Psychopharmacology of Hallucinogens

HALLUCINOGENS AND ATTENTIONAL DYSFUNCTION: A MODEL FOR DRUG EFFECTS AND REALITY TESTING

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Hallucinogens have been traditionally defined as those drugs which produce hallucinations. The word hallucination, in turn, comes from the Latin deponent or half-passive verb *alucinari*, meaning "to wander in mind". To the extent that drugs produce a "wandering in mind" or a "wandering in attention", many, if not most, psychoactive agents qualify as hallucinogens. However, in both pharmacological and psychological usage, hallucinogens have come to refer to those drugs which produce changes in mood, thought, and perception and are further characterized by the presence of sensory distortions, illusions, hallucinations, and impaired reality testing.

Observations on hallucinogen-treated animals are rich with descriptions of these effects. For example, Scheckel and co-workers (1968) found that the general behavioral changes in squirrel monkeys given delta-8 or delta-9-tetrahydrocannabinol (THC) were much more dramatic than changes observed in operant responding. Low doses of THC (4 or 8mg/kg) caused the monkeys to sit quietly near the operant levers and look down at the lower part of the chamber. Higher doses seemed to induce apparent hallucinations that

> excited the monkeys and caused them to walk about the box, apparently looking at something the experimenters did not see, or crouch and move their heads from side to side and up and down as if watching some moving object. Some animals had a blank expression and gazed into space. We assumed that the animals had visual hallucinations... In all monkeys given 32 or 64mg/kg, this apparent hallucinatory reaction was more obvious. Monkeys moved quickly about the box, looked above and behind themselves, seemed to be in a state of panic, and appeared to fight with imaginary objects; their arms would swing rapidly through the air and they would attempt to grasp objects that were not there (p.1467).

Such behaviors are strikingly similar to those of preverbal children given the hallucinogenic anesthetic ketamine prior to surgical procedures (cf. Siegel and Jarvik, 1975). The recovery behavior of these children is frequently marked by pointing, reaching, and grasping at the air; spontaneous head and eye orientations in the absence of apparent stimuli; and, in one case a crawling away from an area of the bed which the child continued to strike at with his hands while screaming and crying.

The nature of the phenomena is better understood when these perceptual-motor behaviors are coupled with verbal reports, as in the case of studies with adult humans. Among the many effects

reported by human subjects are an inability to control thought; a wandering in mind; a shortened concentration span; and distractibility (Hoffer and Osmond, 1967, p.120). Attention to stimuli seems to wander as human subjects gradually shift their attention from outward dimensions to inner private events(Fischer, 1975). Indeed, the perceptual components of these inner private events, the colorful imagery and pseudohallucinations, are often some of the most dramatic and salient features of the hallucinogenic experience. As attention is shifted to these inner stimuli, intellectual functioning based on stimulus control and attention of outward dimensions is impaired. In animals, stimulus control appears to be disrupted (Dykstra and Appel, 1974) and animals shift attention from relevant cues to irrelevant cue dimensions (cf. Sharpe et al., 1967). In humans, performance on tasks measuring concentration, attention, and memory is impaired (e.g., Jarvik et al., 1955) and reality judgments disrupted (Hoffer and Osmond, 1967).

In all such cases, the organism can be described as behaving or not behaving in accordance with environmental stimuli. All these behaviors involve responses to perceived stimuli in the internal or external environment. Even though there are often no objective stimuli as in the case of hallucinations, there are acts of perceptual-motor behavior. Skinner (1963) calls this "seeing in the absence of things seen" and he notes that this behavior is often identical when seeing occurs in the presence of things seen. But the responses of the monkey fighting with imaginary foes, the child striking the bed, and the human subject's confusion with experimental demands are not reliably controlled by objective stimuli. In such cases the notion of attention is invoked. It is sometimes more useful to say that attention is engaged with subjective stimuli or the organism's condition is one of selective awareness or perceptual receptivity to a given class of internal stimuli. The use of such an attentional framework in which to analyse hallucinogen-induced behaviors has considerable merit. Not only does the concept of attention take into account variations in perceptual function, but it assumes an intimate dependency on changes in mood, motivation (set), and cognition, well-known concomitants of the hallucinatory experience. Attention is more than a hypothetical construct here, it lends itself to direct testing. An organism is said to attend to a dimension of stimuli if variations in the value of the stimulus produce variations in behavior, otherwise he is said not to attend (Skinner, 1953). Thus, whether a subject is or is not attending to a stimulus dimension can be determined by analysis of an empirical function relating stimulus values to behavior, such as a gradient of stimulus generalization. Attention theory is also compatible with the language and events of electrophysiology and neurochemistry and mechanisms of action can thus be postulated and tested.

This paper attempts to describe such attentional effects of hallucinogens in both animals and man and to outline the methods used in their experimental analysis. The first section reviews observations on infrahuman species which suggest the

"distractibility" produced by hallucinogens. The second section describes the nature of attentional shifts in human behavior, with particular reference to verbal reports of these effects. The third section reviews several experimental studies on stimulus control in which attentional functions have been directly or indirectly assessed with hallucinations. The fourth part presents a new series of experiments on hallucinogen-induced changes in stimulus control as a model for the further experimental analysis of hallucinations, illusions, and reality testing.

Animal Observations

Observations on hallucinogen-treated animals indicate many reactions to apparent stimuli in the internal or external environments. A description of the exact nature of these stimuli, and whether or not they represent hallucinations, depends ultimately on what we are willing to infer from the associated behaviors. Nonetheless, many behaviors appeal to an intuitive sense of what is reasonable to infer. In addition, so-called drug-induced hallucinations appear clearer and more purposeful as observations are made higher up the phylogenetic scale. The comparatively limited behavioral repertoires of invertebrates and lower vertebrates, and their basic "alien" nature, prevent many human observers from agreeing on the interpretation of hallucinogen-induced changes. However, with mammals and infrahuman primates the range of behaviors is fuller and more familiar, the temptation to anthropomorphize is greater, and human observers find the reactions to hallucinogens more convincingly hallucinatory. Whether simply species-specific behaviors triggered by nervous system excitation and arousal, or hallucinations, the descriptions of the perceptual-motor behavior suggest selective awareness or perceptual receptivity to an "unknown" class of stimuli. Simply stated, they suggest hallucinogen-induced changes in attentional functioning. Representative examples in several species are cited below.

Insects

Web-spinning activity in several species of spiders (*Zilla-X-notata*, *Meta reticulata*, *Arenea diadema*) is highly dependent on good stimulus control and attention. Generally, the regularity of the web pattern is determined by the spider taking the shortest path which demands the least effort in spinning. Slight irregularities occurring in a normal web are usually due to distracting external stimuli that cause the spider to swerve from the shortest path. In a series of elegant studies, Witt (1951, 1956) studied the effects of lysergic acid diethylamide (LSD) and mescaline on this behavior. Low doses of LSD (0.03-0.05mcg per animal, p.o.) decreased the frequency of web making, reduced the number of oversized sectors, increased regularity of the angles between the radial threads of the web, and increased the regularity of the sticky spiral thread. Witt interpreted these effects as greater regularity due to better control over internal sensory impulses and the diminution of extraneous (distracting)

external stimuli. Higher doses of LSD (0.1-0.3mcg per animal) produced a slight reduction in the catching area of the web; longer vertical dimensions in relation to horizontal dimensions; and slight reductions in the regularity of the angles between the radial threads of the web. Mescaline (100mcg per animal) and adrenochrome (4.0mcg per animal) produced marked distortions and irregularities in web construction. Christiansen et al. (1962) found similar disrupting effects of psilocybin and mescaline on web-spinning behavior. These effects were attributed to an increase in the environmental stimulus control of spinning behavior and a concomitant loss of an intrinsic control system. While Witt attributed differences between hallucinogens to different mechanisms of action in the spider, it is also possible that equivalent doses were not tested here.

