorphins makes sense because these naturally produced morphine-like compounds

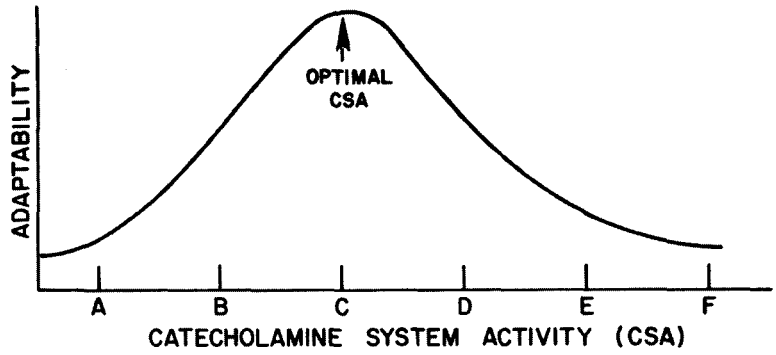
have sedative effects on behavior and could be the source of the cortical inhibition seen in reducers. A rare kind of experimental study on humans showed that administration of zimeldine, a selective inhibiter of serotonin uptake, causes a reduction in the amplitude–intensity slope of the EP, suggesting a direct effect of serotonin on the sensorimotor centers in the brain (L. von Knorring & Johansson, 1980). Serotonin has generally inhibitory effects, in opposition to NE, which produces arousal in the cortex, and DA, which has activating effects on reward seeking behavior.

I previously discussed the behavioral characteristics of the RHA rats (EP augmenters) and the RLA rats (EP reducers). These strains are linked to human sensation seeking by the EP marker so that the RHAs are models for impulsive sensation seekers and the RLAs, for inhibited low sensation seekers. The RHAs show strong dopaminergic increases in the prefrontal cortex, whereas the RLAs show little response of this monoamine. In contrast, the RLAs show a strong serotonergic response and an increase in corticotrophin releasing factor (CRF) in the hypothalamus. CRF releases adrenocorticotropic hormone from the pituitary gland, which would cause the release of cortisol from the adrenal cortex. At the human level, cortisol was found to be inversely related to sensation seeking (high in low sensation seekers). The rat model suggests that stress activates the dopaminergic system in high sensation seekers and the serotonergic system in low sensation seekers. As a consequence, the hypothalamic–pituitary–adrenocortical may be activated in the low sensation seeker, resulting in passive avoidance and inhibitory behavior in the presence of stress or threat. These differences could explain the greater readiness of high sensation seekers to engage in risky behaviors because risk would engender more anxiety and inhibition in the low sensation seekers.

Theoretical Modifications (1984)

By 1979 I had already suggested that the optimal level of cortical activity and the sensitivity of the RAS was not a cogent basis for the trait, which is why that book was subitled *Beyond the Optimal Level of Arousal* (Zuckerman, 1979a). After reviewing the animal and human findings on the monoamines (Zuckerman, 1984b), I formulated a model based on an optimal level of catecholamine system activity (CSA). CSA includes DA and NE. This model is shown in Figure 1.9.

It was suggested that in an unstimulated state and a low basal level of CSA, both DA and NE are low in high sensation seekers and are far below their optimal levels of CSA, producing an aversive state of boredom. This is why the sensation seeker has high boredom susceptibility and a need for sensation seeking through activities (as in TAS), people (as in Dis), or novel experiences (as in ES). The low sensation seeker at the same low



MOOD	1. Depression 2. Anxiety	Boredom, Apathy	Positive Feelings	Euphoria	1. Anxiety 2. Depression	Panic
ACTIVITY	Minimal	Limited	Active	Hyperactive	Aimless Limited	Stereotyped
SOCIAL INTERACTION	Withdrawn or Hostile	Introverted (state)	Sociable	Hypersociable	Unsociable	Aggressive-Hostile Interactive
CLINICAL CONDITION	Major Depression	Normal	Normal	Cyclothymic Hypomanic	Anxiety Disorder	Paranoid Disorder

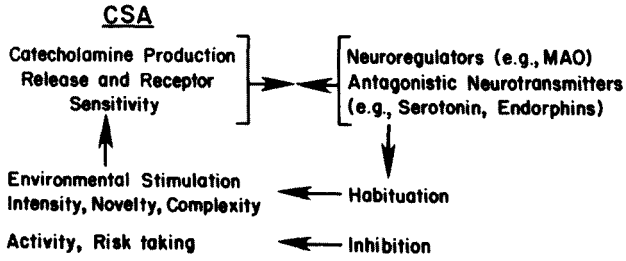


Figure 1.9. A model for the relationships of mood, activity, social interaction, and clinical conditions to catecholamine system activity. MAO = monoamine oxidase. From "Sensation Seeking: A Comparative Approach to a Human Trait," by M. Zuckerman, 1984, *Behavioral and Brain Sciences, 7*, p. 431. Copyright 1984 by Cambridge University Press. Reprinted with permission.

level of CSA is more content and happy. Increases in CSA through activities or drugs may move high sensation seekers closer to their optimal levels for mood but may push low sensation seekers beyond their optimal levels, and positive feelings may shift to negative ones. At an even higher level, the high sensation seeker may become euphoric and manic, whereas the low will become anxious and stressed.

The theory notes the inhibitory effect of serotonin and neuroregulators like MAO on CSA and their role in habituation, which dampens the arousing effect of stimuli by repetition and postulates that it is responsible for inhibition of arousal and sensation seeking activity. It was assumed,

therefore, that low sensation seekers are characterized by higher levels of serotonergic activity as well as MAO and endorphins.

The two catecholamines were assumed to work in the same direction. The only differentiation is that both were said to be involved in the pursuit of novel sensation, with high NE providing the energetic component of the drive and DA, the reward seeking component. Stimulant drugs like cocaine and amphetamine release both DA and NE and therefore are rewarding to high sensation seekers but are likely to make low sensation seekers anxious. However, there was one curious finding that confounded the theory. High sensation seekers should prefer stimulant drugs to drugs that have a sedative effect. But research showed that there is no clear preference for stimulant drugs among high sensation seekers (Zuckerman, 1983a, 1994). Young heroin users are as high in sensation seeking as are cocaine users (Craig, 1982; Platt & Labate, 1976). What distinguishes high from low sensation seekers among drug abusers is that the highs had tried a greater variety of drugs than the lows. Given blind testing of amphetamine, diazepam (a tranquilizer), and placebo, both high and low sensation seekers rated their reactions as more positive to amphetamine (Carrol, Zuckerman, & Vogel, 1982). These findings raised questions for any kind of optimal level theories.

Further Theoretical Modifications (1995)

During the later 1980s, I was influenced by the theories of Gray (1982, 1987). Gray was a bottom-up type of theorist, drawing his basic models from neuropsychological research with rats. What was interesting to me and other theorists was his use of behavioral systems as the connecting constructs between the underlying neurological, neurochemical systems and the overlying personality traits. The three basic behavioral systems are the behavioral approach system (BAS), underlying impulsivity, the behavioral inhibition system (BIS), underlying anxiety, and the fight–flight system, underlying aggression (or H. J. Eysenck's, 1967, Psychoticism [P] dimension). Whereas Gray (1987) regarded impulsivity, the trait expression of the BAS, as a combination of H. J. Eysenck's Extraversion (E), Neuroticism (N), and P, I regard impulsivity as closely linked with sensation seeking (related to E and P in H. J. Eysenck's system but not to N). In my five-factor theory, one of the major factors is described as Impulsive Sensation Seeking (Zuckerman, Kuhlman, & Camac, 1988). Gray regarded the dopaminergic pathway in the mesolimbic system as the neurological site of the BAS. NE and serotonin were thought to be the basis of the BIS. The dorsal ascending NE system is an arousal system activated by novel stimuli or stimuli associated with threat or punishment, but the data from human subjects would suggest that it is low, rather than high, levels of serotonin that are associated with

