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DYNAMIC CHANGES IN REINFORCER EFFECTIVENESS: THEORETICAL, METHODOLOGICAL, AND PRACTICAL IMPLICATIONS FOR APPLIED RESEARCH

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Reinforcers lose their effectiveness when they are presented repeatedly. Traditionally, this loss of effectiveness has been labeled *satiation.* However, recent evidence suggests that *habituation* provides a more accurate and useful description. The characteristics of behavior undergoing satiation differ for different stimuli (e.g., food, water), and these characteristics have not been identified for the noningestive reinforcers often used by applied behavior analysts (e.g., praise, attention). As a result, the term *satiation* provides little guidance for either maintaining or reducing the effectiveness of reinforcers. In contrast, the characteristics of behavior undergoing habituation are well known and are relatively general across species and stimuli. These characteristics provide specific and novel guidance about how to maintain or reduce the effectiveness of a reinforcer. In addition, habituation may lead to a better understanding of several puzzling phenomena in the conditioning literature (e.g., extinction, behavioral contrast), and it may provide a more precise and accurate description of the dynamics of many different types of behavior.

DESCRIPTORS: applied research, establishing operations, reinforcement, satiation, terminology

Behavior analysts have known for many years that reinforcers lose their effectiveness when they are repeatedly presented (e.g., Skinner, 1932). Reese and Hogenson (1962), for example, found that food-reinforced key pecking eventually ceased if pigeons were allowed to respond for a long time. Applied behavior analysts were quick to recognize the potential practical implications of this finding. For example, Ayllon (1963) demonstrated that noncontingent delivery of towels decreased the towel-hoarding behavior of a woman diagnosed with schizophrenia. Ayllon's findings suggest that the extra towels weakened the effectiveness of the towel as a reinforcer for hoarding.

More recently, the study of dynamic

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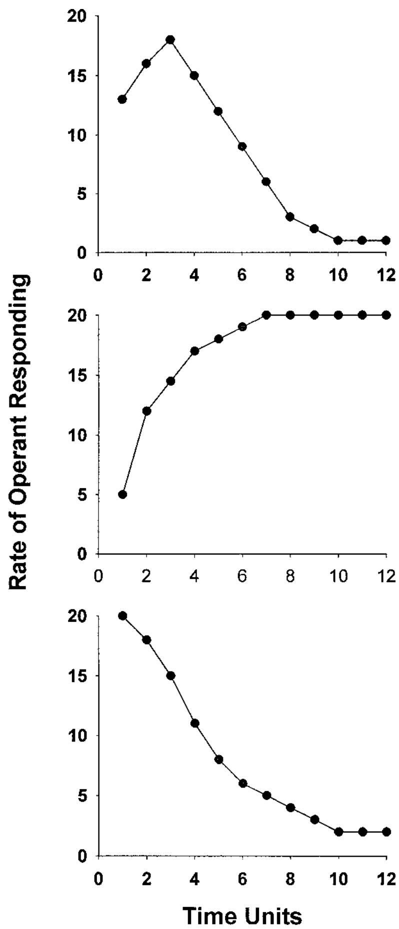

Figure 1. Three common within-session patterns of operant responding plotted as a function of time. The units of time and behavior are arbitrary.

changes in reinforcer effectiveness has been revived by the rediscovery that operant responding may not be constant within experimental sessions. For example, rates of operant responding may increase, increase then decrease, or only decrease across the session, even when the conditions of reinforcement are held constant throughout the session (e.g., McSweeney, 1992). Figure 1 provides examples of these within-session patterns. These changes occur in steady-state behavior, and they are not transitional effects (e.g., acquisition curves).

Within-session changes in operant responding represent a large, orderly, and general behavioral phenomenon (e.g., McSweeney & Roll, 1993). The changes have been reported for many species performing many operant responses, ranging from running in cockroaches (Gates & Allee, 1933) to answering questions on college exams in humans (McSweeney, Coleman, & Melville, 1993). Within-session changes have been documented for both primary (e.g., food pellets, McSweeney, Hatfield, & Allen, 1990; drugs, Murphy, 2003; Roll, McSweeney, Meil, Hinson, & See, 1996) and secondary (e.g., points, Roll, McSweeney, Cannon, & Johnson, 1996) reinforcers. These changes occur when reinforcers are delivered on simple (e.g., McSweeney, Roll, & Weatherly, 1994) and complex schedules of reinforcement (e.g., McSweeney, Weatherly, & Swindell, 1996b). They also occur during discrete-trial procedures, such as maze running (Melville & Weatherly, 1996) and complex discrimination tasks (McSweeney, Weatherly, & Swindell, 1996c).

Much evidence supports the idea that within-session changes in responding reflect systematic changes in the effectiveness of the reinforcer (e.g., McSweeney, Hinson, & Cannon, 1996; McSweeney & Roll, 1998; McSweeney, Weatherly, & Swindell, 1996a). However, the proper characterization of these changes has been disputed in the literature (e.g., Bizo, Bogdanov, & Killeen, 1998; McSweeney & Murphy, 2000). One account suggests that within-session changes in operant responding reflect the processes of arousal and satiation. *Arousal* has been defined as "the amount of responding elicited by a schedule of incentives in the absence of competition from other responses" (Killeen, 1995, p. 429; see also Killeen, Hanson, & Osbourne, 1978). *Satiation,* as it has been defined in behavior analysis, is "an establishing operation, continued presentation or availability of a reinforcer, that reduces its effectiveness (or, as a process, the reduction in effectiveness it produces)" (Catania, 1998,

p. 408; see Malott, Malott, & Trojan, 2000, and Miller, 1997, for similar statements). According to this account, within-session increases in responding reflect arousal; within-session decreases in responding reflect satiation.

