chapter 18

Psychedelic Drugs I: Marijuana

Aside from REM sleep, the most dramatic altered states of consciousness are those produced by psychoactive drugs. Psychedelic drugs, in particular, have been used to produce altered states that will—the user hopes—enhance self-understanding, interpersonal communication, creativity, or mystical experience. Failing more profound achievements, they may provide entertainment—with certain risks attached. Psychologists, too, are interested in the effects of psychoactive drugs, not only for their therapeutic benefits, but also for their implications for understanding the workings of the human mind and consciousness.

A *drug* is a chemical, other than food, that is administered to or taken by an individual in order to affect the functioning of the brain or other body organs. Drugs used primarily for their psychological effects, such as effects on mood, thinking, perception, or behavior, are termed *psychoactive drugs*. Of course, some drugs used primarily for other purposes, such as reduction of blood pressure, may have unintended psychological side effects. Table 18.1 shows a classification scheme for psychoactive drugs.[1]

Psychoactive drugs affect consciousness and behavior by modifying the process of *synaptic transmission* in the brain. Excitatory and inhibitory connections between neurons are carried out by transfer of special biochemicals, termed *neurotransmitters*, across the tiny synaptic gap between neurons. Drugs can affect synaptic transmission in a variety of ways, such as blocking the production or reception of a neurotransmitter or mimicking (imitating) a neurotransmitter, thus effectively increasing its activity level. Different

TABLE 18.1 Six Classes of Psychoactive Drugs*

1. CNS Stimulants
   - Amphetamines (*Benzedrine, Dexedrine, Methedrine*)
   - Cocaine ("coke," "crack")
   - Caffeine (coffee, tea, cola drinks, chocolate)
   - Nicotine (tobacco)
2. CNS Depressants
   - Alcohol (ethanol: whiskey, wine, beer)
   - Sedative-hypnotics (sleep-inducing substances) and antianxiety agents (minor tranquilizers)
     - Barbiturates: pentobarbital (*Nembutal*); secobarbital (*Seconal*)
     - Benzodiazepines: clordiazepoxide (*Librium*); diazepam (*Valium*)
     - Others: methaqualone (*Quaalude*); meprobamate (*Miltown, Equanil*)
   - Anesthetic gasses and solvents (ether, chloroform, etc.)
3. Narcotic Analgesics
   - Opiates: opium (active ingredients: morphine; codeine); heroin (semi-synthetic derivative of morphine)
   - Synthetic opiates: meperidine (*Demerol*); methadone (*Dolophine*)
4. Antipsychotic Agents (Major Tranquilizers)
   - Antipsychotic tranquilizers: chlorpromazine (*Thorazine*)
   - Antimanic agent: Lithium carbonate (*Eskalith*)
5. Clinical Antidepressants
   - Monamine oxidase (MAO) inhibitors (*Nardin, Parnate*)
   - Tricyclic compounds (*Tofranil, Elavil*)
6. Psychedelics
   - Major psychedelics (hallucinogens)
     - Psilocybin mushrooms (active ingredient: psilocybin)
     - Peyote (active ingredient: mescaline)
     - LSD (lysergic acid diethylamide)
   - Minor psychedelics
     - Cannabis (marijuana, hashish; main active ingredient: delta-9-THC)

*Examples in each category are representative, not comprehensive. Representative brand names are shown in italics. The major categories of drugs are based on their most characteristic effects or uses. However, most drugs have multiple effects, and their effects vary depending on dosage, time since administration, and personal and situational factors. For more information about these and other psychoactive drugs see McKim 1986, Ray and Ksir 1987, or Julien 1985.

neurotransmitters are present in different parts or circuits of the brain, and the type of psychological effects that a drug has will depend upon which particular neurotransmitter it affects and how it affects it (McKim 1986).

As Tart (1975) explained, however, the psychological effects of drugs depend on more than just their neurophysiological effects. Drug effects are produced by an *interaction* between pharmacological drug factors (type, dose) and several nondrug factors, including: (1) long-term personal factors (personality, culture, attitudes, knowledge, beliefs, learned drug skills); (2) immediate personal factors (mood, expectations, desires); and (3) situational or experimental factors (physical and social setting, formal instructions, implicit demands). The emphasis in the *interaction model* is on factors of *set* (expectations—what the person believes can and will happen as a result of taking the drug) and *setting* (especially the social context in which the drug is taken).

The topic of psychoactive drugs is a large one, and it gets larger each year as new drugs are invented and marketed, either legally or illegally, and the volume of research literature grows at an overwhelming pace. Several books have dealt comprehensively with the physiological and psychological effects of a wide range of psychoactive drugs—from tobacco and alcohol to cocaine and heroin—and the personal and social problems resulting from drug abuse (for example, Julien 1985; McKim 1986; Ray & Ksir 1987). In the limited space available here, it is not possible to thoroughly review the full range of psychoactive drugs. Rather than superficially reviewing the full range of drugs, I will go into some detail on certain drugs that are particularly important for the study of consciousness and altered states, namely, the psychedelic drugs.

Psychedelic drugs are a heterogeneous group whose most striking subjective effects include changes in perception and imagination. "Psychedelic" literally means "mind manifesting" or "mind expanding": the implication is that these drugs may reveal inherent but normally hidden aspects of the individual's mind and/or expand consciousness in the sense of enabling the individual to have sensory perceptions or mystic revelations that would not normally occur. Tart (1972a) distinguished between minor psychedelics and major psychedelics. For minor psychedelics "the effects are felt to be under a fair amount of volitional control by most individuals who use the drugs" (p. 327). Marijuana is the most important minor psychedelic. The major psychedelics are the *hallucinogens*: drugs such as LSD, psilocybin, and mescaline, which produce hallucinations at normal "social" doses. Marijuana does not produce true hallucinations at normal doses, though it may do so at high doses. Indeed, many drugs not usually classed as hallucinogens will produce hallucinations at high or toxic doses.

This chapter will go into some detail on marijuana for two reasons. First, there has been more systematic research on the psychological effects of marijuana than of any other psychedelic drug. Thus, marijuana is a good example to illustrate drug effects on a variety of psychological processes, and also to illustrate psychopharmacology research methods. Second, of the psychedelic drugs, marijuana is the one most widely used by college students, and I suspect that many readers of this book will have some first-hand familiarity with it. If you have used marijuana yourself, you will be interested in comparing your personal experiences with the research findings on marijuana's effects. If you have not used marijuana, this chapter will help you to weigh the potential novel experiences against the potential risks. In the next chapter I will consider the major hallucinogens—LSD, psilocybin, and mescaline—with an emphasis on the hallucination experience.

A BRIEF HISTORY OF MARIJUANA USE

The hemp plant, *Cannabis sativa*, is one of the most important plants in human history (see Figure 18.1). Its fibers have been used to make rope, sails,

FIGURE 18.1. *Cannabis sativa* (marijuana, or hemp) "is classified as a dioecious plant, that is, the male reproductive parts are on one individual (left) and the female parts are on another (right). Details of the two types of flower are shown at bottom. The active substances in the drug are contained in a sticky yellow resin that covers the flower clusters and top leaves of the female plant when it is ripe." [From Grinspoon, L. (1969, June). Marihuana. *Scientific American*, *221*, 17–25. Copyright © 1969 by Scientific American, Inc. All rights reserved.]

and fine cloth. Its leaves and flowers (marijuana) and resin (hashish) have served as both medicine and euphorant, imbibed through smoking or as a drink or cooked in food.

The main active ingredient of cannabis is *delta-9-tetrahydro-cannabinol* (abbreviated as delta-9-THC or simply THC). However, there are over 80 *cannabinoids* (chemicals found exclusively in cannabis), many of which can contribute to the behavioral effects of cannabis, depending on its method of preparation and administration. For example, when marijuana is taken orally, *cannabidiol* (CBD) is ineffective, but when it is smoked the heat converts CBD to delta-9-THC. Other cannabinoids may be converted to more active forms during digestion and metabolism. THC concentration is greatest in the resin found on the flowers, seeds, and upper leaves of the female plant. The resin is a yellowish sap extruded by the flowers. *Hashish* is the resin scraped from the leaves and dried, whereupon it turns dark, almost black. It is usually smoked in a small pipe. THC is not water soluble, but it is soluble in alcohol and fat. Thus, marijuana drinks are usually made with alcohol, whereas marijuana food recipes (such as cookies or brownies) are made with butter (McKim 1986).

Today marijuana is the second most popular recreational drug in America (alcohol is the first). Like alcohol, marijuana has been used for several millennia in many cultures, and its use has been controversial. There is evidence of early use of marijuana throughout much of Asia, India, the Middle East, and Africa. The ancient Greeks used alcohol as an intoxicant, rather than marijuana; however, they traded with marijuana-using peoples, the Scythians. In the twentieth century, laborers from cultures as diverse as India, South Africa, Greece, South America, and Jamaica have used marijuana while they work, in the belief that it helps them to work more energetically, with less fatigue, and with more enjoyment. The Jamestown settlers brought hemp to Virginia in 1611 to cultivate it for its fiber. George Washington grew hemp at Mount Vernon in 1765 for its fiber and perhaps also for medicinal use (Brecher 1972). We do not know whether George ever got stoned just for fun.