The social behavior of many insects is also under strong stimulus control of both genetic and environmental variables. In a study of LSD effects on hornet behavior in colonies of *Vespa orientalis*, Floru and co-workers (1969) found hypersensitivity and increased aggressiveness. Commenting on this disruption in behavior, they note that "manifestations of aggressiveness towards other members of the colony is an interesting phenomena which constitutes in fact a distortion of functions intended to preserve the species, and indicates that the reflexo-instinctive behaviour of hornets may acquire anti-survival values under the influence of drugs" (p.340). Reviewing these and other studies on insects and lower organisms, Witt (1975) concludes that the most characteristic effect observed across species was that on social interaction: "LSD increased aggressiveness and modified hierarchical rank upwards, wherever this was measurable (wasp, newt, fish)" (p.622).

Fish

Fish behavior is often under well-defined stimulus control. For example, the swimming, pigmentation, and display behavior of Siamese fighting fish (*Betta splendens*) is largely controlled by visual and olfactory stimuli generated by other fish, as well as stimuli in the water environment itself (light, temperature, and visual cues). Abramson and his colleagues (e.g., Abramson and Evans, 1954; Evans et al., 1956) investigated a variety of hallucinogens on this behavior. In general, they found that LSD and its hallucinogenic derivatives produced characteristic changes in behavior including: backward movement with pectoral fins, head up at surface, vertical posturing, vertical barrel-roll, body kinking, quiescent state, slow deliberate movements, lateral display, and darkened pigment. Some of these behaviors, including the last two, are usually elicited by attacking fish but in the Abramson studies they occurred spontaneously with hallucinogens but not with non-hallucinogenic derivatives like bromo-lysergic acid diethylamide (BOL). Unfortunately, the authors tested fish in groups of three or four individuals (this puts them under the constant stress of display with other fish) and they did not specify sex, temperature, or illumination conditions. Therefore, caution must be used in speculating about disruption of stimulus control here. Nonetheless, fish frequently exhibited their

typical rage reaction and display reactions when in otherwise quiescent conditions.

Turner (1956) speculated that the LSD effect on Siamese fighting fish could be due to distortions of information in the visual pathway whereby the spatial and visual organization of the impulses is encoded to the tectum and to other parts of the nervous system. Similar disruptions in the control of swimming behavior were observed with LSD-treated guppies (Keller and Umbreit, 1956a). The characteristic effect with guppies consisted of "a rapid swimming until the wall of the container was reached, at which point the fish continued to swim apparently unaware that they were not making any progress" (p.407). Other studies investigating hallucinogenic responses in fish are reviewed by Weckowicz (1967). In general, these responses include disturbances in social behavior, courtship behavior, and difficulties in orientation. While such behaviors are usually under strong stimulus control in normal fish, the lack of suitable pharmacologic controls prevent any firm conclusions from these studies with respect to hallucinogens. Indeed, reviewing the evidence on tropical fish studies, Chessick et al. (1964) suggest that most of the LSD effects are little more than "non-specific distress" and this "may be produced by a number of agents such as drugs, sudden temperature changes, foul water, disease, etc." (p.392).

Siegel (1971) conducted a series of studies with the tropical fish neon tetra (*Hyphessobrycon innesie*) and carefully controlled for some of these factors. Schools of neon tetra are highly polarized with no more than one body-length between individuals. This inter-fish distance is remarkably invariant and appears to be the minimal distance sufficient for normal swimming behavior. Schooling behavior is under the control of visual cues (modeling other fish), temperature, light, and pH factors. Holding the latter three factors constant, Siegel found that the hallucinogens LSD and bufotenine disrupted this schooling behavior at dose levels which did not affect individual postural behavior. This suggests that the notion of "non-specific distress" may not be valid and that there is a strong interaction between hallucinogens and visual cues controlling schooling behavior.

Rodents

Perhaps the most salient hallucinogen-induced behavior in mice is the head twitch response. This response has been described as resembling a strong pinna reflex involving lateral movement of the entire head without observable tactile stimulation (Corne and Pickering, 1967). In subjective terms, the animal is shaking its head as if to escape from an apparently aversive stimulus. Indeed, concomitant increases in both the frequency and duration of grooming postures (e.g., paroxysmal ear scratching) have even been cited as evidence for "cutaneous hallucinations" (Siegel and Jarvik, 1975). Treatment with hallucinogens induce significant changes in head twitch rates when compared with predrug periods or treatment with other drugs. Siegel and Jarvik (1972) attempted to rank and compare various hallucinogens by determing the minimum effective dose necessary to induce head twitches in at least 50% of the population (MED-50). These MED-50s ranked the hallucinogens in the ascending order of bufotenine, LSD, mescaline, and ketamine. Interestingly, this order is virtually identical to that depicting the degree of central nervous system excitation induced by the same agents in cat brain (see Winters, this volume). Although these responses may not represent hallucinations

50s ranked the hallucinogens in the ascending order of bufotenine, LSD, mescaline, and ketamine. Interestingly, this order is virtually identical to that depicting the degree of central nervous system excitation induced by the same agents in cat brain (see Winters, this volume). Although these responses may not represent hallucinations, the dosages necessary to induce them are highly correlated with doses that produce reports of hallucinations in man (Corne and Pickering, 1967). In addition, prolonged solitary confinement produces identical head twitch responses in mice (Keller and Umbreit, 1956b) as well as hallucinations in man (Zuckerman and Cohen, 1964).

Recent studies have suggested that this head twitch response may represent disruption of stimulus control and attention to tactile stimuli. Boulton and Handley (1973) have demonstrated that the head twitch is highly dependent on sensory input from the pinna. These investigators infiltrated the local anesthetic lignocaine around the base of mice's ears, and this was highly effective in antagonizing both the head twitch response and the pinna reflex. Increasing sensory input from the pinna with the irritant xylene increased a drug-induced head twitch response. In these studies, the authors induced head twitching with 5-hydroxytryptophan (5-HTP). This compound has not been shown to be hallucinogenic in man, but Corne et al. (1963) have argued that this is simply because a large enough dose has not yet been administered. Nonetheless, 5-HTP-induced head twitching has been correlated with rises in 5-hydroxytryptamine (5-HT) levels in the brain stem. Futhermore, it has been hypothesized that hallucinogens such as LSD act by mimicking the central actions of 5-HT (Aghajanian, 1972) which may result in abolition of the sensory filtering mechanisms in the reticular formation (Bradley and Key, 1958). Boulton and Handley's study shows that the 5-HTP head twitch is highly dependent on sensory input from the pinna and that "this response could be due to the perception of previously subliminal stimuli from the pinna region" (p.213) if not hallucinations per se.