An alternative account argues that within-session changes in responding reflect behavioral sensitization and habituation to the repeatedly presented reinforcer (McSweeney, Hinson, & Cannon, 1996; McSweeney & Roll, 1998). *Sensitization* is an increase in responsiveness to a repeatedly presented stimulus (e.g., Groves & Thompson, 1970). Its companion process, *habituation,* is a decrease in responsiveness to a repeatedly presented stimulus (e.g., Groves & Thompson; Thompson & Spencer, 1966). According to this account, within-session increases in responding reflect sensitization to the reinforcer; late-session decreases in responding reflect habituation.

The present paper examines both perspectives. As will be shown, a description in terms of arousal and satiation does not adequately capture the dynamics of changes in reinforcer effectiveness. In contrast, sensitization–habituation provides a highly accurate description of these changes. Then, we consider the implications of sensitization–habituation for theory and practice in applied behavior analysis. What follows is not a formal theory. Instead, we present an empirical generalization of the well-documented properties of sensitization and habituation to findings on within-session changes in operant responding.

SATIATION AND HABITUATION

Satiation

Within behavior analysis, the term *satiation* has described the effects of establishing (or abolishing) operations (e.g., Michael, 1982, 1993) that decrease the momentary effectiveness of stimuli to serve as reinforcers. If this definition is accepted, then the late-session decreases in responding reported in Figure 1 must reflect satiation, and no further analysis is needed. Why should behavior analysts abandon this definition?

First, the behavior-analytic definition of satiation differs from the definition used by other scientists. In the study of ingestive behavior, the field from which the term was borrowed, satiation refers to the termination of ingestive behaviors such as feeding and drinking (e.g., Strubbe & van Dijk, 2002). The factors that contribute to that termination are called satiety factors. In our opinion, using terms in a peculiar manner puts behavior analysis at risk for "epistemological isolation" (e.g., Staddon, 2001, p. 34; see also McSweeney & Murphy, 2000). Epistemological isolation refers to the inability to communicate with other disciplines because of idiosyncratic technical vocabularies (Staddon, 2001). As Vargas (1984) noted, idiosyncratic vocabularies increase as a science matures; however, diverging too much from other verbal communities can reduce progress when profitable collaborations would otherwise be possible (e.g., with behavioral neuroscience; see Kennedy, Caruso, & Thompson, 2001; McIlvane, 2002; Michael, 1998; Moore, 2002). Using an idiosyncratic vocabulary could invite criticisms from other fields. Just as behavior analysts would discount the work of someone who used the term *reinforcer* to refer to anything that he or she liked, so might a member of the Society for the Study of Ingestive Behavior question the work of a behavior analyst who used the term *satiation* to refer to changes in reinforcer effectiveness rather than to the termination of feeding or drinking.

Second, the behavior-analytic definition of satiation is a label of behavior, not an explanation for it. Without the help of an empirical literature on satiety, the definition offers little guidance for an applied behavior analyst who wishes to either weaken or strengthen the effectiveness of a reinforcer. This becomes particularly apparent when the term *satiation* is applied to the many noningestive reinforcers used by applied behavior analysts (e.g., praise, attention). To use the example cited earlier (Ayllon, 1963), attributing the reduction in effectiveness of towels as reinforcers to satiation provides few suggestions about how the effectiveness of those reinforcers could be changed. For example, is satiation for towels faster for larger or for smaller towels, for white or for colored towels, for heavier or for lighter towels, and so forth?

One way around this problem would be to adopt an understanding of satiety as it is understood in the ingestive behavior literature. For example, oral stimulation, distension of the stomach, distension of the duodenum, increases in blood sugar level at the liver, and increases in cholecystokinin in the blood (Mook, 1996) have all been shown to contribute to the termination of feeding (i.e., to satiation for food). It could be argued that these factors should alter within-session changes in food-reinforced responding if satiety contributes to those within-session changes.

Although such an argument is reasonable, it suffers from two problems. First, the characteristics of satiety differ for different ingestive stimuli. Satiety has been studied extensively for feeding and drinking, but not for the noningestive reinforcers often used by behavior analysts. As a result, this strategy is of little practical use to applied behavior analysts. Second, the empirical characteristics of within-session changes in responding are often inconsistent with the predictions of satiety variables other than habituation. This research has been reviewed by McSweeney and Roll (1998) and by McSweeney and Murphy (2000), so only a few examples will be cited below.

Habituation

At one time, habituation was thought to apply only to reflexive or unlearned behavior (e.g., Harris, 1943) and to stimuli that lack biological significance (e.g., Thorpe, 1966). These restrictions may have contributed to the rejection of habituation as a description for within-session changes in operant responding. However, more recent research shows that habituation may be learned (e.g., Wagner, 1976), occurs for complex behaviors (e.g., Poucet, Durup, & Thinus-Blanc, 1988), and occurs for biologically significant stimuli (e.g., food, Epstein, Rodefer, Wisniewski, & Caggiula, 1992; Swithers & Hall, 1994). Therefore, there is no a priori reason to rule out habituation as a process involved in within-session changes in operant responding.