During the nineteenth century, marijuana was often prescribed as a medicinal drug, usually administered as an alcohol extract. It was listed in the official *United States Pharmacopeia* (a catalog of accepted medical drugs) from 1850 to 1942. In 1851 its use was recommended for calming nerves, inducing sleep, stimulating appetite, and for ailments and discomforts including neuralgia, gout, rheumatism, tetanus, hydrophobia, epidemic cholera, convulsions, chorea, hysteria, mental depression, delirium tremens, insanity, and uterine hemorrhage and cramps. In 1898 migraine headache was added to the list (Brecher 1972). Today better treatments are available for these problems. However, in recent years marijuana has been used to reduce the unpleasant side effects of chemotherapy for cancer and to reduce intraocular pressure that can lead to blindness from glaucoma (Cohen & Stillman 1976).

In addition to its medicinal use, marijuana has had a long history of recreational use in Europe and the United States. The French writer Théophile Gautier described his experiences in "The Club des Hachichins" in 1846 (Gautier 1846/1966). He was introduced to the club by Dr. J. J. Moreau, who warned him that his time intoxicated with hashish "will be subtracted from your share in Paradise." In the 1860s, following the suppression of opium dens by the police, hashish houses were opened in New York City; many of their customers were upper-class people.

Marijuana for smoking was introduced into the United States in the early twentieth century by Mexican laborers, and its use slowly spread, especially among racial minorities and jazz musicians. In 1926 two New Orleans newspapers published sensational exposés of the "menace" of marijuana. Marijuana was accused of causing violence, insanity, and moral degeneration, although there was no scientific evidence to support such claims. This was the beginning of a national campaign to suppress the sale and use of marijuana. Congress passed the Marijuana Tax Act of 1937, which effectively outlawed marijuana by imposing exorbitant taxes ($100 per ounce) for nonmedicinal use. The Controlled Substances Act of 1970 denied the medicinal use of marijuana and treated it legally as if it were a narcotic, though pharmacologically it is not a narcotic (McKim 1986). (Narcotics include opium and its derivatives, morphine and heroin. See Table 18.1.)

Of course, making marijuana illegal did not eliminate its use any more than alcohol use was eliminated by the prohibition amendment in the 1920s. The major surge in marijuana use began with the youth counterculture of the 1960s, and its use soon spread from "hippies" to more socially respectable middle-class, even middle-age, citizens. In 1982, according to a survey by the National Institute on Drug Abuse, some 64 percent of young adults in the eighteen- to twenty-five-year age group reported that they had used marijuana at least once, and 27 percent were current users (defined as having used marijuana within the last 30 days). In this age group the frequency of marijuana use was about the same for college students and nonstudents. The number of people using marijuana is remarkably high, considering that users are taking the risk of being arrested and paying fines and/or serving jail sentences, and possibly damaging their careers, as well as their health. Why is marijuana so popular? What are the psychological and physical effects of marijuana?

I will discuss research on the effects of marijuana on conscious experience and behavior, emphasizing the *acute* effects of marijuana, that is, the immediate effects of being stoned (intoxicated) on marijuana. The *chronic* health effects of long-term marijuana use will be discussed briefly in a later section. (For more details on the history, pharmacological aspects, and health aspects of marijuana, see McKim 1986 or Ray & Ksir 1987.)

SUBJECTIVE EFFECTS OF MARIJUANA

Many writers, both literary and scientific, have attempted to describe the subjective effects of marijuana (examples in Solomon 1966). Literary descriptions usually consist of an author describing his or her own experiences—experiences that may or may not be typical. Descriptions from a scientific viewpoint, on the other hand, usually are composites based on the subjective reports of several people. Composite descriptions may give the false impression that everyone has the same subjective experiences during marijuana intoxication. In fact there are few, if any, subjective effects that occur in every person every time they get stoned on marijuana. The best that can be done is to list a variety of *potential* effects, and then try to discover the particular combination of personal, situational, and drug factors that produces each of these effects when they occur.

Charles Tart (1971) did a systematic survey of the potential effects of marijuana and their relative frequencies. He believed that researchers doing controlled laboratory studies would be unable to discover the full variety of marijuana's effects as they occur in more natural physical and social settings. In order to avoid the artificialities of the laboratory, he obtained his data by the public survey method. He had college students in California circulate a 220-item questionnaire addressed "to anyone who has smoked marijuana more than a dozen times." The questionnaires were filled out and returned anonymously. (The questions were based on preliminary research in which marijuana users had been asked to describe the full range of subjective experiences that they had had while stoned.) For each item, respondents indicated on a five-point scale the relative frequency with which they had experienced that particular effect: never, rarely, sometimes, very often, or usually. (Each point was defined: for example, "very often" meant that the experience had occurred on more than 40 percent of the smoking occasions.) Tart's final data were based on 150 completed questionnaires; most respondents were in the nineteen- to thirty-year age range. Table 18.2 summarizes Tart's results, showing the characteristic and common subjective responses to marijuana.

Changes in sensory perception are particularly characteristic of marijuana intoxication, and they are probably the main reason that many people find the experience to be so enjoyable. In addition to the characteristic and common subjective effects listed in Table 18.2, Tart (1971) noted some other effects that are relatively rare but interesting. These include apparent "paranormal" experiences, such as telepathy and out-of-body experiences, and also religious experiences. Unpleasant experiences were relatively rare, though 80 percent of the respondents reported that they had felt paranoid on at least one smoking occasion. If unpleasant experiences were more common or more severe, then marijuana smoking would not be so popular.

Another interesting subjective effect of marijuana—doubling of consciousness—was not included in Tart's questionnaire, though it has been mentioned by other writers (Robinson 1946/1966; Grinspoon 1969). According to Grinspoon:

> There is often a splitting of consciousness, so that the smoker, while experiencing the high, is at the same time an objective observer of his own intoxication. He may, for example, be afflicted with paranoid thoughts yet at the same time be reasonably objective about them and even laugh or scoff at them and in a sense enjoy them (p. 19).

Robinson's subject, Mr. C., reported:

> Throughout the experiment I experienced a peculiar double consciousness. I was perfectly aware that my laughter, etc., was the result of having taken the

TABLE 18.2 Characteristic* and Common Subjective Responses to Marijuana

Sensory perception. 1. *I can see patterns, forms, figures, meaningful designs in visual material that does not have any particular form when I'm straight.
2. *Pictures acquire an element of visual depth.
3. The edges and contours of things stand out more sharply.
4. *I can hear more subtle changes in sounds . . . [for example, the notes and rhythm of music].
5. Touch*, taste*, and smell sensations take on new qualities.
6. *I enjoy eating very much and eat a lot.
7. *My sense of touch is more exciting, more sensual.
8. *Orgasm has new, pleasurable qualities.

Mental imagery. 9. Mental imagery seems more vivid than usual in the modalities of vision*, audition, taste, and touch.
10. Sounds have visual images or colors associated with them, synchronized with them [synesthesia].

Time perception. 11. *Time passes very slowly.
12. Certain experiences seem outside of time, are timeless.

Body image. 13. My body feels very light or as if it is floating.

Sense of identity. 14. I lose all sense of self, of being a separate ego, and feel at one with the world.

Memory. 15. I experience unusually rapid forgetting of conversations that I am involved in*, tasks I have started*, what I have read, and my own train of thought.
16. *I find it difficult to read.

Thinking. 17. *I can understand the words of songs which are not clear when I'm straight.
18. *I have meaningful insights about myself, my personality.
19. My ideas are more original than usual.
20. *I am more willing to accept contradictions between two ideas.
21. I get so wound up in thoughts or fantasies that I won't notice what's going on around me.
22. *I give little or no thought to the future; I am completely in the here and now.

Judgment of meaning or significance. 23.*I appreciate very subtle humor in what my companions say, and say quite subtly funny things myself.
24. Commonplace sayings or conversations seem to have new meanings, more significance.
25. *I feel more childlike, more open to experiences of all kinds, more filled with wonder and awe at the nature of things.

Emotions. 26. *I almost invariably feel good when I turn on, regardless of whether I felt bad before turning on.
27. I feel emotions much more strongly, so they affect me more.

Self-control. 28. *I can 'come down' at will if I need to be straight for a minute to deal with some complicated reality problem.
29. *I get physically relaxed and don't want to get up or move around.
30. *I find it easy to accept whatever happens.
31. I giggle a lot.
32. My inhibitions are lowered so that I do things I'm normally too inhibited to do.
33. *I find it very easy to go to sleep at my usual bedtime.

TABLE 18.2 Continued

Interpersonal relations. 34. *I have feelings of deep insights into other people (regardless of whether they actually check out later).
35. *I empathize tremendously with others.
36. When making love I feel I'm in much closer mental contact with my partner; it's much more a union of souls as well as bodies.
37. I become more sociable.
38. I become less sociable.