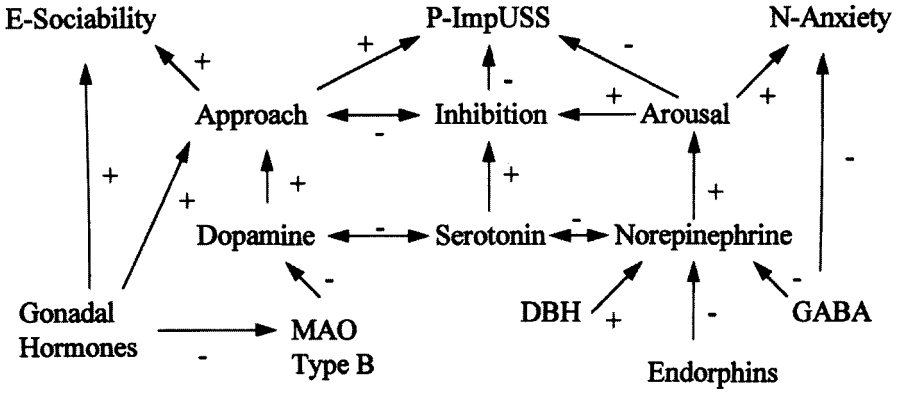


Figure 1.10. A biobehavioral model for sensation seeking. E = Extraversion; P = Psychoticism; ImpUSS = Impulsive Unsocialized Sensation Seeking; N = Neuroticism; MAO = monoamine oxidase; DBH = dopamine beta-hydroxylase. From "Good and Bad Humors: Biochemical Bases of Personality and Its Disorders," by M. Zuckerman, 1995, *Psychological Science, 6*, p. 331. Copyright 1995 by Blackwell. Reprinted with permission.

anxiety and depression. The serotonin reuptake inhibitors, which keep the system activated, are the drug of choice in the treatment of depression and are also effective in the treatment of panic disorder. Because serotonin mediates behavioral inhibition, it was natural for Gray to assume it functioned in the inhibition associated with anxiety. But it also may be involved in the type of behavioral inhibition associated with low sensation seeking. The low sensation seeker is cautious and avoids risky situations but is not necessarily fearful.

My last (for now) version of a biosocial–biochemical model of sensation seeking (Zuckerman, 1995) is shown in Figure 1.10. The figure shows only three of the five traits in the Zuckerman–Kuhlman alternative-five model. There are biological bases postulated for the other two (Zuckerman, 2003, 2006a), but their inclusion would make the figure impossibly complex and the focus here is on the Impulsive Sensation Seeking factor.

Three behavioral mechanisms are assumed to underlie sensation seeking. High sensation seeking is a function of a strong approach and weak inhibition and arousal systems. These are interactive, as are the neurotransmitters underlying them. DA is positively associated with approach, serotonin with inhibition, and NE with arousal. Sensation seeking, therefore, is associated with a strong dopaminergic reactivity, and weak serotonergic and noradrenergic reactivities. Note that I am not talking about basal levels of these neurotransmitters but reactivity to stimuli, whether novel, positive, or negative. Reactivity depends on sensitivity of receptor cells, not the absolute levels of neurotransmitters stored in the presynaptic neurons.

TABLE 1.3
Animal Models for Sensation Seeking (and Related Traits) and Monoamines

Behavioral trait	Biochemical trait
RHA vs. RLA Rats	
General Behavior: RHA VEP augmenters vs. RLA reducers are more exploratory, impulsive, aggressive, nonnurturing to pups, responsive to high-intensity brain stimulation, drink alcohol (Siegel & Driscoll, 1996). *Shock stress:* RHA VEP augmenters exhibit active avoidance; RLA reducers are passive, hyperemotional (Siegel & Driscoll, 1996).	*Basal state:* RHA > RLA in density of D1 receptors in NA. *Stress*: RHA increase DA in prefrontal cortex (D'Angio et al., 1988), decrease 5-HT in hypothalamus; RLA increase 5-HIAA in hypothalamus (Driscoll et al., 1983), increase in CRF and plasma corticosterone (Driscoll & Bättig, 1982).
HR vs. LR Rats (Dellu et al., 1996)	
General Behavior: HR more exploratory, respond more for amphetamine and food reward, more preference for novelty.	*Basal state:* HR higher DA activity in NA lower DA in cortex. DA in NA correlates pos., DA in cortex correlates neg. with activity in novel situations. *Stress:* HR more increase in DA in NA.
Dominant vs. Submissive Monkeys (Kaplan et al., 2002)	
General Behavior: dominance and submission.	*Basal state:* Dominants have higher levels of HVA and MHPG in CSF. HVA and MHPG correlate pos. with social rank. No diff. on 5-HIAA.

Note. RHA = Roman high avoidance; RLA = Roman low avoidance; D1 = dopamine 1 (receptors); DA = dopamine; VEP = visual evoked potentials (cortical); 5-HT = 5-hydroxytryptamine (serotonin); 5-HIAA = 5-hydroxyindoleacetic acid (serotonin metabolite); CRF = corticotropin releasing factor; CSF = cerebrospinal fluid; HR = high reactive (to novelty), LR = low reactive; NA = nucleus accumbens; pos. = positively; neg. = negatively; HVA = homovanillic acid; MHPG = 3-methoxy-4 hydroxyphenylglyco; diff. = difference.

Enzymes like MAO and dopamine beta-hydroxylase (DBH) may also affect reactivity. Interactions among the three monoamines are also a factor, as shown by double-headed arrows in the figure. Hormones like testosterone and the endorphins may affect the trait through their own activation or suppression effects or through their effects on neurotransmitters.

Monoamine Research With Animals

To what extent is the latest model supported by research? Table 1.3 summarizes some of the animal studies. I have already discussed the studies contrasting RHA and RLA rats. Dellu, Piazza, Mayo, LeMoal, and Simon (1996) constructed another rat model, using reactions to novel environments

to select high and low reactives (HRs and LRs), with *reactivity* defined in terms of exploratiVeness. The HRs had higher levels of the DA metabolite dihydroxyphenylacetic acid (DOPAC) in the nucleus accumbens and lower levels in the prefrontal lobes. A measure of exploratiVeness correlated positively with DOPAC in the nucleus accumbens and negatively with DOPAC in the prefrontal cortex. Other investigators have suggested reciprocal effects between DA in the prefrontal lobes and in the nucleus accumbens. The RHA rats did show higher levels of DA reactivity to stress in the prefrontal lobes, but this could be due to enhanced receptor sensitivity produced by low levels in the basal state. The results of these studies suggest that we may have to be more specific in pharmacological studies of personality. The nucleus accumbens is the major site for reward from electrical self-stimulation and stimulant drugs (amphetamine and cocaine; Bozarth, 1987). The nucleus accumbens is part of the medial forebrain bundle hypothesized to be the major neurological locus for sensation seeking.

Dominance is a trait correlated with sensation seeking in humans and exploration in animals. Although it is not a direct analogue of sensation seeking, it would be difficult to find a submissive sensation seeker or a dominant low sensation seeker. A study of monkeys living in a natural colony assessed dominance and aggressiveness and took CSF samples for assay of DOPAC (Kaplan, Manuck, Fontenot, & Mann, 2002). They found higher levels of CSF homovanillic acid (HVA) in the more dominant and aggressive monkeys. CSF levels, of course, do not tell us the origins in the brain (or spinal cord) of the CSF metabolite. Human CSF studies of the monoamines are discussed in the next subsection.

Ellison (1977) did chemical lesioning of the serotonergic and noradrenergic systems in rats living in a specially constructed laboratory community with passageways, burrows, and a common arena in which rats could interact. Chemical lesioning of the serotonergic system produced increases in exploratiVeness, sociability, and aggression. Lesioning of the noradrenergic system produced less social interaction but more exploratiVeness. Lesioning of both systems increased the effects of the lesioning of the serotonergic system alone. These studies support the part of the theory claiming that low levels of serotonin (disinhibition) and low levels of NE (low arousal) are characteristic in high sensation seekers.