In contrast to satiation, a great deal of empirical evidence supports habituation as a description of within-session changes in operant responding (McSweeney, Hinson, & Cannon, 1996; McSweeney & Murphy, 2000; McSweeney & Roll, 1998). The empirical characteristics of habituation are reasonably well understood and are relatively consistent across stimuli and species (e.g., T. B. Baker & Tiffany, 1985). Table 1 provides a recent revision of Thompson and Spencer's (1966) original list of the characteristics of habituation. A decline in responding to a repeatedly presented stimulus is usually considered to be habituation if it shows at least some of these empirical characteristics. To date, within-session changes in responding have shown 11 of the 14 properties listed in Table 1 (McSweeney & Murphy, 2000). It seems unlikely that such an extensive correspondence could occur by chance.

In addition to its empirical accuracy, sensitization–habituation provides a practically useful characterization of changes in reinforcer effectiveness. Therefore, Table 1 makes many specific suggestions about how to increase or decrease the effectiveness of a reinforcer, regardless of whether the reinforcer is ingestive or not. To give some examples from basic behavior-analytic re-

Table 1
A Tentative List of the Empirical Characteristics of Habituation Adopted from McSweeney and Murphy (2000)

*+1. Spontaneous recovery (e.g., Thompson & Spencer, 1966): Responsiveness to a habituated stimulus recovers when that stimulus is not presented for a time.

*+2. Stimulus specificity (e.g., Swithers & Hall, 1994; Whitlow, 1975): Habituation is disrupted by unpredictable changes in the presented stimulus.

*3. Variety effect (e.g., Broster & Rankin, 1994): Habituation occurs more slowly to stimuli that are presented in a variable, rather than a fixed, manner (e.g., after variable, rather than fixed, interstimulus intervals).

*+4. Dishabituation (e.g., Thompson & Spencer, 1966): Presenting a strong, different, or extra stimulus restores responsiveness to an habituated stimulus. Although dishabituation is listed here as a characteristic of habituation, researchers disagree about whether the return of responsiveness occurs because habituation decreases (e.g., Marcus, Nolen, Rankin, & Carew, 1988) or because sensitization is added (e.g., Groves & Thompson, 1970; see the discussion of sensitization below).

5. Dishabituation habituates (e.g., Thompson & Spencer, 1966): Repeated presentation of dishabituators reduces their ability to restore habituated responding.

*+6. Stimulus rate (e.g., Thompson & Spencer, 1966): Faster rates of stimulus presentations yield faster and more pronounced habituation than do slower rates.

7. Stimulus rate and recovery (Staddon & Higa, 1996): Spontaneous recovery may be faster after faster rates of stimulus presentation.

*+8. Stimulus exposure (e.g., Thompson & Spencer, 1966): Responsiveness to a repeatedly presented stimulus decreases with increases in stimulus exposure.

*+9. Long-term habituation (e.g., Wagner, 1976): Spontaneous recovery may be incomplete. Some habituation is learned and persists over time.

*+10. Repeated habituation (e.g., Thompson & Spencer, 1966): Perhaps because of long-term habituation, habituation may become more rapid with repeated habituation followed by spontaneous recovery.

*11. Stimulus intensity (e.g., Thompson & Spencer, 1966): Habituation is sometimes, but not always (e.g., Groves & Thompson, 1970), faster and more pronounced for less intense than for more intense stimuli.

*+12. Generality (e.g., Thorpe, 1966): Habituation occurs for most, if not all, species of animals. It also occurs for most stimuli, including those that have no ingestive consequences (e.g., lights, noises). The exact rate of habituation differs depending on the species, the stimulus, the response used as a measure, and the individual subject (e.g., Hinde, 1970).

Habituation is often accompanied by "sensitization" (e.g., Groves & Thompson, 1970). Therefore, if habituation occurs, then the following phenomena might also be observed:

*+13. Sensitization by early-stimulus presentations (e.g., Groves & Thompson): An increase (sensitization), rather than a decrease (habituation), in responsiveness may occur to a repeatedly presented stimulus during its first few presentations.

+14. Sensitization by stimuli from another modality (e.g., Swithers & Hall, 1994): An increase in responsiveness to a stimulus may be produced by the introduction of a stimulus from another modality (e.g., a light or noise). Both sensitization and dishabituation (Characteristic 4) may involve the introduction of a stimulus from another modality. Results are conventionally described as dishabituation if the stimulus restores responsiveness to an already-habituated stimulus and as sensitization if the stimulus from another modality increases responding before substantial habituation occurs to the other stimulus (e.g., Marcus et al., 1988).

Note. An asterisk indicates that this characteristic of habituation has been confirmed for within-session changes in responding. A plus indicates that this characteristic has been confirmed for behavior undergoing extinction.

search, within-session decreases in responding may be steeper when lower, rather than higher, calorie reinforcers are used (e.g., Melville, Rue, Rybiski, & Weatherly, 1997). This is consistent with habituation, which is sometimes faster for less intense stimuli (e.g., Table 1, Characteristic 11). In contrast, increasing the caloric content of food should increase nonhabituation satiety factors, such as blood sugar levels. Therefore, increasing the caloric content of food should steepen the late-session decrease in responding for calorie-regulating animals, such as rats or humans (Adolph, 1947; Hausmann, 1933).