Characteristic effects (marked with asterisks*) were defined as those that occurred "very often"(over 40 percent of occasions) in at least half of the respondents; common effects occurred at least "sometimes" (10 to 40 percent of occasions) in at least half of the respondents. (In fact, most of the characteristic effects occurred at least sometimes in 80 to 95 percent of respondents; most of the common effects occurred sometimes in 60 to 80 percent of respondents.) In the questionnaire, each statement included the phrase, "the effect is more pronounced during marijuana intoxication than normal."

[Selected from data in Tart, C. T. (1971). On Being Stoned: *A Psychological Study of Marijuana Intoxication.* Palo Alto, CA: Science and Behavior Books. By permission of the author.]

> drug, yet I was powerless to stop it. . . . In the same way the extension of the sense of time induced by the drug was in itself indubitable . . . yet I remained able to convince myself at any moment by reflection that my sense of time was fallacious (p. 258).

The double consciousness experience is particularly interesting in relation to the concept of dissociation discussed in Chapter 15 on hypnosis. Crawford (1974) found that responding to hypnotic-type suggestions was increased as much by marijuana as by hypnotic induction.

Several subjective effects of marijuana are especially noteworthy because of their frequency and the fact that they have been evaluated by objective research (to be discussed shortly). These subjective effects include: (1) sensory-perceptual effects, particularly the impression of increased sensitivity; (2) disruption of memory; (3) changed time experience; (4) increased creativity; (5) enhancement of interpersonal perception and communication; and (6) ability to "come down" at will.

First-time effect. The subjective effects described above are based on reports of experienced users. It is noteworthy that many people do not feel "high" or "stoned" the first time they smoke marijuana, even though physiological measures show clear physiological changes (such as increased heartbeat rate) in first-time users.[2] This finding suggests that feeling stoned depends on more than just the drug itself. It also depends on learning, attitudes, and experience. For example, novice marijuana smokers may not know what to expect initially. But novices may be taught by friends how to perceive the rather subtle effects of marijuana and interpret them positively while ignoring any discomforting effects. On future occasions, the novices will be prepared to easily detect marijuana's effects and to label their experiences as a pleasant marijuana high (Becker 1963; Carlin et al. 1974).

EXPERIMENTAL RESEARCH ON MARIJUANA

Experimental Procedures

Although Tart (1971) may be right in suspecting that the subjective effects of marijuana differ between laboratory and home settings, it is nonetheless important to assess the effects of marijuana under controlled experimental conditions in order to better analyze cause-and-effect relationships. Here I will describe some general procedural considerations that apply to most marijuana experiments.

Subjects. Most marijuana experiments with humans have employed male subjects, eighteen to thirty years old, who are experienced but casual marijuana smokers, not heavy users.

Dose and administration method. Ideally, pharmacological research should obtain dose-effect curves, where the effects of several different dose levels are measured. However, for practical reasons having to do with research costs and research subject availability, most human marijuana experiments have employed a single dose level. Most experiments with smoked marijuana have used a *nominal* dose in the 8 to 14 mg THC range. This dose range has been used because it is the so-called "social dose" level—the amount that experienced marijuana users consume in order to produce a "nice high" in informal social situations. With smoked marijuana the *actual* dose of THC is always somewhat lower than the nominal dose, and it varies depending on the efficiency of people's smoking techniques.

Some experiments have used THC capsules or drinks in order to precisely control the dose and ensure that all subjects get the same actual THC dose level. On the other hand, research using smoked marijuana is more likely to produce effects like those experienced by marijuana users in more natural (nonlaboratory) settings. Smoking produces a "high" faster than oral ingestion, and the subjective nature of the high may be different with smoking, perhaps partly due to a different mix of cannabinoids in smoked marijuana (R. T. Jones 1971). Therefore, in discussing the research literature I will give preference, where possible, to studies that used smoked marijuana.

Placebo controls. One of the main complications of drug research with human subjects is that the apparent effects of the drug may be heavily influenced by subjects' expectations about the effects that will occur. In order to distinguish between the actual pharmacological effects and expectancy effects, it is customary to employ a placebo control condition. A *placebo* is a capsule, drink, or "joint" (marijuana cigarette) that looks, tastes, and smells like the one containing the drug, but which does not contain any of the active drug ingredient. (A marijuana placebo may be prepared by using ethyl alcohol to extract the THC and other cannabinoids from marijuana.) In a *single-blind* experimental design, subjects do not know whether they are taking the actual drug or a placebo. They are led to believe that they are taking the actual drug in both cases, so their expectancies are the same in both cases. Most experiments use a *double-blind* procedure, where neither the experimenter who administers the drugs nor the subjects know which subjects are getting the real drug and which are getting the placebo. (This is accomplished by having a second experimenter prepare the joints or capsules.) The purpose of the double-blind procedure is to avoid having the experimenter unintentionally influence the subjects' expectations by behaving differently toward them in the drug and placebo conditions. Thus, with the double-blind procedure, any difference in response between the drug and placebo conditions can be attributed to the pharmacological effects of the drug.

A *placebo effect*—a response to the placebo similar to the response to the real drug—was demonstrated in a double-blind study by R. T. Jones (1971). Frequent marijuana users (who smoked marijuana seven or more times per week) rated themselves as equally "high" on marijuana and placebo joints (52 and 48, respectively, on a 0 to 100 scale). Infrequent users (less than twice a week) responded much less to the placebo than to the real drug ("high" ratings of 67 and 22, respectively, for marijuana and placebo). Apparently, with the placebo, expectations associated with the familiar smell, taste, and ritual of marijuana smoking produced a marked subjective "high" in the frequent users but not in the infrequent users. On the other hand, there was little or no placebo effect on heart rate; heart rate changes were markedly greater for drug than placebo in both groups.

Physiological Effects of Marijuana

The acute physiological effects (short-term effects—while stoned) of marijuana are relatively mild and not particularly distinctive, at least with normal "social" doses. The most reliable physiological effect is an increase in heartbeat rate (pulse rate). When marijuana is smoked, the heart rate reaches its maximum in about 15 minutes and then declines. (When THC is taken orally, the heart rate change is slower than with smoked marijuana. See Figure 18.2, top panel.) The heart rate increase is greater, the greater the dose of THC (up to about 30 bpm increase at 15 mg THC) (Klonoff & Low 1974). R. T. Jones (1971) found a greater heart rate increase in infrequent users (31 bpm) than in frequent (17 bpm) users, indicating a *tolerance effect* in the frequent users. The heart rate increase is reliable enough that some researchers have used it to determine whether their subjects have smoked marijuana effectively enough to get the chemicals into their bloodstream. Conjunctival injection (reddening of the eyes due to dilation of the capillaries on the eyeball surface) is commonly observed after high doses, though it is less marked or absent with low doses (Weil, Zinberg, & Nelsen 1968).

Smoked marijuana at social doses does not produce any dramatic changes in brain wave (EEG) recordings from the cortex surface. Some rather small, not particularly reliable effects (reduced power and slowing of frequency in the alpha band) have been found at social doses. These effects are stronger with very high THC doses (R. T. Jones 1978; Tassinari et al. 1974).

It now seems likely that the most important neurophysiological effects of marijuana are on subcortical structures of the brain, rather than the cerebral cortex. Heath (1976) took EEG recordings through miniature electrodes implanted in the limbic systems of monkeys. Marijuana produced increased high-voltage, slow waves, and some unusual spikes in the EEG records. Similar observations were made on a human subject, and it was noted that the EEG spikes were associated with subjective feelings of euphoria (Heath 1972). There is evidence that marijuana disrupts cholinergic synaptic transmission in the limbic system, particularly in the septal-hyppocampal circuit, which is important for memory processes (Miller & Branconnier 1983).

Marijuana often makes people feel sleepy, particularly if they smoke alone where they do not have social stimulation to keep them awake. Marijuana tends to increase total sleep time, but it decreases the time spent in the REM sleep stage. When marijuana use is discontinued after a period of prolonged use of high doses, there is a REM rebound effect (Feinberg et al. 1976).

Cognitive Effects of Marijuana

Sensory-perceptual effects. Changes in subjective sensory-perceptual experiences for vision, hearing, taste, and touch are commonly reported by marijuana users. For example, users report that marijuana enables them to hear things in music that they hadn't heard before. In a questionnaire about reasons for using marijuana, users indicated pleasurable sensory-perceptual changes more often than any other reason (Roth, Tinklenberg, & Kopell 1976). However, it is noteworthy that studies with objective measures have failed to find evidence of enhanced sensory-perceptual abilities during marijuana intoxication; in fact, the opposite is often the case.

Moskowitz and McGlothlin (1974) examined the effects of marijuana on performance on an auditory signal detection task. On some trials the signal (a brief, soft, 1000 Hz tone) was presented superimposed on a "white" background noise (like "ssshhh . . ."). On other trials, randomly mixed, the noise was presented alone. The subject's task was to report, on each trial, whether he detected a tone. Signal detection sensitivity (d') decreased with increasing marijuana dose, compared to a placebo control condition. With increasing doses the frequency of hits (correct "yes" responses) decreased slightly, whereas the frequency of false alarms (incorrect "yes" responses) increased more dramatically. Thus, there is no proof that marijuana affects the sensitivity of the auditory system *per se*. Rather, it appears that marijuana interferes with auditory signal detection by increasing the frequency of lapses of attention to external stimuli, due to a shift of attention inward to thoughts and mental images. Also, marijuana changes subjects' response biases, such that they are more likely to say "yes" when they are uncertain, thus making more false alarms. (Alternatively, false alarms might indicate that subjects sometimes hallucinate signals when they are tested during marijuana intoxication.)