Elliot (1971) found LSD-induced head shaking in rats but disputed the notion of hallucinogen-induced attentional dysfunction. He examined nest-building and general maternal care in rats treated with LSD. The rats in this study failed to carry out the more highly integrated activities of nest construction while continuing, although at a reduced rate, the less complex behavior of paper collection. These effects, according to Elliot, are better explained as selective disruption of more complex cognitive behaviors than by a simple shift from extrinsic to intrinsic stimulus control. Thus, he argues that the major pattern resulting from LSD treatment is *cacobiosis* (an abnormal way of life): "The organism's adaptive mechanisms are disrupted, resulting in breakdown of the maintenance of dynamic equilibrium between it and the environment" (p.278). Nonetheless, to the extent that such equilibrium is mediated by stimulus control and attentional factors, the concept of attentional dysfunction cannot be completely dismissed here.

Cats and dogs

Several investigators have noted unusual patterns of behavior in cats treated with various hallucinogens and they have labeled such behaviors "hallucinatory" (see review by Siegel and Jarvik, 1975). For example, Schneider and Sigg (1957) studied the effects of ibogaine hydrochloride (2-10mg/kg, i.v.) on cat behavior and observed that:

> Usually the animal remained in one place, slightly shivering, the tail out-stretched, while making hissing sounds as if trying to scare off an imaginary object. Often the cat tried to move toward a corner, hide there, and bury its head in it. Sometimes the animal approached a corner and tried to climb up the walls, apparently attempting an escape (p.766).

Numerous other investigators have observed responses in cat behavior which appear to reflect marked shifts in attention and disruption in normal stimulus control patterns. These reactions include "fondling mice", head shaking, staring, and abnormal postures. Recently, Jacobs and co-workers (see Jacobs, this volume) observed that hallucinogens induce characteristic behavior in cats including looking around at the floor, ceiling, or walls of the cage. The animals appeared to be tracking objects visually as "when the cat either hisses at, bats at, or pounces at unseen objects".

The effects of hallucinogenic amphetamines on cat behavior as compared with the behavior of other species were examined by Florio et al. (1972). These investigators found that 2,5-dimethoxy-4-methyl-amphetamine (DOM or STP) induced EEG excitation in rats, as well as backward locomotion, head nodding, and a stereotypic pattern of behavior known as "wet dog shakes". Similar effects were induced in rats by *d*,1-3-4-5 methylenedioxy-methoxy-amphetamine (MMDA). DOM produced searching and exploration in rabbits, alternating with periods of stupor and catatonia. As the authors tested animals further up the phylogenetic scale, the amphetamine-induced changes appeared even more purposeful. In cats, DOM (0.25mg/kg) "gave rise to characteristic changes in behavior which we have designated as 'hallucinatory': striking at imaginary objects in the air, sometimes exhibiting bizarre postures, staring intently at a corner of the cage, and shaking the head" (p.406).

Similar behaviors have been observed in dogs treated with hallucinogens. Representative of these studies are the observations of Hardman et al. (1973) on mescaline-induced behavior:

> The convulsive episodes are preceded and followed by barking, yelping, and apparent hallucinations. The dog usually exhibits mydriasis and runs wildly about the room bumping into walls and furniture. The dog also appears to be apprehensive, frightened and disoriented; barking or snarling at inanimate objects is noted frequently (p.304).

Such staring and attending behavior has been observed in dogs treated with many hallucinogens ranging from marihuana to ketamine. Indeed, recovery from ketamine is marked by "barking, whining, ataxia, agitated pawing, rigidty, disorientation, and chasing 'unseen' objects" (Albin et al., 1974, p.127).

Primates

Siegel and Jarvik (1975) have reviewed evidence suggesting that hallucinogens induce perceptual distortions in infrahuman primates. In one study (Boelkins, 1973), a para-chlorophenylalamine (PCPA)-treated monkey was observed to make an oriented and focused visual search of his environment without apparent stimulus targets. In addition, there was an increase in a stereotyped vocalization pattern that functions as an alerting and warning bark "with no external stimulation visible or audible to the observer". In another study, Evarts (1958) found that LSD (1mg/kg) failed to impair the accuracy of monkeys' performance on a variety of learned responses but did produce a syndrome characterized by ataxia and loss of responsiveness to normal visual stimuli. Even when monkeys were treated with doses of hallucinogens which did not produce ataxia, there was marked evidence of spatial disorientation and responses to non-existent stimuli (Cohen, 1965). Garver and colleagues (1975) administered d-amphetamine chronically to stumptail macaques and observed hypervigilance, hyperactivity, fragmented and repetitive behaviors, and progressive social withdrawal as well as the development of solitary stereotypies. The animals also manifested frequent changes of their visual orientation, a behavior termed "checking". Siegel and co-workers (Siegel et al., 1974; Brewster et al., 1976) found these checking behaviors and allied exploration postures to be specific dose-dependent characteristics of hallucinogenic effects in monkeys.

Much of the perceptual-motor behavior observed in these studies is virtually identical to that seen when the animal is responding to real stimuli which are physically present. For example, Stadnicki et al. (1974, p.228) reported that one monkey, following cessation of chronic marihuana treatment, appeared to be hallucinating "as evidenced by the staring at, and following of, an imaginary object with the eyes". Similar reactions were observed in the chimpanzee by Baldwin et al. (1957) and in baboons by Lagutina et al. (1964). It has been suggested that these effects are the result of changes in attentional mechanisms (Sharpe et al., 1967) and cortical responsiveness to visual stimuli (Bermond and Bert, 1969; Heath, 1973) which are projected from internal to external environments (Dement et al., 1970).

Hallucinogens induce similar behavior in totally dark environments in monkeys (Brewster et al., 1976) and in man (Siegel and Jarvik, 1975). The presence of some LSD- or marihuana-induced visual imagery in totally blind subjects (Kirtley, 1971; Krill et al., 1963) as well as non-drug-induced complex hallucinations in recently blinded subjects (Fitzgerald, 1971) would also seem to support the notion that drugs focus attention on internal visual stimuli. Recently, Siegel et al. (in press)

studied the reactions of two blind monkeys to various pharmacological treatments including hallucinogens. LSD and dimethyltryptamine (DMT) could be distinguished from non-hallucinogens by the increased frequency of spasms, stereotypy, bumping, and tracking (checking) behaviors. The hallucinogens also produced dramatic increases in exploration and related behaviors normally seen only in response to real visual or auditory stimuli. Perhaps the most dramatic behavior was observed when one of the blind monkeys, Samson, was given his first hallucinogen treatment (LSD, 50mcg/kg, i.m.). Five minutes following the injection, Samson reached for his eye sockets--a response never before observed in this animal--and started rubbing them while shaking his head and periodically "freezing" in a crouched and attentive posture, a posture characteristically observed in monkeys following treatment with active cannabinoids (Grunfeld and Edery, 1969). The concomitant increases in bumps and exploration of the cage walls with directed hand and mouth movements prompted the inference that this was a startle response to a visual stimulus. Other changes in behavior support this interpretation. Samson's normal reaction to stimuli consisted or rapid head- and ear-orienting responses followed by head turning and swaying "as if" searching for the location of a sound. These behaviors increased dramatically during hallucinogen sessions even though testing was conducted in a soundproof chamber. Seemingly accidental tactile encounters with the cage environment would elicit increased exploration with the hands and the head- and ear-orienting responses. The other blind animal, Lear, following treatment with DMT (2mg/kg) executed numerous "startle-like" reactions coupled with tracking movements. In one sequence, Lear repeatedly stood up and sat down, "looking" or orienting around the cage, while periodically jerking and moving backwards "as if" startled. One such startle reaction was accompanied by a fear grimace.