Monoamine Research With Humans

Table 1.4 summarizes monoamine research done with human subjects. The earliest approach was to examine levels of the neurotransmitters or their metabolites in CSF, plasma, or urine. The CSF measures obtained from lumbar spinal taps are closest to the brain itself, although some of their source may be in the spinal cord. Even the part originating in the

TABLE 1.4
Monoamines and Sensation Seeking: Human Studies

	Results related to sensation seeking
Behavioral expressions	Risk taking, drinking, drugs, smoking, gambling, sex, extreme sports, reckless fast driving, volunteering for dangerous or stressful jobs. Preferences for novel, intense, or complex stimuli.
Dopamine and metabolites basal levels in CSF	No significant correlations with DA metabolites in CSF (Ballenger et al., 1983; Limson et al., 1991).
Responses to challenges by DA agonists	*Apomorphine effect on growth hormone (GH):* Pos. correlation with SSS–BS (Wiesbeck et al., 1996) and NS (Wiesbeck et al., 1995). *Bromocryptine (BC) effect on GH:* GH pos. correlations with NS and neg. correlations with BC inhibition measured by PRL in addicts and controls (Gerra et al., 2000). No correlation of SSS–Dis and SSS–BS with PRL (Depue, 1995). *Lisuride effect on prolactin (PRL):* No correlation of PRL with SSS–ES and SSS–Dis (Netter et al., 1996).
Seratonin metabolite (5-HIAA) in CSF	No correlations with SSS (Ballenger et al., 1983; Limson et al., 1991).
Responses to challenges by serotonin agonists	*Fenfluramine effect on PRL:* PRL and SSS–Dis and SSS–BS (Depue, 1995). Neg. correlation with NS, addicts only (Gerra et al., 2000). Blunted serotonin response in high SSS–ES (Netter et al., 1996). Blunted serotonin responsivity to Pinodel correlates with SSS–Dis (Hennig et al. 1998).
NE and metabolite (MHPG) in CSF and plasma	CSF NE (but not MHPG) neg. correlation with SSS–Gen in normal controls (Ballenger et al., 1983). Plasma MHPG neg. correlation with Total SSS in normal controls (Arqué et al., 1988). Plasma NE pos. correlation with NS in normal males (Gerra et al., 1999).
Challenge to NE by clonidine	No correlation with NS in either addicts or controls, but a pos. correlation with harm avoidance in addicts (Gerra et al., 2000).

Note. DA = dopamine; CSF = cerebrospinal fluid; pos. = positive; neg. = negative; SSS = Sensation Seeking Scale; SSS–BS = Boredom Susceptibility subscale of SSS; SSS–Dis = Disinhibition subscale of SSS; SSS–Gen = SSS General Scale; PRL = prolactin; NE = norepinephrine; MHPG = 3-methoxy-4-hydroxyphenylglycol; NS = novelty seeking.

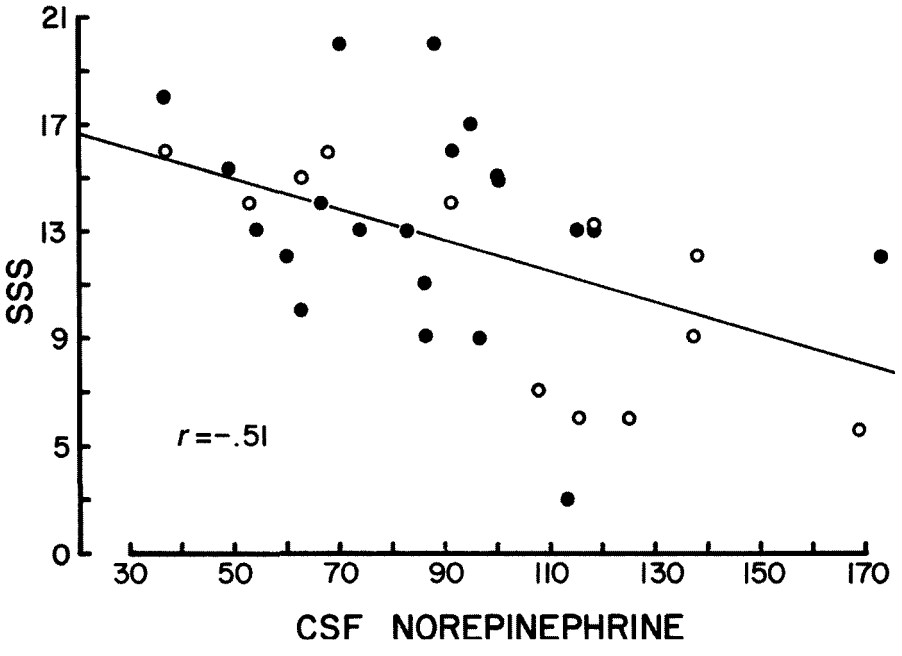


Figure 1.11. A scatterplot for the correlation of cerebrospinal fluid (CSF) norepinephrine and sensation seeking. Solid circles represent male data; open circles represent female data. SSS = Sensation Seeking Scale; CSF = Cerebrospinal fluid. From "Biochemical Correlates of Personality Traits in Normals: An Exploratory Study," by J. C. Ballenger et al., *Personality and Individual Differences, 4*, p. 621. Copyright 1983 by Elsevier Science. Reprinted with permission.

CSF-filled ventricles of the brain is indefinite in the part of the brain it comes from. Although the CSF is obtained in what is supposed to be a basal state, the drawing of a sample from a spinal puncture is not exactly a stress-free situation, either in anticipation or execution of the procedure.

The studies referred to in the table yielded null results in correlating CSF monoamines with personality, except for one notable exception: Ballenger et al. (1983) found a substantial (r = −.51) negative correlation between CSF NE and the SSS General Scale as shown in Figure 1.11. This result has not yet been replicated, although the strength of the association is promising. Perhaps the low level of NE is an indicator of the lack of fearful arousal in high sensation seekers, but plasma NE correlated positively with novelty seeking (NS) in one study (Gerra et al., 1999). The metabolites of NE, DA, and 5-HT (5-hydroxytryptamine [serotonin])—3-methoxy-4-hydroxyphenylglycol (MHPG), HVA, and 5-hydroxyindoleacetic (5-HIAA), respectively—in CSF, plasma, and urine were not related to sensation seeking, except for a negative correlation with plasma MHPG.

Better results on serotonin have been found in studies using neurotransmitter agonists and antagonists to measure the response of the systems as

assessed by hormonal reactions. Several studies found that the prolactin response to a serotonin agonist correlated negatively with the SSS or NS scales (Depue, 1995; Gerra et al., 2000; Hennig et al., 1998; Netter, Hennig, & Roed, 1996) and also with impulsivity, aggression, and H. J. Eysenck's P scale (Depue, 1995). P is the best marker for the Impulsive Unsocialized Sensation Seeking factor. Dis was not related to DA reactivity, although the P scale was negatively related to response to a DA antagonist, suggesting higher DA reactivity in high P scorers. Netter et al. (1996) found insensitivity to a serotonin stimulant in high sensation seekers but no relationship to indicators of DA reactivity to an agonist.

Wiesbeck, Mauerer, Thome, Jakob, and Boening (1995) found a significant relationship between growth hormone (GH) release by a DA agonist (a putative measure of D2 receptor sensitivity) and Cloninger's (1987b) Novelty Seeking (NS) scale. The subjects were abstinent alcoholic individuals, but there was no relationship of the GH response and their alcohol history factors.

In another study using controls as well as alcoholic individuals, Wiesbeck et al. (1996) correlated the GH response to the SSS. Only the BS subscale of the SSS correlated significantly with GH response to the DA agonist in the controls and in the alcoholic individuals with a positive family history for alcoholism. Both alcoholic groups were significantly higher than the controls on BS.

The studies of humans confirm evidence of higher serotonergic reactivity in low sensation seekers found in animals, but there is mixed evidence of high dopaminergic reactivity in high sensation seekers, possibly because this is confined to the limbic system pathway and not evident in the indirect samples of activity measured in humans.