There is really no conflict between subjective reports of increased music appreciation and objective findings of reduced auditory signal-detection sensitivity during marijuana intoxication. What is at issue is not the ability to hear, but the ability to listen, and what one listens to. Marijuana may actually decrease the efficiency and frequency of automatic attention switching, resulting in a tendency to stay focused or "locked in" on a particular internal image or external stimulus for a greater than usual amount of time before switching attention to something else. Thus, when stoned, one might attend to music to an abnormal degree and notice subtle musical events that had not been noticed previously. Many marijuana users have reported that their appreciation of classical music increased during marijuana intoxication; perhaps they noticed and appreciated the music's complexities more with marijuana.

Other research indicates that, contrary to subjective reports, marijuana reduces visual signal detection sensitivity and visual acuity (Moskowitz, Sharma, & Shapero 1972) and color discrimination ability (Adams et al. 1976), and it has no effects on depth perception (Clark & Nakashima 1968). Marijuana increases the autokinetic effect, in which a small stationary light is perceived to be moving when it is viewed in a dark room (Moskowitz et al. 1972). On the positive side, marijuana improved performance on a visual completion task in which subjects had to identify objects from drawings that had large parts of their outlines missing (Harshman, Crawford, & Hecht 1976).

Contrary to subjective reports of increased touch sensitivity with marijuana, a controlled experiment found no effect of marijuana on any of four different measures of cutaneous or tactile sensitivity (Milstein et al. 1974). Studies of effects of marijuana on pain sensitivity and pain tolerance have produced inconsistent results (Milstein et al. 1975). In the past marijuana was prescribed to reduce pain, though its benefits may have resulted more from attentional distraction than from reduced pain sensitivity *per se*.

In conclusion, the striking thing about laboratory studies of sensory-perceptual effects of marijuana is their rather consistent failure to confirm the subjective reports of marijuana users. In retrospect this inconsistency is not very surprising. The subjective reports were not obtained in controlled conditions that would allow users to systematically compare their experiences with and without marijuana. Subjective reports are particularly susceptible to effects of the subjects' attitudes, beliefs, and expectancies. However, this is not to say that the subjective reports are erroneous. Rather, they seem to indicate something different from what is measured by objective means. In one sense, there is nothing more private and at the same time nothing more real than subjective perceptual experiences. Even a perceptual illusion is very real to the person who experiences it. Thus, in future research the important question will not be whether marijuana affects objective sensory sensitivity, but rather how and why does it affect subjective perceptual experience.

Sensory-motor performance. Sharma and Moskowitz (1974) tested the effect of marijuana on the ability to maintain continuous attention to a task. In a *vigilance* task, subjects responded to visual signals that occurred unpredictably, at irregular intervals over the course of an hour. Marijuana caused increasingly greater disruptions of performance, compared to placebo, as the amount of time-on-task increased. Also, performance was disrupted as much on a focused-attention task (one stimulus source) as it was on a divided-attention task, where subjects had to attend to two stimulus sources at the same time (Moskowitz & McGlothlin 1974; Moskowitz et al. 1972). These results suggest that marijuana's effects are due to subjects having periodic lapses of attention to the task, rather than to a decreased ability to perform when they are concentrating on the task.

The same conclusion comes from research on reaction time (RT). Marijuana increases the mean reaction time on both simple reaction-time tasks (one stimulus, one response) and complex reaction-time tasks (several different stimuli and responses) (Borg, Gershon, & Alpert 1975). However, a detailed examination of the results shows that marijuana also increases the variability of reaction times. Most responses are as fast with marijuana as with placebo, but marijuana increases the frequency of unusually long reaction times (Clark, Hughes, & Nakashima 1970). The long RTs reflect lapses of attention to the task.

Automobile driving. Marijuana users often claim that when they are stoned, they can "come down" at will in order to drive safely. Controlled experiments have cast serious doubt on this claim. In a driving simulator apparatus, both THC and alcohol disrupted attempts to maintain a 40 km/hr speed, as well as disrupting distance estimation and slowing braking reaction times (Rafaelsen, Bech, & Rafaelsen 1973). The most dramatic result was one subject on THC who completely failed to respond to eight of ten red lights! Obviously, his attention had drifted away from the driving task.

Klonoff (1974) studied the effects of marijuana on actual driving performance in a restricted test area and on city streets. In the special test area the subjects drove a complex course of sharp turns and narrow "tunnels" marked by cones; they knocked over more cones after smoking marijuana than after smoking a placebo. The test on city streets involved taking a driver's license driving performance test under normal traffic conditions. The testing officer did not know whether the subjects had smoked marijuana or placebo. The mean test score (a composite score based on general driving skills and related cognitive factors such as judgment and concentration) was significantly reduced by marijuana compared to placebo.

These results indicate that marijuana might significantly increase your risk of having a traffic accident, particularly under difficult driving conditions. In a double-blind study, Rafaelsen et al. (1973) found that marijuana slowed automobile braking reaction times by 0.2 seconds, on the average, compared to placebo (0.4 seconds slowing for alcohol, under the doses used). I suggest that you compute how many extra feet your car would travel in 0.2 seconds at, say, 55 miles an hour, and see whether you think the extra distance might be enough to cause a collision if you had to stop quickly to avoid hitting another car or a pedestrian.

Memory. One of the most characteristic subjective effects of marijuana is disruption of memory for recent events. Conversations may be disrupted when you forget what your friend has just said, or you forget what you yourself have just said, perhaps right in the middle of a sentence! Reading can become pointless if a sentence doesn't make any sense because you cannot remember the meaning of earlier sentences. Objective research has confirmed that marijuana disrupts both reading comprehension (Clark et al. 1970) and the production of coherent, meaningful speech (Weil & Zinberg

1969). Both of these effects result from memory disruptions. The memory-disruption effects of marijuana have been systematically studied in several experiments. In fact, memory disruption is probably the most reliable objective behavioral effect of marijuana.

Short-term memory (STM) for letter strings was disrupted by marijuana when subjects had to retain the information for several seconds and rehearsal was prevented by requiring them to do mental arithmetic during the retention interval (the Brown-Peterson procedure) (Dornbush, Fink, & Freedman 1971). However, marijuana does not affect performance on memory span tasks where subjects can report a string of letters or digits immediately (Miller 1976). Nor does marijuana slow the speed of serial search through STM to determine whether a target item is present (the Sternberg task) (Darley et al. 1973a). Thus, marijuana affects short-term memory operations only when reporting is delayed, allowing time for a shift of attention to occur, resulting in interference with STM. It appears that marijuana decreases STM's functional capacity by increasing its susceptibility to interference. Short-term memory (working memory) is critical for complex thinking tasks, where several items of information must be maintained, compared, and manipulated. Performance on logical syllogism and inference problems is disrupted by marijuana, probably due to the disruption of working memory operations (Harshman et al. 1976).

Many marijuana users have noticed that reading or studying while stoned on marijuana is not very effective, since their later recall of the material is poor. Darley et al. (1973b) asked whether marijuana's disruption of recall from long-term memory (LTM) is due to (1) disruption of the learning process, that is, the process of transferring new information from STM to LTM, or (2) disruption of the process of retrieving stored information from LTM, or (3) both. Their experiment involved two parts. The first part was intended to find out whether marijuana (actually, THC capsules in this study) affects retrieval of previously learned material. Subjects learned a series of ten word lists while straight (before taking any drugs). Then, in a double-blind procedure, half of the subjects took a THC capsule, while the others took a placebo capsule. An hour later they tried to recall all of the words learned earlier, and the THC group did as well as the placebo group. Thus, THC did not interfere with retrieval from LTM of material learned earlier while straight.

The second part of the experiment was intended to find out whether THC affects learning, that is, the transfer of new information from STM to LTM. After taking either THC or placebo pills, the subjects learned ten new word lists, and an hour later they tried to recall all of the words. The THC group did significantly worse than the placebo group during both initial learning (fewer words recalled after a single exposure to each list) and during delayed recall testing of all of the words from all ten lists. Thus, THC interfered with learning of new material when subjects tried to learn while stoned. In terms of the multistore theory of memory (Atkinson & Shiffrin 1968), THC interfered with transfer of new information from STM to LTM.[3]

Darley et al.'s (1973b) conclusions are not limited to word lists. Other studies have shown that when marijuana is smoked before initial learning, later recall is disrupted for meaningful prose passages, pictures, and complex visual stimuli (Miller et al. 1977a, 1977b). On the other hand, marijuana does not interfere with retrieval of miscellaneous items of general information (arts, science, current events) learned previously in a nondrugged state (Darley et al. 1977).