Overview

It may be speculated that the type of exploration, tracking, and groping behavior seen in these animal studies constitutes a motor attempt by the organism to verify perceptions. In man, hallucinogenic and hallucinatory states have been associated with changes in perceptual constancies and some psychophysical judgments which interfere with the ability to validate such sensory information (Fischer, 1971). In monkeys, variable changes in psychophysical judgments with some hallucinogens have also been found (Brown and Bass, 1967). Thus, Samson's exploration, tracking, and groping behaviors may represent motor responses to changes and variations in perceptual systems. Similar processes may be involved in lower organisms. The mechanism of action responsible for such effects is largely unknown but may be related, in higher organisms, to recent studies in cats which found that hallucinogens like LSD and DMT mimic the effect of light on the retina (Heiss et al., 1973) or on EEG tracings (Marczynski, 1972) and cause cortical disinhibition (Demetrescu, 1976). Such drugs "might be interpreted by the brain as light and this may contribute to the origin of abnormal reactions within brain structures which are also influenced, leading to hallucinations" (Heiss et al., 1973, p.457).

Alternatively, such behavioral changes may be no more than elicitation of motor patterns of behavior already "programmed" in the organism. The consistent stereotypic and species-specific postures exhibited by most hallucinogen-treated animals are typographically related to the ethological phenomena of "vacuum activities" (cf. Lorenz, 1963). Ethologists refer to activities given in the absence of external signals as vacuum behavior or "displacement activities" which connote that they are given out of context. Many of the investigators in the studies reviewed above used the term "abnormal", "distracted", "disturbed", or "inappropriate" to describe similar behaviors. For example, Kaymakcalan (1973) referred to reactions of *Cannabis* dependent monkeys as including "staring in circles, grasping as if catching flies and slapping the cage wall" (p.43). Lorenz described a similar behavior in a well-fed starling, which was deprived of the opportunity to catch flies. Suddenly, the bird went through all the movements of searching for a fly, catching it and killing it, although no fly was discernible to the observer. Similarly, Doty (1970) describes stimulation of area 18 in one macaque which elicited behavior and movements that "imitated exactly that of macaques catching flies and would also seem to be identical with that made by Foerster's patient who attempted to catch an hallucinated butterfly upon stimulation of the occipital lobe" (p.106). It is possible that no perceptions actually occurred and, therefore, such hallucinations are hallucinations, not in the perceptual sense, but only in the motor sense. Indeed, as Skinner (1963) stresses, "seeing does not require the presence of things seen" and "we need not be concerned about certain mental processes said to be involved in the construction of such things [as hallucinations]" (p.954). However, it will presently be seen, the verbal reports from human subjects (valid motor behaviors in their own right) indicate that much more is going on in the organism besides simple stereotypic or "programmed" postures. Human subjects offer clear and unequivocal documentation of attentional dysfunction and preoccupation with internal stimuli.

Human Reports

The phenomenology of hallucinogenic reactions in man has been extensively described by many investigators (e.g., Hoffer and Osmond, 1967; Barber, 1970; Siegel and Jarvik, 1975). Barber classifies these reactions as somatic-sympathetic effects; changes in body-image; dreamy-detached feelings; reduced intellectual-motor proficiency; changes in time perception; changes in visual perception; changes in audition, olfaction, gustations, and synesthesia; heightened responsiveness to primary suggestion; and changes in moods and emotions. The perceptual changes (discussed below) are clearly related to changes in stimulus control and attention. Other effects may also be influenced by changes in attentional functions. For example, the dreamy-detached feelings "appear to be related to changes in cognitive functioning; concentrating or attention becomes less proficient, and a rapid flow of ideas is at times experienced" (Barber, 1970,p.23).

Indeed, Barber feels that the most important factor in the intellectual-motor impairment associated with hallucinogens is

> a difficulty in maintaining focus on the task. The distractibility and the difficulty in shifting set can be inferred from the subjects' reports that their concentration spans are shortened, their minds wander, and they are unable to control their thoughts. The distractibility becomes quite striking at high doses of the drug [LSD] when subjects are generally unable to maintain attention and concentration to complete the tasks (p.25).

Alterations in time perception may also be due to decreased attention and the changes in mood and emotion in part due to novel experiences "which alert the subject to notice things that he would not otherwise notice and to see the old and familiar in a new light" (Barber, 1970, p.64). Equally important are "negative hallucinations" or not seeing things that are actually present.

Among the perceptual effects reported by human subjects, changes in visual perception are the most striking and characteristic of hallucinogenic intoxication. Hoffer and Osmond (1967) describe a number of these effects including blurring of vision, imagery filling the visual world, changes in three-dimensional space, distortive changes in faces and objects, changes in colors, illusions, hallucinations, increased afterimages, and qualitative changes in objects. Occasionally, these perceptions are accompanied by motor behaviors. Hoffer and Osmond (1967) note some activity changes including restless, impulsive, and "foolish" behaviors. Aggressive outbursts, anxious repetitive acts, and fear and flight reactions are also observed in "panic" or "psychotic-like" reactions (Barber, 1970). Klüver (1966) notes a mescaline-induced oral syndrome in both monkeys and man. This behavior consists of characteristic movements of lips, tongue, and jaws, coupled with occasional "wiping" of the head and face. However, Klüver notes that such behaviors do not necessarily coincide with what human subjects report to be their sensations and he warns against excluding such reports from analysis:

> In other words, the observation of motor movements, whether in man or animals, may not permit reliable inferences as to the nature of the sensory concomitants of such movements or tell us whether the subject in question acts with reference to some sensory information or misinformation (p.xiv).

Hallucinogenic intoxication in man is marked by a shift from external to internal stimuli. Moreau (1845) describes this change as based on his studies with hashish:

> Progressively, as "excitement" grows, our mind shuts itself off from external impressions to concentrate more and more on subjective ones. In brief, as this kind of metamorphosis takes place, drawing us away from real life to throw us into a world where there is no reality except that created by our memory and our imagination; progressively, one becomes the toy, first of simple illusions, and then of true hallucinations, which are like distant sounds coming from an imaginary and fantastic world. When any object, alive or inanimate, strikes our sight or when a sound, such as the song of a bird, the

> hallucinations, which are like distant sounds coming from an imaginary and fantastic world. When any object, alive or inanimate, strikes our sight or when a sound, such as the song of a bird, the explosion of a firearm, or the ringing of bells, strikes our ears while the "excitement" is still weak, we feel very strongly that two distinct phenomena are occurring in our minds. (1) We have seen, we have heard, clearly and distinctly, as happens in the ordinary state. (2) Then suddenly, as the result of certain similarities known or unknown to us, the image of another object and the sensation of another sound are awakened within us. As a result of these intracerebral impressions, because of the action of memory and imagination, the mind pauses, soon confusing the two sensations as one, covering the real sensation with the imaginary one and projecting the latter upon the external object (pp. 75-76).