Habituation is often accompanied by a companion process, sensitization, which is an increase in responsiveness to a stimulus when that stimulus is first presented (Table 1, Characteristic 13). Sensitization is a reasonable description for early-session increases in responding (see Figure 1). In contrast, satiation provides no advantages in describing these early-session increases because an additional process must be postulated. For example, Killeen et al. (1978) proposed that reinforcer presentations induce arousal, as indicated by early-session increases in responding. However, the idea was not developed in great detail. Explicitly specifying the properties of arousal is important because it has been used in a variety of conflicting ways in the past (e.g., Anderson, 1990; Duffy, 1962; Neiss, 1988). Therefore, processes that are well understood, such as sensitization and habituation, describe both an increase and decrease in response rate when a reinforcer is presented repeatedly. Without help from other concepts, satiation accounts only for the decrease.

Other properties of habituation have been empirically demonstrated. *Dishabituation* (Table 1, Characteristic 4), for example, refers to an increase in responsiveness to a habituated stimulus after a strong, different, or extra stimulus is presented in the experimental context (Thompson & Spencer, 1966). Changing the reinforcer for a brief time late in the session increases response rate once the original reinforcer is restored (Aoyama & McSweeney, 2001b; McSweeney & Roll, 1998). Consistent with the property of dishabituation, response rate increases regardless of whether the change is an increase or a decrease in reinforcement and regardless of whether the change produces an increase or a decrease in response rate while it is in effect. This finding is inconsistent with satiation, because providing more reinforcers should decrease, not increase, responding by increasing nonhabituation satiety factors such as stomach distension and blood sugar levels.

Another property of habituation, *variety effects,* can be used to increase or decrease the effectiveness of a repeatedly presented reinforcer. A variety effect (Table 1, Characteristic 3) refers to a slowing of habituation when stimuli are presented in a variable, rather than a fixed, manner (after variable, rather than fixed, interstimulus intervals; Broster & Rankin, 1994). Aoyama and McSweeney (2001b) recently showed that within-session decreases in responding may be steeper when reinforcers are delivered on fixed-ratio (FR) rather than on variable-ratio (VR) schedules, even when the two schedules provide the same amounts of food (see also Ernst & Epstein, 2002). McSweeney and Aoyama's findings are not consistent with nonhabituation satiety factors, because stomach distension and blood glucose levels should be constant when the amount of food is constant.

THEORETICAL IMPLICATIONS OF WITHIN-SESSION CHANGES IN RESPONDING

The idea that sensitization–habituation provides a description of dynamic changes in the effectiveness of reinforcers may help to clarify several puzzling phenomena in the operant literature. As a result, this idea may be useful to any behavior analyst who encounters these phenomena. We will discuss here only multiple-schedule behavioral contrast (McSweeney & Weatherly, 1998), extinction (McSweeney & Swindell, 2002; McSweeney, Swindell, & Weatherly, 1999), and the regulation of many different types of behavior (McSweeney & Swindell, 1999b; Roll & McSweeney, 1999). Additional papers have discussed the implications of this idea for behavioral economics (McSweeney & Swindell, 1999a; McSweeney, Swindell, & Weatherly, 1996) and for the declines in response rates that are often observed at high rates of reinforcement (e.g., McSweeney, 1992).

Multiple-Schedule Behavioral Contrast

Behavioral contrast refers to an inverse relation between the rate of responding in one component of a multiple schedule and the conditions of reinforcement in the other component (e.g., McSweeney & Norman, 1979). For example, a multiple variable-interval (VI) 60-s VI 60-s schedule might be changed to a multiple VI 60-s extinction schedule. If rate of responding during the VI 60-s component increases with this worsening of alternative reinforcement, the increase in response rate would be labeled *positive contrast*. Conversely, if one component of a multiple VI 60-s VI 60-s schedule is changed to a VI 15-s schedule, rate of responding may decrease during the VI 60-s component. This decrease in response rate is labeled *negative contrast*.

Behavioral contrast may have important implications for the treatment of problem behavior. For example, Gross and Drabman (1981) reported that problem behaviors might increase in nontreatment settings following a worsening of the conditions of reinforcement for those behaviors in treatment settings. On the assumption that treatment and nontreatment contexts are similar to different components of a multiple schedule, the subsequent increase in problem behavior in nontreatment settings represents positive contrast—an undesirable result. Although behavioral contrast can be an unplanned side effect, it can sometimes increase the effectiveness of behavioral treatment programs. For example, Charlop, Kurtz, and Milstein (1992) reported an increase in the percentage of acquisition tasks completed (positive contrast) by children with autism after the reinforcement contingency for performing maintenance tasks was removed. Therefore, an understanding of the dynamics of behavioral contrast can aid in the design and implementation of successful behavioral treatments.