Before you conclude that it is all right to take tests while stoned, as long as you do the initial studying straight, you should be aware that some research has shown effects of marijuana on retrieval from LTM. Miller et al. (1977a) had subjects read prose passages under placebo conditions, then tested their recall the next day under either marijuana or placebo conditions. Recall was worse with marijuana. Miller and Branconnier (1983) argued that marijuana does, in fact, interfere with LTM retrieval. They cited evidence that on recall tests, besides decreasing correct responses, marijuana sometimes increases the number of *intrusions* (errors in which subjects report words that were not on the list of to-be-remembered items). Other evidence comes from some studies where marijuana decreased performance on recall tests, but not on recognition tests of memory. Miller and Branconnier argued that by providing retrieval cues to make retrieval easier, recognition tests provide a better measure of what is stored in LTM than do recall tests. Thus, they argued, lack of effect of marijuana on recognition performance shows that it does not affect the storage of material in LTM once it has been learned, but marijuana's disruption of recall performance shows that it interferes with retrieval of stored information. Overall, however, the bulk of the evidence indicates that marijuana disrupts initial learning (transfer from STM to LTM storage) more than it disrupts retrieval from LTM.

What is the process by which marijuana affects memory? The limbic system in the brain, particularly the hippocampus, is known to be critical for memory storage and retrieval. Miller and Branconnier (1983) described several types of evidence that, taken together, suggest that marijuana affects transmission at cholinergic synapses in the limbic system, particularly in the septal-hippocampal pathway: (1) Drugs that disrupt limbic cholinergic transmission have effects on memory and attention similar to marijuana's effects. (2) THC decreases the turnover rate of acetylcholine (a neurotransmitter) in the hippocampus. (3) Electrophysiological recordings show effects of marijuana on limbic system activity (Heath 1972). (4) There are similarities between marijuana effects and certain neurological syndromes (including herpes simplex encephalitis, Korsakoff's syndrome, and Alzheimer's disease) where memory deficits have been linked to disruption of neurotransmission in the limbic system. Thus, the evidence suggests that the effects of marijuana on memory are due to its effects on the limbic system, particularly the hippocampus.

Time estimation. One of the most characteristic subjective effects of marijuana is that time seems to pass more slowly. For example, if you are stoned and your friend goes into the kitchen to get some snacks, it may seem like he has been gone for fifteen minutes when he has really been gone for only five minutes. Several experiments have confirmed that marijuana slows temporal duration experience.

Two different methods have been used to measure temporal duration experience. In the *time-estimation* method the experimenter presents a signal of a certain duration (such as a 30-second tone) and the subject tries to estimate its duration in seconds. (Of course, wristwatches are not allowed in the laboratory.) In the *time-production* method the subject is required to produce an interval of a specified duration (such as by pushing a button to maintain a tone for 30 seconds). With these methods a slowing of subjective time is indicated by overestimation or by underproduction. (For example, if you were asked to produce a 30-second interval, you might hold the button down for 10 seconds, if 10 seconds [subjective time] seemed like 30 seconds to you.)

It is important to understand that when external time seems (subjectively) to be going slower, it is because your "internal clock" is beating faster. For the sake of argument, imagine that you have an internal clock that beats at a rate of one beat per second of external clock time. You can estimate the duration of a time interval from the number of beats of your internal clock during that interval, so long as the beating of your internal clock matches (or is highly correlated with) that of the external clock ("real" time). But if your internal clock speeds up and you don't realize that it has speeded up, then you would estimate a time interval to be longer than it really is. For example, if your internal clock speeds up from one to three beats per second, then you would estimate a 10-second interval to be 30 seconds. (In fact, there is no clear evidence that time estimation is based on an actual internal clock or pacemaker, though "internal clock" is a convenient name for the internal process involved in time estimation, whatever that process might be.)

Tinklenberg, Roth, and Kopell (1976) studied the effects of THC, alcohol (ethanol), and placebo drinks on time production. Each subject was tested under each drug condition on different days in a counterbalanced sequence. One half hour before taking the drink, and periodically thereafter, subjects were asked to produce a 120-second interval. They were instructed to count internally and report when they thought the interval had elapsed. Also, their heart rates were monitored, and they were asked periodically to rate their degree of subjective intoxication on a zero to 100 scale.

Figure 18.2 shows the results on all three measures. In the third panel, time production scores have been converted to internal clock rate, r, which is defined as the number of objective seconds per subjective second. THC produced underproduction (equivalent to overestimation) of time intervals, whereas alcohol produced overproduction (equivalent to underestimation). In other words, the internal clock rate is faster with THC, and slower with alcohol, compared to placebo.[4]

There have been two major approaches to explaining temporal duration experience (Ornstein 1969). According to the biological clock theory, subjective time experience is based on an internal physiological clock or pacemaker. Thus, the slowing of subjective duration estimates with THC might be related to the speeding up of an internal pacemaker, such as heart rate. However, Figure 18.2 shows that changes in internal clock rate were not closely correlated with changes in heart rate across the 4.5-hour test session for either THC or alcohol conditions. In fact, no physiological pacemaker that consistently correlates with subjective duration experience has been discovered.

According to the cognitive theory, the subjective duration of an interval increases with the frequency of conscious mental events during the inter-

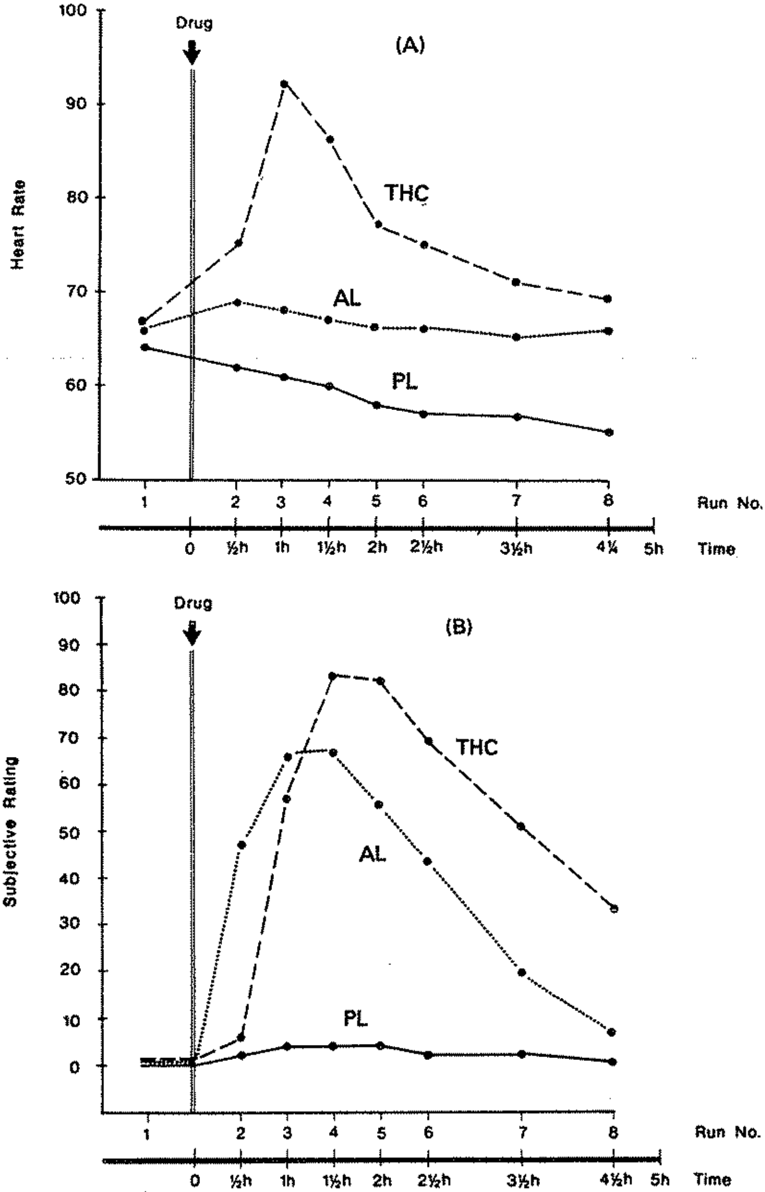

FIGURE 18.2. Heart rates (panel A), subjective intoxication ratings (panel B), and internal clock rates (panel C) during three different drug treatments as a function of time since drug ingestion. Drugs: THC; alcohol (AL); placebo (PL). The internal clock rate, *r*, is the mean number of objective seconds per subjective second. For example, with THC, r = 0.65 means that subjects produced an interval 65% as long as the target interval; with alcohol, r = 1.35 means subjects produced an interval 135% as long as the target interval. [From Tinklenberg, J. R., Roth, W. T., & Kopell, B. S. (1976). Marijuana and ethanol: Differential effects on time perception, heart rate, and subjective response. *Psychopharmacology*, *49*, 275–79. Reprinted by permission of Springer-Verlag, Heidelberg.]