GENETICS

Twin Studies

Individual differences that have a strong biological determination would be expected to show high levels of heritability through the heritability of the biological traits on which they are based. Sensation seeking satisfies this criterion, as I show in this section.

Fulker, Eysenck, and Zuckerman (1980) did the first biometric study of sensation seeking using a sample of English twins (see Table 1.5). They found a heritability for the SSS–V Total score of .58. This is quite high for a personality trait, most of which have heritabilities falling between .30 and .50 (Bouchard, 1994; Loehlin, 1992). There was no evidence of a shared environmental factor (as with most personality traits), and the remainder

TABLE 1.5
Correlations and Heritabilities of Sensation Seeking: Twin Studies

Study	Sex	IT	FT	h^2
Fulker, Eysenck, & Zuckerman (1980):	M	.63	.21	.58
Twins raised together	F	.56	.21	—
Minnesota study: twins separated at or	M & F	.54	.32	—
near birth, raised separately	h^2	.54	.64	.59

Note. Values are from the Sensation Seeking Scale Form V Total score. IT = identical twins; FT = fraternal twins; h^2 = heritability; M = male; F = female.

of the variance is due to nonshared environment and error of measurement. The comparison of identical and fraternal twins raised in the same family environments has been questioned. The higher correlations between identical than between fraternal twins might be a function of the identicals being treated more alike than the fraternals, rather than their 100% genetic similarity, compared with the 50% common genes in the fraternals. Identical twins are treated more alike, but it is hard to tell how much this is a function of their physical similarity, their tendency to be more closely bonded, or the fact that they actually behave more similarly than fraternals. The question can be answered by studying twins who were separated soon after birth and raised in different families.

The Minnesota separated twin study has looked at sensation seeking (Hur & Bouchard, 1997). Lykken (personal communication, 1992) reported the data on separated twins shown in Table 1.5. The correlation between identical twins raised separately ($r = .54$) is also a direct measure of heritability because there is no shared environment. The correlation of separated fraternal twins must be doubled to obtain the heritability because they share only half of their genes. This yields a heritability of .64. If we average these two, we get a heritability of .59, which is nearly the same as the .58 obtained from Fulker et al.'s (1980) study of nonseparated twins. This seems to reinforce the conclusion that the shared environment contributes nothing to the twins' similarities on the trait. I discuss a caveat to this conclusion later in this chapter.

H. J. Eysenck (1983) analyzed the genetics of the subscales of the SSS using the data from the Fulker et al. (1980) study. He found evidence for a common genetic factor among all subscales and also some genetic factors specific to the individual subscales. Heritabilities of three of the subscales (ES, Dis, TAS) ranged from .42 to .56. BS was lower, probably because of its lower scale reliability. Hur and Bouchard (1997) analyzed the subscale data from the separated twin study, and Koopmans, Boomsma, Heath, and Lorenz (1995) did so for a Dutch sample of twins raised together. The heritabilities of the SSS subscales in all of these studies are shown in Table

TABLE 1.6
Heritabilities of the Sensation Seeking Scale (SSS) Subscales

SSS subscale	H. J. Eysenck (1983)		Koopmans et al. (1995)		Hur & Bouchard (1997)	
	M	F	M	F	M & F	*M* (all)
Dis	.51	.41	.62	.60	.46	.50
TAS	.45	.44	.62	.63	.54	.54
ES	.58	.57	.56	.58	.55	.57
BS	.41	.34	.48	.54	.40	.43

Note. Dis = Disinhibition; TAS = Thrill and Adventure Seeking; ES = Experience Seeking; BS = Boredom Susceptibility; M = males; F = females. From *Molecular Genetics and the Human Personality* (p. 198), edited by J. Benjamin, R. P. Ebstein, and R. H. Belmaker, 2002, Washington, DC: American Psychiatric Publishing. Copyright 2002 by American Psychiatric Publishing. Adapted with permission.

1.6. With the exception of the BS scale, the heritabilities for all of the other scales are relatively high (.50–.63) and not too different from one another.

Judging from the results comparing (a) identical and fraternal twins and (b) twins raised apart with twins raised together, sharing a common family environment, there is little or no effect of the shared environment. The environment itself is not assessed in these studies. Kraft and Zuckerman (1999) compared personality scores with college students' descriptions of their fathers' and mothers' affection, punishment and rejection, and control, using a parental description questionnaire. Children raised entirely by both biological parents and children from families with a stepfather were both used. Within the intact families, the Impulsive Sensation Seeking (ImpSS) subscale of the Zuckerman–Kuhlman Personality Questionnaire (ZKPQ; Zuckerman, 2002; Zuckerman, Kuhlman, Joireman, Teta, & Kraft, 1993) did not correlate with any of the dimensions of parental attitudes and behavior for either parent. If there had been some positive results, their interpretation would have been ambiguous because they could be expressions of genetic or environmental influences. But the absence of any significant results tends to support the idea of a lack of shared environmental influence on ImpSS.

Bratko and Butkovic (2003) gave parental attitude and behavior scales to the parents themselves and correlated parents' self-reports and those of their partners describing themselves and their spouses with their children's SSS scores. Only the father's control score correlated with the SSS Total and Dis scores. Fathers who were more permissive and less controlling in regard to their children's behaviors had children who were more disinhibited. Of course, this could be a genetic as well as an environmental effect because fathers who are more permissive of disinhibited behavior in their children are more likely to be disinhibited themselves.

Another way of examining the influence of shared family environment was used in a twin study conducted in the Netherlands. The study compared twins who had been raised in a nonreligious home and those who had been raised in a religious home (Boomsma, de Geus, van Baal, & Koopmans, 1999). The Dis subscale had shown significant genetic effects but no effect of shared environment in the total population. However, when the twins were subdivided on the basis of their religious upbringing, the twins raised in a religious background showed 0% effect of genetics for males and only a weak one for females (37%). In contrast, the shared environment effect was 62% for males and 37% for females, both significant. But those raised in a nonreligious environment had the same results as the total population, a significant effect of genetics (61% for females and 49% for males) and practically none (0% for females and 11% for males) for shared environment. Religious upbringing itself was not genetic but purely environmental.

As one would expect, those raised in a religious home had lower scores on the Dis subscale, but there was no difference between the two groups in the variance that might have affected the heritabilities. Few twin studies use this approach, and these results suggest that one may have to assess critical environmental factors within the twin samples to detect heredity–environment interactions like this one. There may be more variation in parental control in religious homes than in permissive nonreligious homes.

Moffitt, Caspi, and Rutter (2006) called this type of interaction *heritability–environment interaction* and distinguished it from *gene–environment interaction*. In the latter, a specific interaction in the DNA sequence interacts with a specific environmental factor. As an example of the latter, Caspi et al. (2002) found that variations in the genotype affecting Type-A MAO expression interacted with childhood maltreatment to influence later expressions in conduct disorder, antisocial personality disorder, and violent crimes.

Twin studies assess broad heritability, including additive, Mendelian, and epistatic types of genetic mechanisms. The last of these depends on specific gene combinations rather than on the sheer number of genes involved in a trait. Parent–child or sibling studies assess only the narrow additive type. Discrepancies between the two methods could be due to the effects of nonadditive genetic mechanisms only found in identical twins because of their identical sets of genes. Many personality traits do show such discrepancies.