Although many theories have been proposed to explain behavioral contrast (see Flaherty, 1996, and Williams, 1983, for reviews), no theory has been entirely successful (Williams, 2002). Recently, McSweeney and Weatherly (1998) suggested that reinforcers retain their effectiveness better across the session (less habituation) when only approximately 30 reinforcers are presented per hour during the multiple VI 60-s extinction schedule than when approximately 60 reinforcers are presented per hour during the multiple VI 60-s VI 60-s schedule. As a result, the more effective reinforcers support a higher rate of responding during the VI 60-s component of the multiple VI 60-s extinction schedule (positive contrast) than during the same component of the multiple VI 60-s VI 60-s schedule. More reinforcers are delivered during the multiple VI 60-s VI 15-s schedule (approximately 150 reinforcers per hour) than during the multiple VI 60-s VI 60-s schedule (approximately 60 reinforcers per hour). As a result, the reinforcers are less effective (more habituation) and should support a lower rate of responding during the VI 60-s component of the multiple VI 60-s VI 15-s schedule (negative contrast) than during the same component of the multiple VI 60-s VI 60-s schedule.

According to McSweeney and Weatherly's (1998) theory, Charlop et al.'s (1992) results may reflect differential habituation across the baseline and treatment conditions. During their baseline conditions, both maintenance and acquisition tasks were supported by contingent attention (FR 1) and contingent food reinforcement (VR 3). During one treatment condition, food reinforcement was discontinued for maintenance tasks, but contingent attention continued. During the second treatment condition, both reinforcement contingencies were removed for maintenance tasks. McSweeney and Weatherly's theory predicts the substantial increase in the percentage of acquisition tasks completed during both treatment conditions (positive contrast) because fewer reinforcers were delivered during each of the treatment sessions (less habituation). Therefore, the remaining reinforcers were able to support more behavior.

McSweeney and Weatherly's (1998) theory of behavioral contrast is parsimonious, and it relies only on processes that have been established by independent evidence. Their theory is consistent with much of the literature on behavioral contrast (McSweeney & Weatherly, 1998), and it makes many novel predictions about when behavioral contrast should occur. For example, it predicts that introducing variability in the delivery of reinforcement during one component of a multiple schedule should reduce habituation (Table 1, Characteristic 3) and, therefore, produce positive contrast in the other component (see McSweeney, Murphy, & Kowal, 2003, for an additional test of this theory).

Extinction

Extinction refers to a decrease in operant response rate that occurs when a conditioned response is no longer followed by the reinforcer. It also refers to a decrease in the conditioned response in classical conditioning, when the conditioned stimulus (CS) no longer predicts the unconditioned stimulus (US). Extinction is one of the longest known and most fundamental properties of conditioned behavior (e.g., Pavlov, 1927). It also seems obvious that extinction should occur. It seems reasonable that animals would stop making a response if the reason for making that response (e.g., the reinforcer) no longer occurs. Nevertheless, there is no generally accepted theory of extinction. Many theories are challenged because behavior undergoing extinction shows some complicated and unexpected characteristics. For example, extinguished behavior spontaneously recovers after a period of time (spontaneous recovery) or after the presentation of a sudden stimulus such as a tone or light (disinhibition).

McSweeney and Swindell (2002) argued that many characteristics of extinguished behavior could be understood if habituation occurs to some of the stimuli that support conditioned responding. For example, the CS is presented repeatedly (without the US) during the extinction of classically conditioned responding. The experimental context is presented for a prolonged time during the extinction of both operantly and classically conditioned responding. These stimuli help to support conditioned responding either directly (the CS) or by acting as a discriminative stimulus for, or a facilitator of, that responding (the context). As a result, conditioned responding should decrease during extinction as habituation occurs to the stimuli that support conditioned responding.

This idea is parsimonious and evokes only processes that are well established by other evidence. It also has face validity. Habituation is such a ubiquitous phenomenon that an explanation would be needed if it did not occur to stimuli that are presented during extinction. McSweeney and Swindell (2002) also showed that the idea has extensive empirical support. Behavior undergoing extinction shows 10 of the fundamental properties of behavior undergoing habituation (indicated by + in Table 1; see also McSweeney et al., 1999, for another test of this idea).

The idea that sensitization–habituation accurately characterizes behavior undergoing extinction has implications for the treatment of problem behaviors. For example, Lerman, Kelley, Van Camp, and Roane (1999) extinguished inappropriate screaming of a mentally retarded woman by discontinuing access to preferred toys while simultaneously reinforcing hand clapping. As expected, rate of screaming decreased within each extinction session but screaming also recovered from the end of one session to the beginning of the next. The present idea predicts this recovery because habituated behavior spontaneously recovers in the absence of the habituated stimulus (Table 1, Characteristic 1). If their idea is correct, the literature on the spontaneous recovery of habituated behavior might provide useful information about how to attenuate the recovery of screaming between sessions (e.g., Table 1, Characteristics 7 and 9; see Lerman, Iwata, Shore, & Kahng, 1996, for an additional application of extinction in an applied setting).

A Common Description of Many Different Types of Behavior

The termination of behavior is usually attributed to different factors for different behaviors. For example, termination of responding for ingestive reinforcers (e.g., food, water) is usually attributed to satiation (e.g., Bizo et al., 1998). Termination of energetic responding (e.g., running) is usually attributed to fatigue (e.g., Belke, 1997). Termination of cognitive behaviors (e.g., studying) is usually attributed to the waning of attention (e.g., Hinson & Tennison, 1999). Finally, termination of drug taking is usually attributed to pharmacodynamic factors, such as obtaining a particular high (e.g., Ahmed & Koob, 1999).