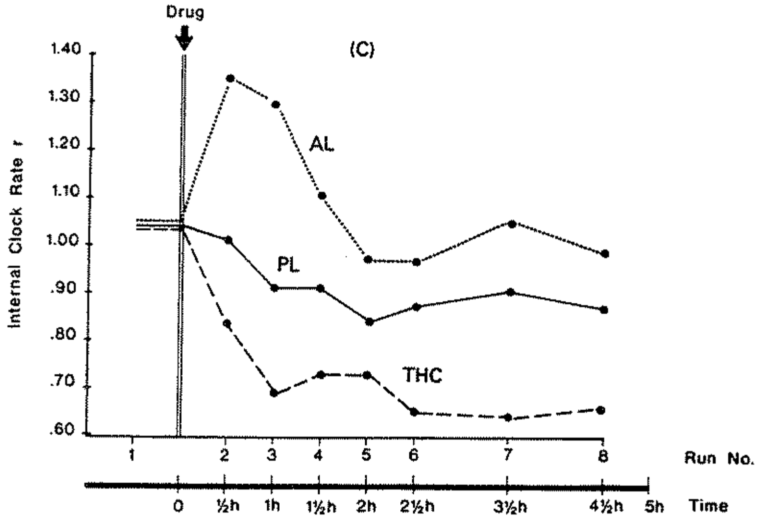

FIGURE 18.2 Continued

val. Thus, the overestimation (or underproduction) of time intervals during marijuana intoxication can be explained by the fact that many users report an increased rate of flow and change of ideas during marijuana intoxication. For example, one of Tinklenberg et al.'s (1972) subjects reported: "My mind shifts rapidly from one new thought to another, each very different . . . I feel hopped up and want to really groove with an experience, but the subject keeps changing." Conversely, the fact that alcohol makes many users feel mentally sluggish is consistent with the underestimation (and overproduction) of time intervals during alcohol intoxication, according to the cognitive theory of time perception. A further prediction of the cognitive theory is that, after a marijuana intoxication period has ended, a retrospective estimate of its duration would be reduced, compared to a placebo condition, since fewer events would be recalled from the marijuana intoxication period. This prediction agrees with some subjective reports, though it has not been experimentally tested.

The motivation problem. In evaluating the disruptive effects of marijuana on cognitive task performance, it is important to determine whether the effects are due to decreased *ability* to perform or decreased *motivation* to perform. Some marijuana users claim to be able to "come down" at will, suggesting that marijuana effects are at least partly motivational. This notion has been tested in several studies, where subjects were given incentives to perform to the best of their ability.

Cappell and Pliner (1973) gave subjects either marijuana or a placebo and then gave half of the subjects in each group special motivating instructions urging them to use whatever means they could to try to overcome the drug's effects and perform to the best of their ability. (Bear in mind that placebo subjects believe that they are smoking real marijuana.) The motivating instructions reduced the disruptive effects of marijuana on time estimation, but not on a memory test. Casswell (1975) used a monetary incentive to motivate subjects to perform as well as possible. The incentive did not reduce marijuana's disruptive effects on either a complex reaction time task or a speeded cognitive task requiring decoding a set of arbitrary symbols. However, the incentive reduced marijuana's disruptive effects on a mental arithmetic task, but only for those subjects with the highest mental arithmetic ability. In conclusion, the evidence indicates that increased effort can reduce the disruptive effects of marijuana on some tasks, but not others. The ability to "come down" is not a general one. It seems to depend upon both the nature of the task and upon the subject's prior skill at the task. Prior practice doing the task while stoned may also be important. Klonoff (1974) found that only a minority of subjects could drive as safely with marijuana as with placebo. Where your safety or important academic or professional goals are at stake, it would be wise not to count on being able to "come down" and perform well when you are stoned.

Creativity. Many marijuana users have reported that when they are stoned they have a lively imagination and sometimes have creative inspirations. These inspirations may involve a variety of topics, such as art, music, humor, scientific theory, or the solution of personal or practical problems. People sometimes write down their "profound" and "creative" thoughts while they are stoned, but afterward their thoughts usually seem quite mundane or even incomprehensible. Yet, even if only a minority of the marijuana-induced inspirations are truly creative and useful, it is a phenomenon worth studying.

In discussing the question of whether marijuana enhances creativity, it is important to keep in mind that true creativity involves more than mere novelty of responses. MacKinnon (1962) pointed out that true creativity also implies that an idea is adaptive in the sense of serving to accomplish some recognizable goal, and that the idea is fully developed, elaborated, and evaluated. Of course, having a creative idea during marijuana intoxication does not prove that marijuana increases creativity; it is necessary to compare marijuana with a placebo control condition to see whether creativity is greater with marijuana than with placebo. Also, it is important to use blind testing and scoring procedures, where judges who score the creativity of productions do not know whether they came from the marijuana or the placebo condition. Unfortunately, no suitably controlled experiments have been done to evaluate the effects of marijuana on creativity in solving "real-world" types of problems.

The best available evidence on possible effects of marijuana on creativity involves studies using so-called creativity tests. For example, Guilford (1967) argued that tests of divergent thinking are related to creative ability. *Divergent thinking* involves producing several potential solutions to a problem, whereas *convergent thinking* (which is emphasized on most intelligence tests) is involved in solving problems where there is only one correct solution. An example of a divergent thinking test is the Alternate Uses Test, where subjects are given one minute to think of as many uses as possible for a common object, such as a brick or paper clip. Tests of divergent thinking can be scored on several dimensions: fluency (number of responses), flexibility (number of conceptually different types of responses), originality (rarity of responses), and elaboration (embellishment or figural detail).

Tinklenberg et al. (1978) found no effect of marijuana on divergent thinking tests. Carlin et al. (1972) found that marijuana lowered scores on two divergent thinking tests (alternate uses and verbal associations). Weckowicz et al. (1975) used a battery of fourteen different tests of convergent and divergent thinking. Marijuana lowered scores on most tests and increased scores on only one test that might be related to creativity (originality in predicting possible consequences of a specified situation).

Roth et al. (1975) found that oral THC increased the novelty of stories produced in response to pictures on the Thematic Aperception Test (TAT) cards, though it did not lead to production of polished literary creations. According to the authors, "Under marijuana the stories had a timeless, nonnarrative quality, with greater discontinuity in thought sequence and more frequent inclusion of contradictory ideas" (p. 261). Similar conclusions were reached by Weil and Zinberg (1969) in a study of the effects of smoked marijuana on spontaneous oral narrations. While Roth et al. found that marijuana changed the stories, making them unusual in several ways, their results did not demonstrate an enhancement of creativity in the socially relevant manner described by MacKinnon (1962), where adaptiveness and development are important in addition to novelty.

In conclusion, there is no convincing evidence that marijuana enhances the creativity of people while they are stoned. It may sometimes increase the fluency or unusualness of ideas, without increasing creativity in the fullest sense involving novelty combined with adaptiveness and full development of ideas. This is not to say, of course, that worthwhile creative ideas never occur to people while they are stoned. Creative artists, for example, have sometimes had creative inspirations while stoned, but these people were creative before they smoked marijuana; marijuana cannot turn a noncreative person into a creative one (Krippner 1977). In any case, people's subjective impressions that their ideas are very witty and creative is undoubtedly one of the enjoyable aspects of marijuana that provides an incentive for its use.

Social and Personality Effects of Marijuana

Social cognition. One of the common subjective effects of marijuana is the feeling of having deep insights into other people and enhanced interpersonal communication. If this is true then one would expect that people under the influence of marijuana would be particularly good at perceiving the emotional reactions of others. Experimental research shows that this is not necessarily the case. Clopton et al. (1979) had subjects view filmed social encounters and found that marijuana reduced the accuracy of emotion perception, compared to a presmoking score, whereas a placebo caused no such decline. The detrimental effect of marijuana on emotion perception might be due to changes in complex social perception processes, or it might be due to changes in more elementary processes of attention and memory.

Janowsky et al. (1979) evaluated interpersonal skills in live social encounters, in which each male subject conversed with a female stranger about her personal problems. Each subject was tested twice, once with marijuana and once with placebo. The conversations were filmed, and the subjects' interpersonal skills were scored on several dimensions: regard (warmth), empathy, unconditionality (acceptance), congruence (genuineness), and a composite total score. The authors concluded:

> Overall, it seems that intoxication with marijuana leads to a decrease in interpersonal skills. . . . In our view, those subjects evidencing the most severe decrements in interpersonal skills became confused easily and had obvious difficulty following conversations. They also became withdrawn and seemed to be more interested in their own thoughts and behavior and less interested in their partners. In a few subjects, the deterioration was so severe that the experimental subjects became afunctional as interviewers. [The minority of] subjects who improved in their interpersonal skills after the administration of active marijuana were observed to become more communicative, more outgoing, and less defensive during the active-marijuana interview (p. 784).

Janowsky et al. also assessed subjects' moods and found that the degree of congruence (similarity) between the moods of the male subjects and their female partners was reduced by marijuana, compared to placebo. This finding is contrary to users' reports of an increased emotional resonance with their friends during marijuana intoxication. However, the decreased emotional resonance under marijuana in Janowsky et al.'s study might be related to the fact that only the subjects were stoned, and not their partners, and/or the fact that the subjects and partners were strangers. The experimental setting was quite different from the usual marijuana-smoking situation where people get high with their friends. Rossi, Kuehnle, and Mendelson (1978) found increased mood congruence during marijuana smoking in a group of subjects who lived together in a hospital and had unlimited access to marijuana for three weeks.