Parent–Child Studies

Bratko and Butkovic (2003) analyzed parent–child correlations on sensation seeking (see Table 1.7). The midparent scores' (average of mother and father's SSS scores) correlation with their children's scores on the SSS

TABLE 1.7
Parent–Child and Father–Mother Correlations on the Sensation Seeking Scale (SSS) and Its Subscales

Relationship	TAS	ES	Dis	BS	Total SSS
Father–Child	.25**	.26**	.27**	.18	.33**
Mother–Child	.02	.15	.24**	.11	.16
Midparent–Child	.24*	.25**	.32**	.19	.31**
Father–Mother	.15	.26**	.46**	.31*	.44**

Note. TAS = Thrill and Adventure Seeking, ES = Experience Seeking, Dis = Disinhibition, BS = Boredom Susceptibility. From "Family Study of Sensation Seeking," by D. Bratko and A. Butkovic, 2003, *Personality and Individual Differences, 35,* p. 1564. Copyright 2003 by Pergamon Press. Reprinted with permission.
*$p < .05$. **$p < .01$.

is a measure of narrow heritability, and in this case ($h = .31$) it is about half of the heritability estimate from the twin studies ($h = .59$) described previously. These results suggest that there are either nonadditive genetic factors involved in sensation seeking or biasing factors in the twin studies.

In a previous study (Kish & Donnenwerth, 1972), mothers' scores alone did not correlate at all with children's scores, but the fathers' and daughters' scores on the SSS General were significantly correlated ($r = .39$). In the more recent study (Bratko & Butkovic, 2003), this correlation was also significant for the Total score ($r = .36$). Fathers' TAS scores did not correlate significantly with their sons' Total scores ($r = .28$), but the father–son correlation on the TAS subscale itself ($r = .38$) was significant.

Assortative Mating

There are two opposite sayings regarding the personality attractions between those who marry: *like attracts like* and *opposites attract.* The first is probably truer for attitudes, interests, and values, but there is little evidence for either in studies of personality resemblance or differences between spouses. Personality trait correlations between spouses are usually low or close to zero (Ahern, Johnson, Wilson, McClearn, & Vandenberg, 1982; Donnellan, Conger, & Bryant, 2004; H. J. Eysenck, 1990). Sensation seeking is an exception. Correlations have been found between the SSS scores of husbands and wives in the United States, Germany, Israel, and the Netherlands (Bratko & Butkovik, 2003; Farley & Davis, 1977; Farley & Mueller, 1978; Ficher, Zuckerman, & Neeb, 1981; Ficher, Zuckerman, & Steinberg, 1988; Glicksohn & Golan, 2001; Lesnik-Oberstein & Cohen, 1984). Couples in long-term premarital relationships also show a moderate correlation between partners on the SSS (Thornquist & Zuckerman, 1995).

The high degree of assortative attraction and mating for the trait of sensation seeking suggests its biological importance. If it has an evolutionary

history, it would explain the continued variation in sensation seeking trait because there would be selective breeding at both ends of the trait distribution. For the female there may be a trade-off between reliability in a mate (low sensation seekers) and attractiveness as a sexual partner (high sensation seekers). D. M. Buss et al.'s (1990) study of mate selection across 37 different cultures found remarkable consistency across gender and culture in the highest three attributes, ranked from highest to lowest: kind, intelligent, exciting personality. The third-ranked trait would likely pertain to sensation seekers. Linton and Wiener (2001) compared personality and a measure of potential mating success (PMS) in a male sample. Dis correlated with PMS in the single heterosexual sample, and TAS correlated with PMS in the attached heterosexual sample.

Molecular Genetics

The completion of the human genome project has opened new possibilities for the identification of specific genes involved in personality and its disorders. During the past 2 decades, the search for major genes involved in psychiatric disorders has dominated research efforts, with little success in finding replicable results. The problem is that nearly all of these disorders are polygenic and may involve contributions from many genes of small effects. There is always the possibility of finding genes with major effects, but even these will require very large samples of patients afflicted with the disorder.

More recently, attention has turned to finding genes associated with normally distributed personality traits. One of the first fruits of this research was the discovery by Ebstein et al. (1996) in Israel of an association between the gene for the dopamine 4 receptor (DRD4) and the Cloninger (1987b) scale, called Novelty Seeking (NS). NS correlates highly (r = .68) with the ImpSS scale (Zuckerman & Cloninger, 1996). Although there are a number of forms of the gene, ranging from 2 to 10 repeats of the base sequence, the most common forms in Western populations, including the Israeli, are a short form, with four repeats, and a long form, with seven repeats. The longer forms were associated with high scores on the NS scale, and the shorter forms with low to medium scores on this scale. This finding was followed by many attempts to replicate it, although some used other personality scales. Prolo and Licinio (2002) summarized the studies to that date with successful replications in 11 out of 21 groups. Schinka, Letsch, and Crawford (2002) did a meta-analysis of these groups and concluded that there was no overall effect contrasting the seven-repeat allele with shorter repeats, but studies comparing all short and long sequences yielded a small but significant effect.

Given the polygenetic nature of this and other personality traits, a combination of related genes might yield a larger effect. Comings, Saucier, and MacMurray (2002) found that four dopamine receptor genes acted in an additive manner to contribute 5.25% of the variance of NS. Noble (1998) reported similar additive effects for the dopamine 2 receptor (DRD2) and DRD4.

Interactive genetic effects are entirely likely, given the evidence for epistatic genetic variance in many of the behavior genetic studies of personality. One study found such evidence for genetic interaction (Strobel, Lesch, & Brocke, 2003). The DRD4 long allele form by itself was not associated with high NS, but when the short allele of the serotonin transporter gene and an allele of the catechol-O-methyltransferase (COMT) were present, the association of DRD4 with NS was significant. What gives one more confidence in the role of the DRD4 in sensation seeking is the association of the gene with forms of behavior found in high sensation seekers, like heroin and alcohol abuse, gambling, and attention-deficit/hyperactivity disorder (Ebstein & Kotler, 2002).

The long form of the gene in newborn infants is associated with orientation to novel stimuli, an early measure of the strength of the approach mechanism (Ebstein & Auerbach, 2002). In an earlier section, I described the results showing stronger OR responses in high than in low sensation seekers. There was also an interaction of the DRD4 with the serotonin (5-HT) transporter promoter. The short form of the 5-HT promoter is associated with anxiety in humans (Munafò et al., 2003). The investigators found that the long form combines with the long form of the DRD4 to enhance the infants' ORs, whereas the short form of the promoter combined with the short DRD4 reduces orientation and increases negative emotionality and distress.

Ebstein and Auerbach (2002) interpreted their findings in a manner consistent with my humoral model of sensation seeking that was shown in Figure 1.10: Dopaminergic pathways mediate approach behavior and impulsive sensation seeking, whereas serotoninergic pathways inhibit such behavior. The strength of the approach mechanism and ImpSS depends on the relative reactivity of dopaminergic and serotonergic systems, which act in reciprocal opposition.

NEW FORMS OF SENSATION SEEKING SCALES

Since the development of SSS–II, SSS–IV, and SSS–V, new forms have been developed for different reasons. Some are merely attempts to shorten the scale (e.g., Hoyle, Stephenson, Palmgreen, Lorch, & Donohew, 2002), although the form 40-item SSS–V takes only about 20 minutes.

Some, like Form VI (SSS–VI; Zuckerman, 1984a), are put in a different form to separate desire or intention from actual behavioral experience. The older forms confound the two types of items. The ImpSS scale was developed from factor analyses of sensation seeking items with items from other personality trait scales and is in a true–false, rather than forced-choice, form (Zuckerman, Kuhlman, Joireman, Teta, & Kraft, 1993). It also combines impulsivity and sensation seeking items, as the title of the scale implies.

Cloninger's (1987b) NS Scale (a true–false form) resembles the ImpSS scale and is highly correlated with it. Of all the modified forms, it has received the most attention from researchers, particularly in the psychiatric and psychobiological fields. Arnett's (1994) Inventory of Sensation Seeking (AISS) represents a new conceptualization of sensation seeking, including two major factors: novelty and intensity.