Recently, McSweeney and Swindell (1999b) argued that the dynamic properties of habituation may aid in understanding the termination of many behaviors. They showed that the empirical characteristics of several behaviors are similar to the empirical characteristics of behavior undergoing sensitization and habituation (Table 1). Additional experiments have confirmed specific predictions of this idea. For example, decreases in the rate of wheel running over time are usually attributed to fatigue (e.g., Belke, 1997), but Aoyama and McSweeney (2001a) demonstrated that rats' wheel running shows at least three properties of behavior undergoing habituation. First, spontaneous recovery was larger when the rats were more (i.e., 2 days) rather than less (i.e., 1 day) deprived of the opportunity to run (Table 1, Characteristic 1). Second, response rates temporarily increased when irrelevant, extra, or intense stimuli (e.g., flashing the houselight) were presented late in the experimental session (dishabituation; Table 1, Characteristic 4). Finally, rate of running increased when the sensory properties of the wheel were altered half way through the session (violations of stimulus specificity; Table 1, Characteristic 2). Note that the second and third findings are not compatible with the idea that running terminates because of variables related to muscular fatigue, such as the accumulation of lactic acid in the muscles. There is no reason to expect that flashing a houselight or changing the floor would lessen lactic acid and, therefore, increase the rate of running through a reduction of fatigue.

The idea that the properties of habituation describe the termination of different types of behavior has implications for applied behavior analysis. For example, Dunlap and Koegel (1980) studied the target behaviors (e.g., nonverbal imitation) of autistic children in two experimental conditions. During the constant-task condition, the children were presented with a single task throughout an experimental session. During the varying-task condition, the children were presented with the same task as in the constant condition, but other tasks, such as counting objects, were interspersed between presentations of the constant task. Consistent with McSweeney and Swindell's (1999b) theory, the percentage of correct responses declined more rapidly within experimental sessions during the constant-task condition (variety effect, Table 1, Characteristic 3). Therefore, acquisition of target behaviors can be improved if tasks are presented in a variable, rather than a fixed, manner.

IMPLICATIONS FOR APPLIED RESEARCH

The idea that the properties of sensitization and habituation describe dynamic changes in the effectiveness of a repeatedly presented reinforcer has many implications for applied behavior analysis. This idea can lead to new ways of conceptualizing behavioral problems of social importance. It also suggests how to maintain the effectiveness of the needed reinforcers and how to weaken the effectiveness of problematic reinforcers. An example of each of these ideas will be given.

Sensitization and Habituation As Establishing Operations

Adopting the sensitization and habituation viewpoint does not necessarily require abandoning powerful behavior-analytic concepts, such as establishing operations (see Michael, 1982, 1993). An establishing operation is "an environmental event, operation, or stimulus condition that affects an organism by momentarily altering (a) the reinforcing effectiveness of other events and (b) the frequency of occurrence of that part of the organism's repertoire relevant to events as consequences" (Michael, 1993, p. 192). Perhaps the most common procedure for increasing the effectiveness of a reinforcer is deprivation. That is, depriving an organism of a stimulus (i.e., food) establishes that stimulus as a reinforcer and increases the frequency of the behavior that it follows (e.g., Michael, 1982). Finding an increase in responsiveness (i.e., frequency) is consistent with spontaneous recovery (Table 1, Characteristic 1), an increase in responsiveness to a habituated stimulus after a period without contact with that stimulus. A common procedure for decreasing the effectiveness of a stimulus is increasing the amount of exposure that an animal has to it. In practice, increasing exposure to a reinforcing stimulus might involve using dense schedules of reinforcement and increasing the reinforcer magnitude (i.e., size). Although this procedure is commonly termed satiation, it is more accurately labeled habituation because both examples are consistent with its known properties. For example, using a dense schedule of reinforcement is consistent with stimulus rate (Table 1, Characteristic 6), a property that states that faster rates of stimulus presentation yield faster rates of habituation. Using reinforcers of high magnitude should decrease their effectiveness faster than a reinforcer of smaller magnitude. Finding this relation is consistent with stimulus exposure (Table 1, Characteristic 8), which states that habituation increases directly with increases in exposure to the repeatedly presented stimulus.

The sensitization–habituation description of reinforcer effectiveness offers novel predictions about how environmental events may alter the effectiveness of reinforcers. To mention just one, the introduction of extraneous stimuli in the experimental context can momentarily increase the effectiveness of a repeatedly presented reinforcer (dishabituation; Table 1, Characteristic 4; see Aoyama & McSweeney, 2001a, 2001b). Therefore, adopting the sensitization–habituation model expands rather than limits the understanding of establishing operations. Below, we address how viewing sensitization and habituation as establishing operations can aid applied behavior analysts in the design of new behavioral treatments.

Maintaining the Effectiveness of a Reinforcer

Applied behavior analysts may encounter problems in maintaining the effectiveness of a reinforcer needed to correct a problematic behavior. In that case, the behavior analyst should take steps to slow habituation or to increase sensitization to the sensory properties of the reinforcer. For example, food delivered according to a differential-reinforcement-of-other-behavior (DRO) schedule is often used as the reinforcer during instruction with children with autism. These DRO schedules tend to be quite dense, with edible items presented several times in the course of a brief instructional session. In such cases, preserving the effectiveness of the edible items as reinforcers is important. Many clinicians do so by offering a variety of food (e.g., pieces of potato and corn chips, candy, pieces of cookies, etc.) throughout the instructional session (variety effect; Table 1, Characteristic 3). The clinician should also present the reinforcers according to a variable, rather than a fixed, schedule (Table 1, Characteristic 3). He or she should deliver sensitizers by introducing extraneous stimuli (Table 1, Characteristic 14). Finally, giving the child a nibble of food might restore the effectiveness of food as a reinforcer once that effectiveness has been lost (e.g., Cornell, Rodin, & Weingarten, 1989; Table 1, Characteristic 13).