Metzner (1968) has collected a number of these reports which illustrate the phenomenology of hallucinatory experiences. Many such reports refer to the shifts in attention and stimulus control. Consider the following account by Rolf von Eckartsberg (1968) based on a psilocybin experience:

> The first noticeable change came about with regard to strange color effects. The room changed in illumination and therefore also in feeling tone from bright and sharp to glowing reddish and warm. For the first time I seemed to understand the existential-phenomenological experience of shifts in one's total state of being and the transformation of one's perceptual world as a consequence of this. Everything is pulling together and tightening up or expanding and receding with the concomitant change in color perception which leads to or precipitates a diffuse and global experience of warmth or other feeling dimensions...Next, peculiar boundary shifts enter into one's awareness, perhaps dissociations, definitely shifts of perspective...It is a most striking experience that the vertical and horizontal ordering principles gently disappear, they slip away, so to speak, the coordinate system vanishes, perhaps the most vivid experience or realization of perceptual change...The next stage, so to speak, although not directly distinguishable because of the extreme fluid boundaries and the elimination of structured spatiality, was an acute loss of time perspective or time-boundness...The ordering principles, particularly the directing forces of our mind, are relinquished. The self-reference recedes into the background and the judgmental ability or the motivation for forming opinions and judgments vanishes. One's gaze is synonymous with the direction of one's living. One is fully tuned in. One lives in one's senses, mostly visual....I am wandering, gliding, soaring through fantasy world in exploration. (pp. 38-45).

Many subjects refer to experiences evolving one into the other. Moreau noted that dreams, illusions, and hallucinations are often merged in hallucinogenic experiences and one "dreams while awake" in hallucinations. Other researchers refer to the experiences as coming and going in a wavelike fashion. Indeed, the periodic or wavelike alterations characterize many hallucinogenic effects (Barber, 1970, p.24). Examining such reports from a philosophical perspective, Savage (1975) proposes that sensations,dreams,

fantasies, hallucinations, perceptions, and thoughts are not really sharply distinguishable from one another. He argued that drug-induced hallucinations may appear to be similar to perceptions and they should be separable, but often are not, from the other experiences in terms of vivacity, coherence, voluntariness, concreteness, veridicality, and causality. For example, perceptions are more vivid than hallucinations, thoughts are less concrete than hallucinations, etc.

Reviewing the clinical literature on these experiences, Horowtiz (1975) offers a useful definition of these phenomena in terms of stimulus control and attentional functioning:

> Hallucinations are images based on immediately internal sources of information, which are appraised as if they came from immediately external sources of information. A close relative of the hallucinatory experience is the pseudohallucination, an image phenomenon in which the representations, based on internal information, are uncommonly vivid yet lack the sense of reality found in "ideal" hallucinatory experiences. An alternate definition of pseudohallucination is that the person responds emotionally as if the image were real, although in terms of cognitive appraisal, he knows it is not. Note that these two definitions are only points along a dimension of experience, a dimension that is itself a composite including attributes of representational modality, vividness, intensity, appraisal, emotional reaction, and volitional control (pp.165-166).

Laboratory Studies

Humans

A number of experimental studies have confirmed the presence of these phenomena (see reviews by Barber, 1970; Siegel and Jarvik, 1975). Among the results of these studies, primarily conducted with LSD, were: the Mueller-Lyer illusion is slightly enhanced; increased displacement of the vertical produced by body tilt; augmentation of variability in judging the size of test objects; increased duration and frequency of afterimages; increased duration, frequency, and shifts in dimensions of visual imagery; changes in reaction time to visual and auditory stimuli; and changes in psychomotor performance which are correlated with the above listed effects.

Animals

Several animal studies have analyzed hallucinogen-induced changes in stimulus control and attention by employing the method of stimulus generalization. In stimulus generalization studies, an animal is trained to respond in the presence of one stimulus or to respond differentially in the presence of two or more stimuli. A generalization test is then given during extinction: a number of stimuli along the same dimension as the training stimulus are presented and the animal's responses in the presence of each stimulus test value is recorded. The extent to which behavior is controlled by the training stimulus is related to the

slope of the generalization gradient obtained. A flat gradient, indicating equal amounts of responding to test stimuli, indicates little discrimination. Conversely, a steep gradient, showing peak responding to the training value, indicates that the animal has learned to discriminate and is under good stimulus control. Information about a drug's effect on stimulus control and discrimination can be obtained by measuring the amount of generalization during drugged and undrugged states. It is generally agreed that such testing procedures assess both discrimination learning and perceptual processes. The slope of the gradient indicates the extent to which the subject paid attention to that feature of the training situation and the extent to which he learned the discrimination required. The gradient also tells us about the organism's ability to respond to similarities between dimensional stimuli and in this sense it is a measure of perceptual processes which intervene in learning and performance situations.

Key has conducted an important series of studies on the effects of LSD on stimulus control and attention in cats (Key, 1961a, 1961b, 1964a, 1964b). In one study (Key, 1961b), the effects of LSD and chlorpromazine (CPZ) were studied on stimulus generalization and discrimination of auditory stimuli in an avoidance task. LSD (15mcg/kg) elevated response rates with no change in the shape of the gradient. CPZ (5mg/kg) produced lower response rates with no alteration of the generalization gradient. Surprisingly, Key interpreted this change in response rate as a change in "stimulus significance" for the animals: "If, by the administration of certain drugs such as LSD 25, the level of significance of the sensory information is altered, thus inducing changes in the balance of generalisation, then distortions of perception may occur, for the animal now responds, pays attention or arouses to stimuli which normally would not produce such an effect" (p.362). Similar effects were found in rats by Lowe (1972, 1973) who observed that LSD altered arousal levels and significance of visual stimulation. However, since the slope of the gradient in the Key studies was not altered, and this is the more conventional measure of increased "significance", this interpretation must be accepted with caution.

In another study, Key (1964b) examined the effects of LSD and amphetamine on generalization of visual stimuli in cats. He found that LSD (5-20mcg/kg) produced a broadening of the gradient with a slight reduction in response rate. Amphetamine produced an increase in response rate with a smaller flattening of the gradient than that produced by LSD. However, Dystra and Appel (1972) studied the effects of LSD on sensitivity to auditory stimuli in rats. These investigators found that the shape of the generalization gradient was changed after administration of the drug only with a dose which produced decreases in relatively high rates of responding. Thus, Key's data here may simply reflect changes in response rate and not attention per se.

A number of studies on the perceptual effects of hallucinogens have been carried out in the pigeon because of that animal's visual acuity and proven ability to perform complex tasks demanding good stimulus control and attention (see review by Siegel and Jarvik, 1975). Typically, low doses of LSD improve the accuracy of some visual discriminations. For example, LSD causes an improvement in the accuracy of a brightness and flicker discrimination, and little change in hue discrimination. Higher doses usually lower the response rate, thus making it difficult to assess performance. Siegel (1969) studied the effects of hallucinogens in pigeons on the separate dimensions of form and color, dimensions along which human subjects report hallucinogenic disturbances. The results suggested that hallucinogens may selectively impair stimulus control on the color dimension and that the animals may have been responding to stimuli which were not provided by the experimenter (i.e., hallucinations).