Some of the criticisms of the standard sensation seeking scales are valid. The original scales (II, IV, V) contained some now-anachronistic terms, like *hippies*, *jet-setters*, and *swingers*, that are unfamiliar to younger generations. I made some attempt to modify the test by either substituting other terms or including a definition of the older term in the item (Zuckerman, 1996a). The forced-choice form is unnecessary because social desirability did not prove to be a problem with this scale as it is for scales measuring neuroticism or psychopathology. Despite these drawbacks, the scale has established its validity in many hundreds of studies, and most subjects do not find much problem in taking the forced-choice form. The Likert-type form used in some of the new forms has its own response-set problems, like the tendency to use extremes or middle points on the scales. Likert-type scales are used to get some range of scores on short forms using a small number of items. Of course, this limits the representativeness of the items selected and, therefore, the content validity. The SSS was designed for late adolescents and adults only. Russo et al. (1993) constructed a children's scale, which can be used from ages 9 to 14. There are also child versions in Spanish (Pérez, Ortet, Pla, & Simó, 1986) and Swedish (Björk-Åkesson, 1990). The Spanish version is for children 11 to 15 years of age, and the Swedish scale is designed for children between 12 and 15 years old.

There have been many translations of the SSS and new forms in other languages. Translations are tricky because equivalent terms from two languages are sometimes difficult to ascertain. Back-translations are desirable to make sure the translated items are still close to their originals in English. It is reassuring that the same four-factor structure has appeared in most of the translations. Some of these scales are described in Appendix I of Zuckerman (1994). Newer translations are mentioned in the text as they are used in research.

Readers may want to consider these new scales if they see an advantage in them for particular populations, economy of time, or their appropriateness

for particular kinds of research. One cannot automatically assume that findings on the older sensation seeking scales will hold for the new scales. I attempt to describe some of the validity studies done with these newer scales, but details can be found in the subsequent chapters on different types of risk taking.

Sensation Seeking Scale Forms II and IV General Scale

The General Scale was the first SSS scale to be developed. I include it here because I am often asked for a shorter form for the SSS. Those in search of a scale that is shorter than the 40-item SSS–V might consider the 22-item SSS–II General Scale (Zuckerman et al., 1964), which was carried over into SSS–IV (Zuckerman, 1971). The items were selected from those loading most highly on the first unrotated factor from an item factor analysis and confirmed with item–total correlations. Internal (alpha) coefficients in SSS–II range from .68 to .74. In SSS–IV, the alphas range from .68 to .80. Retest reliability after 1 week is .89; after 3 weeks, .89; and after 6 to 8 months, .75.

The experimental scale (SSS–I), from which the SSS–II General Scale was derived, included mostly items from the future TAS, ES, and BS subscales, but not from the Dis subscale. One cannot get subscale factor scores from the General form. It correlates .74. with the SSS–V Total score, which is balanced with 10 items for each of the four factors. Much of the earlier research on volunteering, drinking, drugs, and extreme sports was done using the SSS–II General Scale. Details on reliabilities and interscale correlations of SSS–IV and SSS–V and can be found in previous volumes (Zuckerman, 1979a, 1994). A copy of SSS–IV can be found in Zuckerman (1979a), and a copy of SSS–V (including some revisions in item wording) is contained in Zuckerman (1994). A copy of SSS–V and its unpublished manual can also be obtained from the author.

Sensation Seeking Scale Form VI

The older forms of the SSS included two types of items referring to behavior. One type expressed a desire to engage in some type of activity. Most of the TAS items were of this type because it was assumed that most younger persons would not have had the opportunity to engage in sports like skydiving, scuba diving, or flying an airplane but that the intention to do so would indicate a TAS tendency that might be expressed in other ways, like reckless or fast driving. Another type of item was put in terms of actual experiences, for instance, "I like wild, uninhibited parties." Most of these items were on the Dis subscale. Most items on the ES and BS

scales are expressed as preferences not easily translatable into behavioral expressions.

The separation of items expressing desire or intention from those describing experience could be useful. Although I expected intention and experience scales to be substantially correlated, it is possible that some persons are "latent sensation seekers" with a strong desire to do sensation seeking kinds of things but are restrained from doing so by life circumstances, like family responsibilities or economic circumstances. They would have high scores on desire or intention but low scores on experience. Sensation seeking declines with age, particularly on TAS and Dis subscales. But in some cases, this decline is more precipitous than in others. Depression or negative life experiences might create a discrepancy between intentions for the future and experiences from the past. This kind of information could be useful for clinicians. The experience scales of the SSS–VI resemble omnibus risk-taking scales that are described in chapter 2.

The SSS–VI (Zuckerman, 1984a) consists of four subscales: TAS Intentions (TAS-Int), Dis Intentions (Dis-Int), TAS Experience (TAS-Exp), and Dis Experience (Dis-Exp). Each item on the intentions subscales has a corresponding item on the experience subscales. For instance, "I would like to try skydiving" (TAS-Int) and "I have gone skydiving" (TAS-Exp). Norms are provided for each subscale so that discrepancy scores can be calculated by subtraction of *T* scores. There are 64 items on the experience scales and 64 on the intentions scales, for a total of 128 items. Items are in the form of 3-point Likert-type scales. Retest reliabilities for the four subscales are high (.84–.93). Internal reliabilities are high for TAS-Int, Dis-Int, and Dis-Exp (α = .83–.94) but are lower for TAS-Exp, probably because of its more restricted range. A copy of the scale and college population based norms are included in Zuckerman (1994).

Impulsive Sensation Seeking

The ImpSS scale is part of a five-factor personality scale, the Zuckerman–Kuhlman Personality Questionnaire (ZKPQ; Zuckerman, 2002; see also Zuckerman et al., 1993). The scale is a 19-item true–false form. The five primary subscales in the ZKPQ were derived from factor analyses of scales including the subscales of SSS–V and a variety of impulsivity scales (Zuckerman, 1991; Zuckerman, Kuhlman, et al., 1988). All of the subscales of the SSS and impulsivity scales loaded on a factor along with H. J. Eysenck's P scale. At the opposite pole of this factor were scales for socialization, restraint, responsibility, and inhibition of aggression. We therefore named the factor Impulsive Unsocialized Sensation Seeking. Later item factor analyses also found this factor including all scale elements, except for the items

representing socialization. We therefore shortened the name of the scale to Impulsive Sensation Seeking (ImpSS). Aggression and Inhibition of Aggression loaded on another factor (Aggression–Hostility [Agg-Host]) in a five-factor analysis. Aggression represents the unsocialized aspect of the broader factor found in three factor analyses. The other three subscales in the ZKPQ are Sociability, Neuroticism–Anxiety (N-Anx), and Activity.

Alpha reliabilities for the ImpSS are .77 for men and .81 for women in an American college population. The ZKPQ has been translated into Spanish, Catalan, German, Chinese, and Japanese. Reliabilities of ImpSS in these translated scales range from .68 to .83, and all but the lowest of these are in the range of .76 to .83 (Zuckerman, 2002). Retest reliabilities for 3 to 4 weeks in American students is .80. Men score significantly higher than women. Factor analyses of the items within the scale revealed two subfactors: Impulsivity and Sensation Seeking. The type of impulsivity in those items is the "nonplanning" sort. The "Imp" in ImpSS does not think ahead to possible complications when acting on impulse. One may easily engage in risky behavior if one does not think about the risks. The items in the SS part are a combination of Dis and ES types. Unlike items on the SSS–V, there are no specific activities mentioned in the items except for a liking of "wild parties." Most of the items are stated in general terms like "I sometimes do 'crazy' things just for fun." The alpha reliabilities of the Imp subscale are .74 for males and .77 for females. Those for the SS subscale are .64 for males and .68 for females.

The ImpSS is meant to be used as part of the five-factor ZKPQ because it is often a combination of ImpSS with other factors that distinguishes groups. Generalized risk takers, for instance, score high on ImpSS, Agg–Host, and Sociability (Zuckerman & Kuhlman, 2000). Prostitutes score high on ImpSS and Aggression subscales (O'Sullivan, Zuckerman, & Kraft, 1996). Severity of drug abuse and addiction and treatment outcomes among cocaine abusers is related to ImpSS, Agg-Host, and N-Anx (S. A. Ball, 1995). If the ImpSS scale is used out of the context of the entire ZKPQ, it would be desirable to scatter the items among other types of items so that the basic trait is not as obvious as it would be if all the items were grouped together.