Some evidence suggests that these techniques will work. For example, Egel (1981; see also Bowman, Piazza, Fisher, Hagopian, & Kogan, 1997) contrasted the effects of using constant versus varied food reinforcers for the task-related behaviors of 3 children with developmental disabilities. Both percentage of correct responding and percentage of intervals on task increased for all children when stimuli were varied within sessions. Another example is Ayllon and Azrin (1968), who increased the utilization of token reinforcers by patients in a mental health hospital by giving them brief access to the reinforcing activity (listening to music or going for a walk) for which the token could be exchanged. If desired, the patients could exchange tokens for reinforcing activities during the baseline conditions. During treatment conditions, all patients were required to sample the activity for 3 min prior to using their token. As a result, token utilization increased in the treatment conditions for walking outside and listening to music. Ayllon and Azrin's results suggest that brief samples of the reinforcer can increase its reinforcing effectiveness, which is consistent with sensitization (increase in responsiveness) by early stimulus presentations (Table 1, Characterization 13).

Reducing the Effectiveness of a Problematic Reinforcer

Undesirable behaviors may be maintained by reinforcers that are too effective. In that case, the behavior analyst might weaken the reinforcer by increasing habituation or decreasing sensitization. Overeating provides a potential example. The traditional approach to controlling obesity focuses on increasing exercise and on changing a number of behaviors related to eating (e.g., eating smaller portions of lower calorie foods). Assume instead that obesity occurs in part because food acts as a very powerful reinforcer and that the power of that reinforcer could be reduced by increasing habituation or by decreasing sensitization to food stimuli. In that case, dieters might be urged to eat a less varied diet because habituation is faster under more constant conditions (Table 1, Characteristic 3). Dieters might put foods away as soon as they stop consuming them to curb nibbling. If they do not, then sampling the food might yield to sensitization and increase the ability of food to increase consumption (Table 1, Characteristic 13). In addition, eating meals alone rather than in social situations and avoiding watching television while eating should decrease extraneous stimuli that act as sensitizers (Table 1, Characteristic 14).

As another example, practitioners often use time-based delivery of a reinforcer to decrease the frequency of a problematic behavior maintained by that reinforcer. The effects of such schedules, often termed noncontingent reinforcement (NCR; Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993), may reflect habituation to the reinforcer with its repeated presentation. If this is correct, then the practitioner should deliver the reinforcer according to procedures that promote habituation, such as fixed schedules (Table 1, Characteristic 3). The practitioner should also avoid events that result in sensitization, such as unpredictable changes in the stimuli (Table 1, Characteristic 4) or presenting different or extra stimuli (Table 1, Characteristic 2). However, the mechanisms responsible for the effect of NCR are not well understood. Many factors may be involved, and accounts in terms of extinction (e.g., Kahng, Iwata, Thompson, & Hanley, 2000) and alternative reinforcement (e.g., Hagopian, Crockett, van Stone, DeLeon, & Bowman, 2000) remain tenable.

An Example of a Reconceptualization: Priming

Priming refers to the finding that small amounts of a previously abused drug may increase the desire for, and the probability of consuming, that drug (e.g., de Wit, 1996). Priming occurs for many drugs including alcohol, amphetamine, nicotine, cocaine, and heroin. Many have argued that the difficulty in curing addiction results not from problems in detoxification but rather from preventing relapse once a drug-free state has been achieved (e.g., DeVries, Schoffelmeer, Binnekade, & Vanderschuren, 1999). Priming may contribute to relapse because it makes full relapse likely after an addict samples only a small amount of a drug.

Although many theories of priming have been proposed (e.g., classical conditioning, Bouton & Swartzentruber, 1991; operant conditioning, Bickel & Kelly, 1988; motivation, Stewart, de Wit, & Eikelboom, 1984; memory, Spear, 1978), no theory is generally accepted. We argue that progress might be made by regarding priming as an example of sensitization to the sensory properties of the drug. Consistent with this idea, many authors have argued that priming results from a motivational aftereffect of the prime that increases the probability or vigor of subsequent behavior (e.g., Eiserer, 1978; Gallistel, 1974). Such a description would be difficult to distinguish from sensitization. Consistent with our argument, brief exposure to a drug does not just increase desire for the drug. Instead, it increases the ability of the drug to act as a reinforcer, as measured by an increase in preference for the drug or an increase in the rate of, or time spent making, an operant response for the drug (e.g., Bigelow, Griffiths, & Liebson, 1977; Chutuape, Mitchell, & de Wit, 1994; de Wit & Chutuape, 1993; Ludwig, Wikler, & Stark, 1974).