Fuster (1957), using LSD in monkeys, also reported disruptive effects on a visual discrimination task. Monkeys were trained to press a lever paired with one of a pair of objects presented tachistoscopically. LSD (2-8mg/kg) decreased accuracy and increased reaction time. Fuster concluded that the disruption of attentional processes was caused by the inhibitory action of LSD on the central nervous system.

Sharpe and co-workers (1967) trained squirrel monkeys to displace one of two vertically presented circular black discs, differing only in size, in order to obtain a reward. Low doses of LSD (.1-.4mg/kg) disrupted performance on a difficult task (size ratio 1.12:1) but not on an easy task (size ratio 1.96:1). Motor responding was not impaired since animals were capable of responding in both tasks, but accuracy was affected on the difficult problem. The investigators speculated that a shift of attention to irrelevant dimensions had taken place during the difficult task.

Brown and Bass (1967) trained monkeys in a shock avoidance task to respond to a series of different sized stimuli. Six of the stimuli were all varying sizes smaller than a constant test stimulus. A trial presentation consisted of two constant stimuli and one test stimulus and the animal was required to select the test stimulus. After two weeks of error-free performance, the monkeys were given a variety of psychoactive agents. LSD (0.5-0.3mg/kg) produced a dose-dependent decrement in accuracy but not in reaction time. Conversely, CPZ produced variable changes in reaction time with no disruption in accuracy except at the highest dose. Unfortunately, a large amount of variability in the data, and an incomplete presentation of accuracy and latency data, prevent a firm profile for hallucinogens from emerging here.

Roberts and Bradley (1967) studied the effects of various drugs on the performance of monkeys in a delayed response task. Animals were overfed or underfed in order to vary the motivational levels, and they were presented with distracting stimuli in an

attempt to disrupt attentional processes. In general, the distracting stimuli were effective in disrupting accuracy but manipulation of motivational levels had little effect. In addition, LSD (15mcg/kg) produced increased responding and impaired accuracy at delays greater than three seconds. The investigators suggested that LSD produced an attentional shift similar to that produced by the distracting stimuli. Indeed, Key (1964a) showed a similar distracting effect of LSD in auditory discrimination in cats.

Using a procedure similar to Siegel's (1969), Ferraro (1972) found that THC (1mg/kg, p.o.) produced a significant decrease in correct responses to a delayed matching-to-sample problem with monkeys. In this procedure, a time delay is introduced between the sample stimulus and the choice stimuli to which the animal will try to match the sample. As the delay grows longer, the problem becomes more difficult for the animal. THC produced no decrement at 0-second delay, thus demonstrating that the animal still had the motivation, attention, and motor responses necessary for correct responding. However, the same dose of THC did disrupt performance at delays of 5-20 seconds, indicating some interaction between attention and short-term memory.

In general, these studies, as well as others, have shown that hallucinogens impair accuracy (Jarvik and Chorover, 1960, Becker, 1967; Blough, 1957); disrupt stimulus control (Fuster, 1955; Siegel, 1969); and produce attentional shifts (Roberts and Bradley, 1967; Sharpe et al., 1967; Ferraro, 1972). However, these investigations have failed to provide an adequate assessment of the perceptual events which specifically characterize hallucinogenic effects or to specify the stimulus control nature of the attentional shifts. For example, the experiments do not indicate whether hallucinogens alter the discrimination between perceptions with objects and perceptions without objects, a defining characteristic of hallucinatory states. In addition, most studies have used limited dose levels of LSD and little or no testing with other hallucinogens. Furthermore, the clinical literature and reports from human subjects suggest that researchers have not employed those stimulus dimensions which are reported to be most affected by hallucinogens (e.g., concreteness, vividness, etc.).

Hallucinations, Illusions, and Reality Testing

The observations on animals suggest that animals are responding to stimuli which are not apparently present, that they are manifesting stimulus-specific behaviors in the absence of those stimuli but in the presence of hallucinogens. The reports from human subjects suggest that perception is being focused on subjective stimuli as in the case of hallucinations and imagery changes. Human subjects also report attention to real stimuli often shifts along dimensions of color, shape, brightness, vividness, and size, creating variations of the real stimuli. It is precisely these dimensions which have been traditionally cited

by both scientists and philosophers to distinguish real perceptions from dreams, images, thoughts, and hallucinations. Real stimuli are more vivid, brighter, coherent, concrete, and veridical than the others. Both hallucinogenic drug users and schizophrenics are impaired in their ability to discriminate real fron unreal stimuli, a deficit in discrimination learning often referred to as faulty reality testing (Aggernaes, 1972; Straube, 1975).

A suitable model for assessing these hallucinogenic effects would be to use a task involving discrimination between real and unreal stimuli (e.g., between real stimuli and imaginary or illusory stimuli). Consider the case of an illusion. An illusion is the perception of something objectively existing in such a way as to cause misinterpretations of its acutal nature. If an illusory (unreal) stimulus and a corresponding real stimulus were side-by-side, they should, by definition, appear identical. However, they would also differ in some properties, albeit subtle, which can be called reality properties. These properties would include the dimensions of vivacity, coherence, voluntariness, concreteness, and veridicality, exactly those dimensions which distinguish experiences such as dreams, thoughts, hallucinations, perceptions, sensations, and fantasies (Savage, 1975). A number of studies with animals have attempted to employ these relatively subtle differences as a basis for discrimination tasks.

Révész (1924) was one of the first to experiment with animal illusions when he trained hens to attend to the larger of two objects and then introduced an area illusion making the upper object appear further away from the hen than the lower object, thus producing a misjudgment of the actual size of the two objects. The hens were able to learn correctly to identify the smaller object. Several other experimenters have reported similar results with the Müller-Lyer illusion with the ring dove (Warden and Baar, 1929); with chicks (Winslow, 1933); with pigeons (Malott et al., 1967); and even with flies (Geiger and Poggio, 1975).

Dominguez (1954) studied illusions in three different primates. She trained rhesus, mangabey, and cebus monkeys to discriminate among three types of illusions: rectangular illusions, vertical illusions, and horizontal illusions. Here, animals were similar to humans in that they responded to some of the geometric figures in systematically inaccurate ways. These results were partially replicated by Harris (1968). Angularity distortion, a type of perceptual illusion, has been demonstrated in the pigeon (Lyon and Thomas, 1968) and similar illusions have been shown in monkeys (Reid et al., 1965).

Thus, animals are indeed capable of responding to perceptual illusions. However, none of the illusions discussed are clear and direct tests of the type of reality functioning impaired by hallucinogens. What is needed is a type of illusion which Gregory (1973) describes as a strategy illusion or conjurer's illusion, an illusion involving some kind of cognitive hypothesis testing together with motor validation. The illusion must

present a test of discrimination between real and illusory stimuli, a discrimination which would initially appear to be uncertain, ambiguous, and paradoxical. In order for the subject to directly verify which is real and which is illusory, perceptual data would be insufficient and the subject would have to use a motor validation of the stimuli's physical properties. The following experiments were designed to test the effects of hallucinogens on such an illusion in monkeys and develop a model for clinical evaluation. A preliminary report of these findings was given by Siegel and Popek (1975).