ImpSS is not a substitute for the SSS–V, because it does not include the four subscales of the latter. It does correlate highly with the SSS–V Total score (r = .66) but only moderately with the subscales TAS, ES, and Dis (rs = .43–.45) and lower with BS (r = .37). If only an overall measure of sensation seeking is desired, then the ImpSS may serve. But if other research and theoretical considerations indicate a need for one of the SSS–V subscales, then use of ImpSS alone may be less effective. ImpSS should be useful in research on drugs, drinking, and sex, because unlike the SSS–V, it does not confound the item content with the activities predicted and

includes a subscale, Impulsivity, which is often involved with sensation seeking in these activities.

Novelty Seeking Scale

Cloninger (1987b; Cloninger, Svrakic, & Przybeck, 1993) has a psychobiological model for personality from which he developed questionnaire measures. He is the only other test designer to make sensation seeking, or *novelty seeking* (NS), a major personality factor rather than a facet of some other factor like Extraversion in the Big Five. NS was originally regarded as one of the three major personality factors, the others being Reward Dependence and Harm Avoidance, and was part of the Tridimensional Personality Questionnaire (Cloninger, 1987b). More recently, the test was expanded to include additional dimensions of personality: persistence, self-directiveness, cooperativeness, and self-transcendence. NS is described as having a "heritable bias in the activation or initiation of behaviors such as frequent exploratory activity in response to novelty, impulsive decision making, extravagance in approach to cues of reward, and quick loss of temper and active avoidance of frustration" (Cloninger et al., 1993, p. 977).

One can see the similarity in definition of NS to SS, particularly ImpSS. The items in NS include impulsivity items of the nonplanning type, as in the ImpSS. The correlation between a 20-item form of NS and ImpSS was .68 (Zuckerman & Cloninger, 1996). NS also correlated highly (r = .55) with the SSS–V Total Scale. NS correlated significantly with all of the SSS subscales but most highly with ES and Dis (rs = .46, .43).

More recently, Cloninger et al. (1993) constructed four facet scales for the NS: (a) exploratory excitability versus rigidity, (b) impulsiveness versus reflection, (c) extravagance versus reserve, and (d) disorderliness versus regimentation. Harrod (personal communication, 1996) correlated the ImpSS and SSS–V Total score with the NS scale. The SSS Total score correlated highly with NS1 and NS4, and these two facets of NS correlated most highly with Dis and ES among the SSS subscales.

Short Forms for the Sensation Seeking Scale

As previously described, the 22-item SSS–II General Scale can still be used as a shortened form. However, this scale was developed before the four subfactor scales were constructed for the SSS–IV and SSS–V.

Huba, Newcomb, and Bentler (1981) developed a brief form selecting four forced-choice item pairs from each of the SSS subfactors, removing items in which alcohol or drug use was mentioned. The items were put into Likert-type form. Internal consistencies ranged from poor to adequate

(.43–.70). Not much follow-up has been done on this scale, but another group of investigators criticized the deficiencies of the scale and developed one of their own (Hoyle et al., 2002).

Hoyle et al. (2002) selected items from the four SSS–V factors in which the content was appropriate for young and older adolescents and avoided mention of alcohol or drug abuse, dated colloquialisms, or activities unfamiliar to most adolescents. Each of the primary dimensions of sensation seeking is represented by two items, and responses are in a 5-point Likert form ranging from *strongly agree* to *strongly disagree*. No attempt is made to score the subfactors. There is only a total score, adding the weighted responses for eight items, referred to as the Brief Sensation Seeking Scale (BSSS).

Internal consistencies for White and Asiatic/Hispanic groups fell between .74 and .79, whereas those for African American groups were somewhat lower (.68). African American groups scored lower than other groups, particularly because of their lower TAS and ES item scores. There were no ethnic differences on the Dis and BS items. This pattern of ethnic differences is similar to those found for the SSS. Validity consisted of correlations between the BSSS and attitudes toward, and usage of, tobacco, alcohol, and various types of drugs. All of these correlations were significant in all ethnic groups but were generally higher for White than for African American adolescents. The specific results are discussed further in the chapter on drug risk taking.

In a preceding section, I described the development of the ImpSS scale as part of the five-factor ZKPQ scale. Aluja et al. (2006) decided to develop a short form of the ZKPQ using the data from four countries: the United States, Spain, France, and Germany. The data from outside the United States were collected by using translations from the English version into the languages of those countries. The goal was to find a subset of 50 items (10 for each subscale) that loaded on the designated factors in all four countries. They were successful in finding the equivalent five factors among the larger 89-item test and a sufficient number of items loading on the designated factors in all countries. This 50-item cross-cultural short form (ZKPQ-50-CC) more or less guarantees equivalence for the test in these countries and languages. The 10-item ImpSS scale is of particular interest for this book in that it represents the essence of the impulsive sensation seeking factor across countries. The 10 items are listed in Exhibit 1.1. Although only 2 of the 10 items (Items 1 and 9) are from the impulsive facet of the ImpSS, as designated in the longer form, the other sensation seeking items reflect a tendency to engage in spontaneous novelty seeking behaviors without worry about possible risks. Alpha coefficient reliabilities of the short ImpSS scale ranged from .72 to .74 in the four countries. The correlation between the short and long forms of the ImpSS in the total sample was .87.

EXHIBIT 1.1
Short Impulsive Sensation Seeking Scale Based on Item Factor Analyses Done on Translated ZKPQs in Four Countries

1. I often do things on impulse.
2. I would like to take off on a trip with no preplanned or definite routes or timetables.
3. I enjoy getting into new situations where you can't predict how things will turn out.
4. I sometimes like to do things that are a little frightening.
5. I'll try anything once.
6. I would like the kind of life where one is on the move and traveling a lot, with lots of change and excitement.
7. I sometimes do "crazy" things just for fun.
8. I prefer friends who are excitingly unpredictable.
9. I often get so carried away by new and exciting things and ideas that I never think of possible complications.
10. I like "wild" uninhibited parties.

Note. ZKPQ items as presented in Aluja et al., 2006. ZKPQ = Zuckerman–Kuhlman Personality Questionnaire (Zuckerman, 2002; Zuckerman et al., 1993).

Arnett Inventory of Sensation Seeking

Unlike the sensation seeking scales that merely attempt to shorten the standard SSS forms and correct the item content wording, the AISS is also based on a revised construct of sensation seeking (Arnett, 1994). The original definition of *sensation seeking* included both novelty and complexity as characteristics of stimuli sought by high sensation seekers, but it did not include intensity. As described in earlier sections of this chapter, the findings on the HR OR and the visual and auditory cortical EPs, as well as research on music and media preferences (Zuckerman, 2006b), indicated the importance of intensity as well as novelty of stimuli. The more recent definition of sensation seeking includes both factors (Zuckerman, 1994). However, the selection of items for the four factors in the SSS–IV and SSS–V was based on the empirical results from factor analyses of items. Arnett, however, used qualities of novelty and intensity to devise two different subscales for his AISS. He also rejected the use of any items involving "illegal or norm-breaking behavior" such as many of those in the ES and Dis subscales of the SSS. The Total Scale consists of 10 items for a Novelty subscale and 10 for an Intensity subscale. The items are in the form of a four-point Likert scale.

Internal reliabilities were .70 for the Total score and .64 and .50 for the Intensity and Novelty subscales (Arnett, 1994). A more recent study (Roth, 2003) obtained lower reliabilities: .61 for the Total, .53 for intensity, and .52 for Novelty. The AISS Total correlated .41 with the SSS Total

score, and the two subscales correlated even lower (Arnett, 1994). The correlations were practically the same for the two subscales of the AISS. Apparently, the SSS includes some of both in its subscales. The Intensity subscale correlated significantly with TAS and Dis, whereas the Novelty subscale correlated with TAS and ES but not with Dis. Neither intensity nor novelty correlated with BS. Demographic data are consistent with those for the SSS if intensity is equated with Dis and Novelty is equated with ES. Adolescents score higher than adults, and males score higher than females, on the Intensity subscale but not the Novelty subscale. On the SSS, scores on the TAS and Dis decline with age after a peak in late adolescence, and males score higher than females on these subscales. ES shows much less decline with age and does not differ between the genders.