Mood. Regular marijuana users report marijuana smoking to be a pleasurable experience most of the time. Anxiety, depression, and paranoia sometimes occur, but more common is frequent laughter when people smoke in a group, or pleasurable daydreaming when they smoke alone. When a variety of moods have been measured systematically in experimental studies, no consistent effects of marijuana have been found, other than the fact that marijuana is typically rated as more pleasurable than placebo. Insofar as people's moods tend to be strongly affected by their companions' moods, we would expect that people's moods during marijuana smoking would be affected more by the social situation than by marijuana *per se*.

Psychiatric symptoms. In normal people using normal social doses, acute marijuana intoxication does not cause psychiatric symptoms. Marijuana does not typically increase anxiety, hostility, or depression, compared to placebo (Janowsky et al. 1979). Contrary to old myths about marijuana, there is no evidence that marijuana increases violence or aggression. However, anxiety and paranoid reactions sometimes occur. Negative reactions to marijuana have been linked to personal fears about losing self-control and an altered sense of personal identity. It is suspected that marijuana can precipitate full-blown psychosis in people with psychotic tendencies, and it can intensify schizophrenic and paranoid symptoms that already exist (McKim 1986; Tunving 1985).

INTERPRETATIONS OF MARIJUANA'S EFFECTS

Regardless of the results of objective experiments on marijuana's perceptual, cognitive, and interpersonal effects, there is no doubt that marijuana alters subjective experience. Going beyond the analysis of specific symptoms of marijuana intoxication, Andrew Weil (1972) characterized marijuana intoxication as a shift in the style of thought from "straight thinking" to "stoned thinking." Our normal, reality-oriented straight thinking is analytic and intellectual, whereas stoned thinking is holistic and intuitive. Also, stoned thinking involves "acceptance of the ambivalent nature of things" and the "experience of infinity in its positive aspect." The characteristics of stoned thinking are similar to those of the mystic experience (Deikman 1966) and what Ornstein (1977) described as the right-hemisphere mode of consciousness.

In a related proposal, Harshman, Crawford, and Hecht (1976) suggested that the process of becoming high on marijuana consists, in part, of shifting into a new cognitive style or mode that involves "less reliance on analytic, sequential, verbal processing, and more reliance on synthetic, holistic, imagistic processing." Several types of evidence support this characterization. Marijuana disrupts the smooth and coherent flow of conversational speech (Weil & Zinberg 1969) and decreases reading comprehension (Clark et al. 1970). Also it decreases performance on logical syllogism and inference problems (Harshman et al. 1976). Conversely, marijuana produces subjective effects of enhanced spatial and figural perception, music appreciation, flow of imagination, and novelty or creativity of ideas. It increases performance on a measure of holistic perception, where subjects try to recognize objects in drawings that have large parts of their outlines missing (Harshman et al. 1976). Also, marijuana increases primary suggestibility, the performance of hypnotic-type suggestions, which is believed to be related to an increase in imagination and a decrease in reality orientation (Crawford 1974; Kelly, Fisher, & Kelly 1978).

It has been suggested that the shift in cognitive style during marijuana intoxication involves a decrease in left-cerebral-hemisphere activity, and an increase in right-hemisphere activity (Harshman et al. 1976; Ornstein 1976). However, there is no direct evidence (such as EEG studies) supporting this hypothesis. As we saw earlier (Chapter 5), the linking of alternative modes of consciousness or cognitive styles with the two hemispheres appears to be an oversimplification, since many complex thought processes involve both hemispheres.

Although marijuana's effects can be described as a shift in cognitive style, this is not an explanation of its effects. No theory, either psychological or neuropharmacological, has been developed that adequately explains all of marijuana's subjective, cognitive, and behavioral effects. One approach to a cognitive psychological theory would be to try to explain effects on more complex or higher-level processes in terms of effects on simpler, more basic processes. For example, it is clear that marijuana makes short-term memory (working memory) more susceptible to interference. Working memory is critical for many cognitive operations, such as judgment of new inputs against information retrieved from LTM, speech comprehension and production, imagery processes, and elaborative rehearsal for storing new information in LTM in an organized, retrievable manner.

IS MARIJUANA HARMFUL?

Marijuana has always been controversial. In the early years of marijuana use in the United States, straight society disapproved of marijuana because of its association with racial and ethnic minorities. Also, since violent criminals sometimes smoked marijuana, it was claimed that marijuana causes violence and moral degeneracy. In the 1960s, marijuana was associated with hippies and their political liberalism and contempt for middle-class values. More recently marijuana has been condemned as a "stepping-stone" drug that leads to the use of more dangerous drugs, such as cocaine. Opposition to marijuana was based more on guilt by association and myths about its harmful effects than on research evidence on its actual harmful effects. What is the evidence on harmful effects of marijuana? I have already discussed the effects of acute marijuana intoxication. Here the emphasis will be on the effects of chronic (frequent, long-term) use on health and mental functioning.

Cognitive effects. At extremely high doses, marijuana can cause delirium, toxic psychosis, and loss of consciousness; this is true of most other drugs, too (McKim 1986). Long-term (daily for six months) high-dose THC administration produced learning deficits in rats, from which they did not recover after THC was discontinued (Feher et al. 1976). The implication is that maintained very high doses of marijuana may cause brain damage, as occurs also with alcohol. However, studies of chronic marijuana users (daily use at fairly high doses over several years) have failed to find any evidence that marijuana causes permanent deficits in cognitive functioning or psychopathology (Grinspoon 1977; Schaeffer, Andrysiak, & Ungerleider 1981).

The absence of clear proof of harmful cognitive or behavioral effects of chronic marijuana use should not, however, be interpreted as proof that marijuana is safe. While work adaptation has been found to be adequate in chronic marijuana users, the subjects have been employed at jobs that do not have heavy intellectual demands, such as agricultural work and physical labor. Also, while chronic users have usually been found to be average or above in performance on intelligence tests and other cognitive measures, it is possible that their scores would have been even higher if they had not been habitual marijuana users. Due to practical problems of such research, studies of chronic marijuana use have been correlational, rather than experimental. They have not taken psychological measures before chronic use to compare with measures taken after long-term use, nor have they had suitable control groups. Despite the absence of clear evidence of permanent cognitive impairment being caused by chronic marijuana use, people whose careers depend on being mentally sharp should ask themselves whether the pleasure of marijuana (as well as alcohol and other drugs) is worth the risk.

Amotivational syndrome. Habitual marijuana use, particularly among adolescents, has been associated with changes in behavior termed the *amotivational syndrome.* Its symptoms include:

> apathy, loss of effectiveness, and diminished capacity or willingness to carry out complex, long-term plans, endure frustration, concentrate for long periods, follow routines, or successfully master new material. Verbal facility is often impaired both in speaking and writing. Some individuals exhibit greater introversion, become totally involved with the present at the expense of future goals, and demonstrate a strong tendency toward regressive, childlike, magical thinking (McGlothlin & West 1968, p. 372).

Some studies have found lower grade averages and higher dropout rates among marijuana users than among nonusers, though this is not always the case, as some marijuana users continue to function at high levels of motivation for academic or career advancement. Recent studies continue to suggest an amotivational syndrome correlated with marijuana use in adolescents, involving not only achievement orientation but also deviant behavior and poor interpersonal relations with peers and parents (Brook et al. 1989).

Though the amotivational syndrome is correlated with frequency of marijuana use, there is no proof that marijuana causes the amotivational syndrome. A plausible alternative interpretation is that the personality and social factors that produce the amotivational syndrome also lead to frequent marijuana use. People who are not motivated to study or work are likely to spend more time on idle recreation, including marijuana smoking. Nonetheless, the possibility remains that some individuals would find the pleasures of marijuana to be so reinforcing that marijuana-smoking behavior would increase to the point that it would interfere with other behavior, such as studying and work, associated with less pleasurable or longer-delayed reinforcers. Also, even for those who maintain their motivation for studying, marijuana can interfere with attention, learning, and memory, thus producing the same effects as loss of motivation (McKim 1986).

"Stepping stone" to other drugs. Most people who use stronger, more dangerous drugs, such as heroin or cocaine, used marijuana first. It has been claimed that marijuana was somehow responsible for the progression to "harder" drugs. Yet, as with the amotivational syndrome, the evidence is entirely correlational, and there is no proof that marijuana *causes* progression to other drugs. Marijuana use does not produce any physiological need or craving for stronger drugs. Most marijuana users do not progress to harder drugs. But for those who do make the progression, the explanation is psychological and sociological, not pharmacological. The personality traits of curiosity and risk taking that lead some people to use marijuana will lead some of them to try harder drugs. And where people have the opportunity to buy marijuana, harder drugs may also be available (McKim 1986). Many false or exaggerated claims have been made about harmful effects of marijuana, so that people who have tried marijuana without any apparent bad effects may subsequently disbelieve claims about harmful effects of harder drugs, and thus be willing to try the harder drugs. The stepping-stone hypothesis is, at best, an oversimplification of the facts.