The Model

The apparatus employed a set of two opposing parabolic mirrors. When an object is placed in the bottom mirror, a three-dimensional image of the object appears at a small opening on the top surface of the upper mirror. Upon presentation of this device to humans or monkeys, their immediate response has been to reach for the object, but their hands will only go through the visual projection. The illusion thus appears remarkably real and compelling. The principle employed in this device is similar to that used in "parabolic display units" often used in science museums and school demonstrations. Interestingly, and conveniently, the manufacturers call the device "Illusion" and promote it as a test of illusion vs. reality.

The apparatus was arranged so that two sets of concave parabolic mirrors were placed adjacent to one another inside a sliding tray (Fig. 1). The lid of the tray had two large holes

Fig. 1. Monkey seated at illusion apparatus. Real M&M is in lower well, illusory M&M is in upper well.

located over the respective centers of each mirror. A glass plate, placed under the lid, covered the holes from below and provided depressions or wells on the top of the tray when the lid was closed. The tray, attached to a small table, could be pushed out so that the center of each well was within reach of the animal. The illusion was effective for human observers at visual angles between 20° and 65°. Since stereopsis in man and monkey are comparable (Sarmiento, 1974), the monkey was placed in the center of the apparatus and restrained in a chair at a visual angle of 30°. During a discrimination trial, the illusory S- stimulus was placed at the bottom of a mirror, producing an image at the top, and the real S+ was placed on the top of the depression of the other well. The monkey is, of course, then able to grasp only one stimulus, the S+, thus executing the motor validation of his perception. This latter behavior is essential to reality testing and Fischer (1975) has coined the descriptive phrase: "The proof of the sensory pudding is in the motor eating."

Four rhesus monkeys, approximately six months old and 2-3kg were used for the initial study. They were not food deprived but fed a standard amount of food following each daily training session. A training session consisted of 20 trials, simultaneously presented, of a real M&M candy (S+) and an illusory M&M candy (S-). Two animals, R1 and R2, were assigned to a color group and trained with color and reality relevant so that S+ was always a real red M&M and S- was an illusory M&M of any color except red. The reality group, animals R3 and R4, were given a real M&M S+ of any color and an illusory M&M S- of any color but no training trials were given on S+ and S- of the same colors. In other words, the color group had only to learn about color in order to select correctly from among the real and illusory stimuli, and they did not have to learn about reality in order to solve the discrimination. The reality group could not use color as a cue and they had to learn about reality in order to select correctly. A trial started when the tray was fully extended and wells were within reach of the animal. The trial terminated when the animal picked up the real M&M, touched one of the wells, or after 100 seconds, whichever event occurred first. The well positions and colors of S+ and S- were randomly varied between trials, except the S+ for the color group was always red. A more balanced design would have called for the color group being rewarded for responding to illusory red M&Ms, but this was, of course, contradictory to the requirement of motor validation for a correct response. While some reality learning would thus be acquired by the color group, it was felt that since color is generally very salient for discrimination tasks with monkeys, the color cues would overshadow learning on the reality dimension. Indeed, Behar (1973) has argued that monkeys first identify the cue value which signals reward and this is all that is learned. His experiments showed that color is so overpowering a cue that discriminations differing only on a dimension of color are learned as rapidly as those differing on two dimensions (i.e., color and form) or three dimensions (i.e., color, form, and size).

Each daily session consisted of 20 trials plus probe trials when given (weekly or during drug sessions as described below).

Figure 2 shows the discrimination ratios (percent of total responses made to S+) for each animal during acquisition training over 150 daily sessions. Here we see that all animals acquired respectable discrimination ratios after only 10 sessions. Starting on session 11, animals received a series of probe trials interspersed among regular training trials in order to assess stimulus control. One set of probes presented an illusory red M&M and a real M&M of another color. Animals trained in the color group consistently reached for the red, even though it was illusory; this indicated control by the color cue. Animals in the reality group, trained with color irrelevant, consistently reached for the real, regardless of color. Another set of probes presented matched-pairs of real red M&Ms and illusory red M&Ms. On these trials, which held color constant, the color group responded randomly while the reality group consistently chose the real M&M. Other probes paired real red M&Ms with real M&Ms of other colors, thus holding reality constant and varying color. This resulted in the color group again chosing the red while the reality group chose randomly, When probe trials paired two illusory M&Ms, monkeys in the color group picked a red one if present or reached randomly. Monkeys in the reality group would

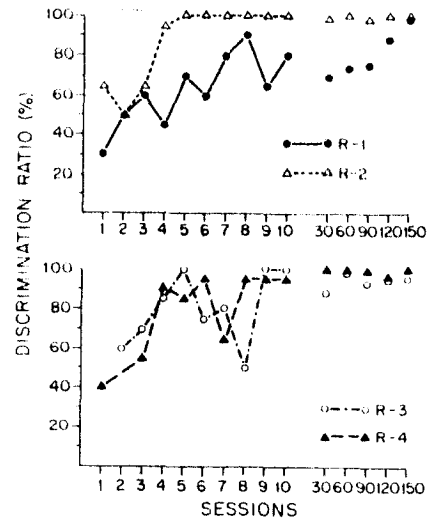

Fig. 2. Mean discrimination ratios for each animal during first 10 sessions and means for each following block of 30 sessions. Color group: R1, R2; Reality group: R3, R4.

often refuse to respond on these probes, or responded randomly. In addition, they often emitted "alarm" barks and aggressed against the tray. Taken together, these probe tests indicate that stimulus control was certainly on the color dimension for R1 and R2, while R3 and R4 were able to choose correctly on the basis of reality cues. However, following additional training sessions, the color group acquired the discrimination on the basis of reality (as indicated by probe responses) and both R1 and R2 correctly chose the real red M&M when paired with the illusory red, but otherwise continuing to choose red with paired with other colors.

Figure 3 illustrates the gradual reduction in response latencies throughout acquisition until performance stabilized. After stable performance was achieved, drugs were administered in one session each week, with regular training sessions between drug sessions. The drug sessions consisted of regular training trials and probe trials. Drugs were administered intramuscularly 10 minutes prior to the start of the session and given in a counterbalanced design consisting of five doses of each of 12 different drugs. The drugs and range of doses tested were: LSD, .001-.128mg/kg; BOL, .001-.128mg/kg; DMT, 0.5-4.0mg/kg; PCP, .05-.50mg/kg; scopolamine, .025-.100mg/kg; THC, 1.0-4.0mg/kg; pentobarbital, 1.0-10.0mg/kg; morphine, .30-3.0mg/kg; CPZ, .03-.50 mg/kg; caffeine, 5.0-50.0mg/kg; haloperidol, .003-.100mg/kg; strychnine, .01-.10mg/kg; and saline.