Despite its low internal reliabilities, particularly on the subscales, the AISS is correlated with a variety of types of risky behaviors. These findings are discussed in the next chapters.

Other Tests Highly Related to Sensation Seeking Scale Measures

Variety seeking is part of the definition of *sensation seeking* and is found to be a factor in many kinds of behaviors and preferences. For instance, it is the variety of drugs tried rather than a preference for a specific type of drug that is related to sensation seeking among drug users. Among those sensation seekers who watch television, channel switching is more prevalent among high than low sensation seekers. It is not surprising, therefore, that the SSS General Scale is highly related, close to equivalent, with Garlington and Shimona's (1964) Change Seeker Index and Penney and Rienehr's (1966) Stimulus Variation Seeking Scale. The Need for Change, as measured by Jackson's (1974) Personality Research Form, is also strongly related to the SSS–V Total score.

Novelty seeking has always been a central factor in the definition of sensation seeking, and this is the title Cloninger (1987b) gave to his scale, as discussed in previous sections. Pearson (1970) developed a Novelty Experiencing Scale, which distinguished four types of novelty seeking: external sensation (activities), internal sensation (fantasy and feelings), external cognitive (puzzles, games), and internal cognitive (conceptual problems). All of these four scales were significantly correlated with the SSS General Scale, but only the external sensation scale reached levels of near equivalence (Kohn, Hunt, & Hoffman, 1982). Cognitive experience seeking is not related to sensation seeking as defined by the SSS.

I previously mentioned the confusion between (a) the physiological trait of augmenting–reducing based on cortical EP reactions to different intensities of stimulation and (b) Petrie's (1967) use of the term *augmenting–reducing* to describe individual differences in a psychophysical task, the

Kinesthetic Figural Aftereffect (KFA). Vando (1974) developed a questionnaire called the Reducing–Augmenting (R-A) Scales, designed to identify augmenters and reducers without using Petrie's method. The concept of augmenting–reducing pertains to reactions to intensity of stimulation. One difficulty with the test is that it does not actually correlate with the KFA (Davis et al., 1983). Nearly half of the items on the test are quite similar to those found on the SSS. If endorsed, these are scored as "reducing." Some of the remaining items reflect the preference for intense loud types of music. The remaining two factors are called "General Lifestyle" and "Physical Thrill Seeking." Given the item overlap, it is not surprising that the R-A Scales full scale correlates very highly (*rs* = .60–.71) with the SSS General and Total scores (Dragutinovich, 1987; Kohn, Hunt, Cowles, & Davis, 1986; Kohn et al., 1982). Because of his theoretical identification with the Petrie (1967) model, Vando called what would be high sensation seekers "reducers" and regarded lows as "augmenters," in contradistinction to the findings in humans, cats, and rats using the cortical EP method. There is a patterning of the KFA scales with the SSS subscales. The R-A Scales musical intensity factor correlates most highly with the SSS Dis; the R-A Scales general lifestyle, with the ES and BS; and the R-A Scales thrill seeking, with the TAS.

It is a peculiarity of personality trait research that many times personality tests with different names measure the same thing, or those with the same name measure different things. Block (1995) referred to this as the "jingle-jangle" phenomenon. The real question is not what a test is named but how relevant it is to the construct it purports to operationalize.

The original SSS was developed to measure the optimal level of stimulation and its corollary the optimal level of arousal. Both novelty and intensity increase arousal, and therefore it could be arousal that the high sensation seeker is pursuing, although that theory of sensation seeking was rejected in Zuckerman (1979a). Arousal is regarded now as an epiphenomena of sensation seeking rather than as its primary motive. Mehrabian (1978) developed the scale Arousal Seeking Tendency (AST); many of the items are similar to those on the SSS. It is not surprising that the AST is highly correlated with the SSS General or Total scales (*rs* = .56–.71) in studies by Kohn et al. (1982) and Furnham (1984). The SSS Total is also negatively correlated (*r* = –.54) with the Arousal Avoidance subscale of Apter's (1982) Telic Dominance Scale (Murgatroyd, 1985). More jingle-jangle!

Sensation Seeking and the Big Five

Costa and McCrae (1992a) regarded the Big Five model as the "longitude and latitude" of personality measurement, or the criteria of classification for all other personality tests. However, sensation seeking combined with

impulsivity is a major factor in another five, the alternative five (Zuckerman, Kuhlman, et al., 1988). However the majority of personality investigators today seem to subscribe to the Big Five, and they seem to want to know the longitude and latitude of sensation seeking on the Big Five map. McCrae (1987) correlated the SSS–V with the NEO Personality Inventory (Costa & McCrae, 1992b) Openness to Experience (OE), their fifth factor. OE correlated moderately with the SSS Total (r = .45) and significantly with all of the SSS subscales except BS. But by far the highest correlation was with the SSS ES subscale (r =.51). Both OE and the SSS correlated with tests of divergent thinking.

Openness in the Revised NEO Personality Inventory (NEO-PI-R; Costa & McCrae, 1992b) has six subscales: Fantasy, Esthetics, Values, Feelings, Actions, and Ideas. Recalling the study by Kohn et al. (1982) relating sensation seeking to Pearson's Novelty Seeking Scale, one would expect that the strongest correlation would be between sensation seeking and Actions (closest to the NS external sensation scale). Within the SSS, the scale most resembling the NEO-PI-R OE is ES.

McCrae and Costa (personal communication, 1990) reported that the total SSS correlated significantly with all six facet scores for OE, but those with Values were highest, followed by those for Action and Fantasy, and those with Esthetics and Ideas were lowest. Again, the highest correlation of OE Total was with the SSS ES scale (r = .54).

Zuckerman et al. (1993) compared the ZKPQ five, the NEO-PI-R five, and the H. J. Eysenck three scales in a factor analysis. The ZKPQ ImpSS, the NEO Conscientiousness, and the H. J. Eysenck P scale all had strong loadings on a common factor. The OE scale did not load on this factor. ImpSS correlated –.51 with Conscientiousness, .28 with NEO Extraversion, and –.23 with NEO Agreeableness, but zero with NEO OE and Neuroticism (Zuckerman, 2002). The connection between sensation seeking and OE is probably limited to the experience seeking aspect of sensation seeking. The main connection between sensation seeking and the NEO is with the conscientiousness dimension. Sensation seekers are open to new experiences and sensations (but not ideas) if they are novel, intense, and exciting, but within the NEO they are mostly distinguished by their lack of conscientiousness. This does not mean that they are antisocial but that they are impulsive and nonconforming.

DEFINITION OF *SENSATION SEEKING*

Although the theory of sensation seeking, in terms of its biosocial sources, has changed, the definition of the trait in terms of its behavioral aspects has only slightly changed since the first book written on the topic

(Zuckerman, 1979a). The main change was the inclusion of intensity as a characteristic of sensations and experiences that are rewarding for high sensation seekers and nonrewarding or aversive to low sensation seekers (Zuckerman, 1994). The following definition from the 1994 book is unchanged as given in the following statement: "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, 1994, p. 27).

It should be noted that in this definition, sensation seekers do not seek risk for its own sake. It is not the riskiness of their activities that make them rewarding. In fact, many or most experiences sought by high sensation seekers are not at all risky. Listening to rock music; partying with interesting, stimulating people; and looking at intensely erotic or violent movies or television involve no risk. However, other types of activities, such as driving very fast, engaging in extreme sports, getting drunk or high on drugs, and having unprotected sex with a variety of partners, do involve risk. In the next chapter, I analyze the nature of risk and why sensation seekers are willing to engage in risky behavior for the sake of the rewards of novel and intense stimulation.