Physiological effects. Heavy marijuana use can lead to physiological *tolerance*, in the sense that physiological responses (such as heart rate) to a given dose are reduced. However, this tolerance effect does not lead to a craving for higher doses, as it does with some drugs such as heroin and cocaine. Physical dependence (or physiological addiction) was found in a study where very high doses of THC were taken every four hours for ten to twenty days. When THC use was stopped, subjects had withdrawal symptoms—such as irritability, nausea, and sleep disturbances—that peaked after eight hours and declined over the next three days (Jones & Benowitz 1976). However, physical dependence and withdrawal symptoms do not occur with ordinary chronic use and normal doses (Ray & Ksir 1987).

Are there any harmful physiological effects of chronic marijuana use? Yes. Marijuana reduces the activity of the body's immune system, which fights against invading microorganisms to prevent disease. Like tobacco smoke, marijuana decreases the activity of macrophages in the lungs, which attack bacteria and foreign substances. Also, like tobacco smoke, marijuana smoke is an irritant to lung tissue. However, though it is highly plausible that heavy marijuana use can cause an increased frequency of lung infections, and possibly lung cancer, there is no clear proof that this is the case. A major problem complicating research on effects of chronic marijuana use is that heavy marijuana users usually use other drugs—such as tobacco and alcohol—so it is virtually impossible to distinguish the effects of marijuana from the effects of other drugs (McKim 1986).

Some studies have found that marijuana use lowers levels of the male hormone testosterone. It is not clear whether this has any functional significance in adult males, since testosterone levels vary widely between different men and from time to time within individuals. More important is the role of testosterone in biological development. Testosterone is important for the growth spurt and physiological changes that take place at puberty in males, including secondary sex characteristics such as beard growth and lowered voice pitch. Heavy marijuana use at puberty might interfere with these changes. Also, in the unborn fetus, at eight to ten weeks after conception the male fetus starts secreting testosterone, which plays a critical role in differentiation of the brain and the urogenital system, including the male sex organs. Thus, normal physical development of the male fetus could be disrupted if the mother uses marijuana. Again, there is no clear evidence that this happens, because mothers who are heavy marijuana users usually use other drugs, too.

Conclusion. It is clear that marijuana is not a "killer weed," nor does casual marijuana use make people violent, crazy, or stupid. Most of the possibly harmful effects of chronic marijuana use are suggestive, rather than proven. It has been impossible to get clear proof of harmful effects of chronic marijuana use in humans because of the limitations of correlational studies and the fact that most heavy marijuana users also use other drugs, such as tobacco and alcohol.

Without exaggerating the dangers of marijuana, three cautions about its use are in order: (1) Acute marijuana intoxication has been shown to interfere with safe automobile driving by slowing reaction times, increasing attentional distraction, and interfering with judgment. The claim that stoned people can "come down" to drive safely is a myth. For the safety of yourself and your friends, as well as innocent strangers, don't drive stoned. (2) Acute marijuana intoxication increases susceptibility to attentional distraction, disrupts thought processes, and interferes with learning. If you want to do your best work as a student, you should study and go to classes straight, not stoned. The same point applies if you have a job that requires flexible, intelligent thought. (3) Though the proof is not as clear for marijuana as it is for some other drugs, such as tobacco and alcohol, there is reason to suspect that marijuana can interfere with the development of the unborn fetus. If you are pregnant, or think that you might be pregnant, avoid using marijuana and other drugs, except those prescribed by your doctor. You might be willing to take risks for yourself, but it would be wrong to take risks for your unborn child.

THE MARIJUANA PARADOX

The marijuana paradox is that so often the strongly felt subjective effects of marijuana turn out to be illusions when they are tested by objective methods. For example, subjective impressions of increased sensory sensitivity conflict with the results of psychophysical tests, which typically show no change or a decrease in sensitivity. Intuitive social perceptions often turn out to be false, and apparently creative insights often turn out to be mundane in the light of sober judgment. Even the "reverse tolerance" effect (the belief that experienced users become more sensitive to marijuana) has turned out to be an illusion by objective criteria (R. T. Jones 1971).

Believers in the reality of "alternative realities" that appear during altered states of consciousness will protest that the claim that the subjective experiences are illusions is incorrect or even arrogant, since it assumes that the experimenter's "objective reality" is more real or true than the marijuana smoker's subjective reality. I prefer not to get sidetracked by philosophical arguments about how to decide whether one reality is more valid than another. However, it is important to stress the point that, regardless of their correspondence with objective measurements, the altered subjective experiences during marijuana intoxication are often intensely real to the user and are an important psychological phenomenon in their own right. We need to know more about the reasons why people who are stoned on marijuana have such unusual but intense subjective experiences, such as feelings of increased sensitivity, insights into oneself and others, changed judgments of the humorous and the profound, and feelings of creativity, regardless of whether any of these beliefs correspond to the results of objective measurements. I predict that part of the explanation of marijuana's subjective effects will come from a further understanding of its neurophysiological effects, but that a complete answer will also have to consider the social psychology of attribution, expectation, and belief.

SUMMARY

Psychedelic ("mind manifesting") drugs are a heterogeneous group whose most striking subjective effects include changes in perception and imagination. They include marijuana and the hallucinogens. As Tart explained, reactions to psychoactive drugs depend on an *interaction* of drug factors (type, dose) with long-term personal factors (personality, attitudes, knowledge, beliefs), immediate personal factors (mood, expectations), and situational or experimental factors (physical and social setting, instructions, implicit demands).

Marijuana (active ingredient, THC) can produce a variety of subjective effects, which vary from one individual or occasion to another. The *marijuana paradox* refers to the fact that some strongly felt subjective effects are not supported by objective evidence. Important subjective effects and objective results during marijuana intoxication include the following: (1) Subjective reports of increased sensory sensitivity are contradicted by results of signal-detection experiments; in fact, sensitivity is decreased, mainly due to attention shifts during testing. (2) Subjective reports of memory disruption are supported by laboratory experiments. Marijuana disrupts short-term memory by increasing its susceptibility to interference. It also interferes with learning (transfer of new information from STM to LTM). (3) Subjective reports of changed time experience are confirmed by quantitative studies showing overestimation of time intervals. (4) Subjective feelings of increased creativity are not supported by objective measures, such as tests of divergent thinking. (5) Subjective impressions of enhanced interpersonal perception and communication are contradicted by experimental results; in fact, the opposite usually occurs. (6) The subjective impression of ability to "come down" at will is contradicted by evidence that marijuana slows automobile braking time and increases driving errors. The subjective and cognitive effects of marijuana have been interpreted as a shift in cognitive style, but no theory adequately explains all of marijuana's effects.

Marijuana has been blamed for the "amotivational syndrome" in adolescents and accused as a "stepping stone" to stronger drugs, but the evidence has alternative interpretations. Claimed harmful effects of marijuana have often been exaggerated or unfounded, but caution was advised especially in regard to three situations: automobile driving; school or work requiring peak intellectual performance and learning; and pregnancy.

ENDNOTES

[1]William McKim advised me that it is impossible to devise an entirely satisfactory classification of psychoactive drugs based on their psychological or behavioral effects, since they have

such a wide variety of effects and clinical uses. But I wanted a concise table, and I thank him for his suggestions on Table 18.1. For more information on the drugs in Table 18.1, see McKim 1986.

[2]In surveys conducted in General Psychology classes at the University of Maine, students were asked whether they had ever smoked marijuana, and if so, did they get "stoned" the first time they smoked (a lot, a little, or not at all). Between 1976 (n = 157), 1983 (n = 151), and 1989 (n = 169), the percent who had ever smoked marijuana decreased from 72 to 68 to 46 percent. But of those who had smoked, the percent who felt stoned the first time increased from 36 to 43 to 59 percent. It is uncertain whether the changes in percent who felt stoned are due to changes in the smoking population, changes in the quality of marijuana, or some other variable (G. W. Farthing, unpublished data).

[3]In the study described here, Darley et al. (1973b) used a free-recall procedure and examined effects of THC on the primacy and recency effects in the serial position curve. Briefly, THC affected the primacy effect (recall of words early in the list, which depends on recall from LTM), but not the recency effect (recall of the last few words on the list, which involves recall from STM). The serial position curve and its significance is described in most cognitive psychology textbooks (for example, Best 1989; Klatzky 1980). Readers interested in more details on the effects of THC on the serial position curve should consult Darley et al. (1973b).

[4]Computationally, r = produced interval divided by target interval. For example, under THC, when asked to *produce* a 120-second target interval, a subject might sound the tone for only 80 seconds (underproduction), since 80 (objective) seconds seems to him (subjectively) like 120 seconds. This would compute to 80/120 = 0.67 objective seconds per subjective second. In other words, his internal clock has speeded up. It "ticks" once every 0.67 seconds, or three ticks in two seconds. But he assumes it is still ticking once per second. Thus, if asked to estimate the duration of a tone, this subject would *estimate* a 120-second tone to be 180 seconds long (overestimation), since his inner clock would beat 180 times in 120 seconds. Underproduction is equivalent to overestimation of time intervals.