Finally, consistent with our argument, priming does not occur just for drugs. It also occurs for other reinforcers such as food and water (A. G. Baker, Steinwald, & Bouton, 1991; Bruce, 1938; Eiserer, 1978; Konorski, 1967; Murphy, McSweeney, & Kowal, 2003; Terry, 1980), electrical brain stimulation (e.g., Gallistel, Stellar, & Bubis, 1974), imprinting objects (Eiserer, 1977; Eiserer & Hoffman, 1973), exploration (Glanzer, 1961), and aggression (Heiligenberg, 1974). To give an applied example, presenting brief access to a reinforcer (preferred activities in the form of painting) immediately prior to an instructional session increased the likelihood that an individual with disabilities would complete the task to earn contingent access to the reinforcer without engaging in self-injurious behavior (SIB). Abrupt task presentation without brief presession access to the reinforcer resulted in decreased compliance with the task to earn contingent access to the reinforcer and elevated rates of SIB (Hoch, McComas, & Cicero, 2002).

If this reconceptualization is correct, it might prove to be practically useful. If priming is an example of sensitization, then the literature on sensitization to stimuli such as lights and tones could be used to design experiments that would increase our understanding of priming to drugs. This information could, in turn, be used to reduce the probability of priming to drugs, and therefore, to reduce the probability of a relapse in drug addicts.

Directions for Future Research

The majority of the research on dynamic changes in reinforcer effectiveness has been conducted on nonhumans (e.g., pigeons and rats) using food reinforcement (see McSweeney, Hinson, & Cannon, 1996, and McSweeney & Roll, 1998, for reviews). In addition, most of the applied research cited earlier did not explicitly test the hypothesis that within-session changes in responding reflect sensitization and habituation to the reinforcer. As a result, Table 1 can be thought of as presenting a research agenda for applied behavior analysis. Testing for properties such as dishabituation (Table 1, Characteristic 4) and stimulus specificity (Table 1, Characteristic 2) would be of particular interest. As argued earlier, these characteristics of operant behavior are uniquely predicted by sensitization and habituation. They are not anticipated by alternative conceptualizations, such as satiation or fatigue.

PROBLEMS WITH SENSITIZATION AND HABITUATION

The idea that dynamic changes may occur in the effectiveness of a reinforcer with its repeated presentation provides a powerful idea that may help in the understanding and control of behavior. However, we do not wish to imply that this idea will not encounter problems. Some of these problems have been discussed elsewhere (e.g., McSweeney & Murphy, 2000). To briefly list a few problems, the theory has a great deal of latitude because it includes processes that both increase (sensitization) and decrease (habituation) response rate. Although these processes seem justified by the data, they do give the theory an ability to account for many different results.

Until a generally accepted theory of habituation is adopted, our argument also presents an empirical generalization rather than a formal theory. An empirical approach is necessary because the leading models of habituation (e.g., Sokolov, 1963; Wagner, 1976) have been severely criticized (e.g., Mackintosh, 1987; Staddon & Higa, 1996). Nevertheless, many questions cannot be answered until such a theory is developed.

Many questions remain to be answered about how habituation occurs during operant conditioning. For example, the strength of habituation and sensitization varies across stimuli and species (e.g., Hinde, 1970). The factors that account for this variation are not known. The precise nature of the stimuli to which animals habituate during operant conditioning is unknown. For example, it is not known how much habituation accrues to discriminative stimuli and how much is due to the repeatedly presented reinforcers. The characteristics of the reinforcer to which the animal habituates are also unknown. Do animals habituate to the taste of food, its texture, the sound of the food hopper, the duration of feeder presentation? The present hypothesis will not be complete until these questions are answered.

The following example also provides a potential empirical challenge to our argument. During the “satiation” phase of a study on the effects of presession variables on operant behavior (Vollmer & Iwata, 1991), participants received continuous exposure to stimuli that were subsequently used as reinforcement for task completion. During one phase of the experiment, attention was used as the putatively reinforcing stimulus, and presession procedures exposed participants to 15 min of continuous attention from the experimenter. After two sessions, 1 participant began to escape during the presession procedure. Initially, the participant merely moved across the room or ran away from the experimenter but, subsequently, the participant threw objects at the experimenter as the experimenter attempted to continue to provide attention. These outcomes are not predicted by an habituation account. That is, the results show an apparent shift in the functional properties of attention from a positive reinforcer to an aversive stimulus, rather than merely a decrement in the effectiveness of the stimulus in controlling behavior. To date, this effect has been anecdotally reported but not empirically evaluated. Additional research is needed to document the appetitive and aversive properties of stimuli following different lengths of preexposure to those stimuli.

CONCLUSION

Dynamic changes occur in the effectiveness of reinforcers with their repeated presentation. The term *satiation,* as it is defined in either behavior analysis or the study of ingestive behavior, is an inadequate description of changes in reinforcer effectiveness. The term *habituation,* however, captures many of the dynamic changes in reinforcer effectiveness often reported by behavior analysts. For example, habituation, but not satiation, can accurately describe increases in responsiveness to a reinforcer when extraneous stimuli are presented in the experimental situation (dishabituation; Table 1, Characteristic 4). Understanding the properties of habituation (Table 1) can aid in the understanding of many puzzling conditioning phenomena, such as behavioral contrast, extinction, and the regulation of many different types of behaviors. An understanding of habituation may also expand our understanding of establishing operations. For example, reconceptualizing habituation as an establishing operation gives applied behavior analysis more sophisticated ways of decreasing the effectiveness of problematic reinforcers and increasing the effectiveness of needed reinforcers in treatment settings. Finally, formally testing the habituation hypothesis sets a challenging research agenda for applied behavior analysts.

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