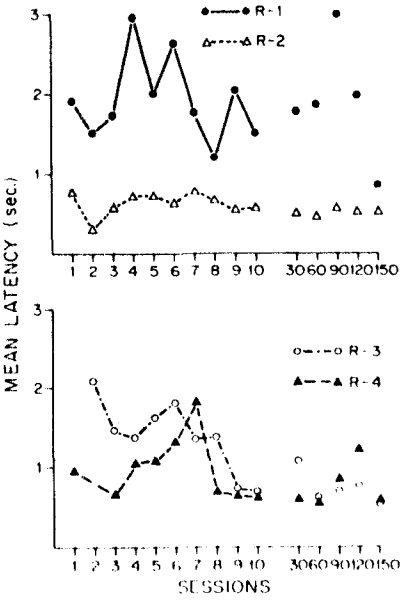

Fig. 3. Mean latencies in seconds for each animal during first 10 sessions and means for each following block of 30 sessions. Color group: R1, R2; Reality group: R3, R4.

Figure 4 shows dose-response curves for LSD in terms of the discrimination ratios for each animal. Here there were significant linear trends as dose increased. Concomitantly, there were increases in latencies with increasing doses (Fig. 5) but, at least for LSD, such dose-response curves were highly variable. This LSD data was prototypical of the hallucinogens tested.

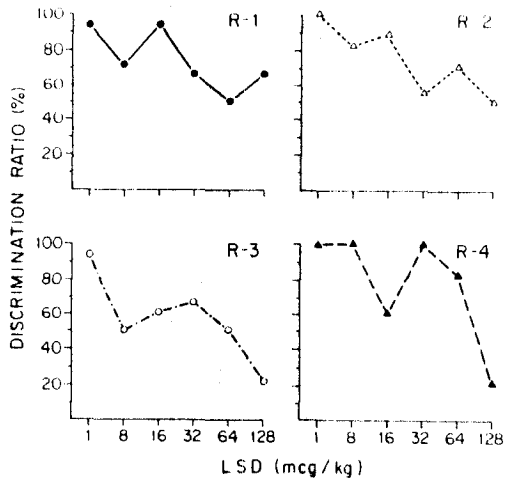

Fig. 4. Mean discrimination ratios for each animal during LSD sessions.

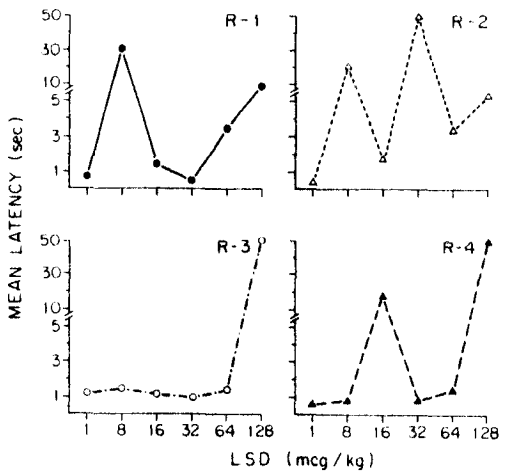

Fig. 5. Mean latencies for each animal during LSD sessions.

Conversely, the other classes of drugs did not produce significant changes in discrimination ratios. Table 1 lists all drugs that were tested in terms of effects on discrimination accuracy. All hallucinogens produced dose-dependent impairment in the discrimination ratios. Drugs which did not produce significant changes in ratios are listed in the lower part of the table and these were tested in doses up to and including those which incapacitated the animal and prevented him from responding. Some drugs, however, did affect latency. Morphine and CPZ, for example, increased latencies while caffeine and strychnine decreased them.

TABLE 1

DRUG EFFECTS ON DISCRIMINATION BETWEEN REAL AND ILLUSORY STIMULI

SIGNIFICANT IMPAIRMENT	Lysergic acid diethylamide	.001-.128
	Dimethyltryptamine	.5-4
	Phencyclidine	.05-.5
	Scopolamine	.025-.1
	Delta-9-tetrahydrocannabinol	1-4
NO CHANGE	Pentobarbital	1-10
	Morphine	.3-3
	Chlorpromazine	.03-.5
	Caffeine	5-50
	Haloperidol	.003-.1
	Strychnine	.01-.1
	Bromo-lysergic acid diethylamide	.001-.128
	Saline	

* All doses in mg/kg

During hallucinogen sessions, the probe trials with matched-pairs of real and illusory red M&Ms were disrupted as were regular trials. However, those probe trials in which reality was held constant (e.g., illusory red vs.illusory of another color) were not disrupted for the color group by doses which impaired the other probe trials or training trials. In other words, discrimination was not disrupted intra-dimensionally on reality, but was impaired inter-dimensionally on that same function. These results suggest that hallucinogens impair reality discrimination as assessed by this illusion model. The may do so by shifting attention from relevant or salient dimensions to irrelevant or less salient dimensions.

Recently, this model was used in tests with young children

recovering from ketamine anesthesia (Siegel, 1976), a recovery period marked by hallucinations with little motor ataxia in latter stages. Additional nondrug tests were conducted with infants (6-12 months) who would not yet have learned the concept of reality (cf. Piaget, 1929, 1931) and with three groups of older children. One group of children (4-6 years) had imaginary playmates, an hallucinatory behavior considered indicative of impaired reality testing. The second group (4-6 years) and the third group (8-10 years) had no imaginary playmates. The results indicated that children in ketamine recovery, infants, and children with imaginary playmates could not reliably discriminate between real and illusory stimuli. However, children without imaginary playmates could discriminate extremely well.

It is important to note that the visually guided reaching seen in these studies, even when discrimination was impaired with hallucinogens, was not the type of groping and clumsy reaching associated with blind or ataxic animals. Both the monkeys and children reached quickly and efficiently for one of the stimuli. When their grasp literally went through the projection of the S-, there would often appear facial expressions of surprise or alarm. At this point, the monkeys would frequently emit alarm barks (signifying uneasiness at the presence of an object) and clear movement calls (calling attention to the object being gazed upon) (cf. Rowell and Hinde, 1962). Sometimes after "missing" the S-, both monkeys and children would attempt to reach for the S+, but the tray would be quickly removed for the next trial. When latencies were increased with high doses of hallucinogens, often the monkeys would stare alternatively at both stimuli before reaching, as if "pondering a difficult decision" or "checking".

These results are probably related to the central nervous system excitation produced by hallucinogens coupled with functional disorganization of the reticular modulating system and augmentation of sensory input. Electrophysiologically, this is marked by fluctuation in evoked potentials, events characterized as "increased distractibility". Nonhallucinogens, like CPZ, are said to facilitate or mimic habituation and consequently reduce the amplitude of an evoked response (cf. Brown, 1974). Behaviorally, as indicated by this model, this translates into an hallucinogen-induced impairment in a discrimination based on attention to reality.

But hallucinogens have other properties which accompany these perceptual changes, properties which seem to change the mood and thinking of the subject. The resultant effect is undoubtedly synergistic and the "psychedelic" state they produce has prompted Lewin (1931) to call the "Drugs of Illusion" the Phantastica. Indeed, perhaps it is time now to investigate those other properties which Lewin has so dramatically described:

> *the properties of evoking sense-illusions in a great variety of forms, of giving rise in the human soul as if by magic to apparitions whose brilliant, seductive, perpetually changing aspects produce a rapture which is incessantly renewed and in comparison with which the perceptions of consciousness are but*

pale shadows. Harmonious vibrations of sounds beyond all human belief are heard, phantasms appear before men's eyes as if they were real, always desired but never attained, offered to them as a gift from almighty God (pp. 94-95).

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