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Toward an Explicit Analysis of Generalization: A Stimulus Control Interpretation

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Producing generality of treatment effects to new settings has been a critical concern for applied behavior analysts, but a systematic and reliable means of producing generality has yet to be provided. We argue that the principles of stimulus control and reinforcement underlie the production of most generalized effects; therefore, we suggest interpreting generalization programming in terms of stimulus control. The generalization programming procedures identified by Stokes and Baer (1977) are discussed in terms of both the stimulus control tactics explicitly identified and those that may be operating but are not explicitly identified. Our interpretation clarifies the critical components of Stokes and Baer's procedures and places greater emphasis on planning for generalization as a part of training procedures.

Key words: generalized effects, generalization programming, maintenance, quantal interpretation, stimulus control, stimulus generalization

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Promoting generality of treatment effects across settings and responses has been a critical concern for applied behavior analysis (Baer, 1982a; Baer, Wolf, & Risley, 1968; Marholin & Seigel, 1976; Marholin, Seigel, & Phillips, 1976). The most influential article concerning such generality may be Stokes and Baer's (1977) review of the literature, which identified nine different procedures for assessing and promoting generality of treatment effects.[1] These procedures have proven to be effective and practical in many, but not all, instances (e.g., Fowler & Baer, 1981; Holman & Baer, 1979; Stokes, Baer, & Jackson, 1974). Stokes and Baer offered the review only as a beginning (cf. Baer, 1982a). It established the importance of programming for generality, since merely hoping for its emergence was not likely to be successful. Stokes and Baer meant to encourage research toward further "understanding of the critical variables that function to produce generalization" (Stokes & Baer, 1977, p. 365).

Such understanding could be furthered in at least two ways. In the first and most widely followed approach, investigators apply one of the nine procedures, make variations and adjustments, and report the relative effectiveness of those alterations. A set of rules specific to the application of the particular procedure results from such an approach. Overall, this method has proven beneficial in the improvement of a technology for producing generality of effects (cf. Baer, 1982a).

In the present paper, we follow a second approach that involves analysis of the principles underlying the production of generalized behavior. Such principles are not specific to any one of Stokes and Baer's generalization programming procedures, but are fundamental to them all. Consequently, this one set of rules—the principles—should improve our technology and understanding of the critical variables involved in producing generalized effects.

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[1] By 1983 this review had become a citation classic (see *Current Contents, 7*(10), March 7, 1983).

Although Stokes and Baer (1977) intended to promote further research toward understanding the variables that function to produce generality of treatment effects, their usage of the term "generalization" may have discouraged progress toward this goal by obscuring the actual principles at work (Johnston, 1979). Stokes and Baer used the term "generalization" as a generic descriptor of any appropriate behavior change occurring in a nontraining setting. Johnston (1979) argued that this usage suggested that all appropriate behavior changes in nontraining settings were a result of behavioral processes such as "stimulus generalization" or "response generalization." These terms refer to specific processes that have been studied extensively in basic laboratories. Johnston suggested that additional behavioral principles and processes (e.g., reinforcement) were likely involved in producing generality of treatment effects across settings and responses, and thus Stokes and Baer's use of the term "generalization" was misleading.

We believe that the procedures described by Stokes and Baer rely heavily on two behavioral principles: stimulus control and reinforcement. Furthermore, we suggest that the process of stimulus generalization need not be considered a phenomenon that is separate, distinct, or opposite to stimulus control. The influence of a discriminative stimulus does not spread in a continuous and decremental fashion to stimuli that are different but similar to the training stimulus. Instead, we argue that the apparent spread of effect is a function of discrete and incompletely understood stimulus control relations. From this perspective, the term "generalization" as used by Stokes, Baer, *and* Johnston is a summary descriptor of a behavioral effect, and stimulus control is the principle involved in the production of stimulus generalization.[2]

THE QUANTAL INTERPRETATION

The view referred to above—the quantal interpretation of stimulus control (Bickel, 1987; Bickel & Etzel, 1985; Rilling, 1977)—is based on the assumption that "behavior is never undetermined, that all responses are controlled, if not by the stimuli the experimenter has specified, then by others" (Sidman, 1980, p. 286). Stimulus control may fluctuate so that it is difficult both to measure and to understand; this does not mean, however, that the training stimulus is exerting partial or weak control. Rather, the quantal stimulus control interpretation specifies that the relation between a controlling stimulus and the response it controls does not vary in a continuous fashion (Sidman, 1969). Given this perspective, the controlling stimulus-response relation is an integral unit. Therefore, proportions, parts, or differing strengths of a stimulus-response relation cannot occur. At any given instant, the relation either exists completely or does not exist at all. A subject's response to a particular stimulus on 75% of the trials is not the result of a weak controlling stimulus-response relation or a decremental spread of effect to similar stimuli; like any measure of stimulus control that does not account for 100% of the behavior, the result is produced by averaging across two or more controlling relations (e.g., Bickel, Richmond, Bell, & Brown, 1986; Bickel, Stella, & Etzel, 1984; Sidman, 1969, 1980). Consider the example of an experimenter training a simple red-green color discrimination. Two keys are illuminated, one red, one green, and responding to the red key is reinforced intermittently. Imagine that another stimulus that is not controlled by the experimenter, say the buzz from a machine in the next room, accidentally enters into the controlling relation. The subject learns to respond to the red key when the buzz is on and to the key on the left when the

[2] Throughout this paper the term *generalization* is used to describe a behavioral outcome thought to be a function of principles such as stimulus control and reinforcement. It is not meant to refer to a distinct behavioral process such as stimulus generalization. It is possible that the process known as response generalization may also be reduced to an analysis of stimulus control and reinforcement, and that such an analysis would make our understanding of generalized behavioral outcomes more complete, but such an analysis is the topic of another paper.

buzz is off. The result will be that the subject responds 100% to the red key when the buzz is on and 50% to the red key when the buzz is off (assuming the experimenter has randomized position of the colors). If the buzz is present during half of each session, when the experimenter examines responses to the red key the result will be 75% responding to the red key during the experimental session. The experimenter has not established a weak controlling relation; the result is produced by averaging across two controlling relations. Understanding generalized effects requires specifying these controlling relations.

IMPLICATIONS OF THE QUANTAL INTERPRETATION FOR PROGRAMMING GENERALIZED EFFECTS

As the above example of the red-green color discrimination implies, the establishment of simple or conditional stimulus control need not be explicitly programmed (e.g., Bickel et al., 1986; Bickel, et al., 1984; Ferster & Hammer, 1966; Ray & Sidman, 1970; Sidman, 1969). The sheer number of stimuli available in a given setting allows for responses to stimuli unspecified by the researcher to be followed by reinforcement to a degree sufficient for these stimuli to acquire control not intended by the experimenter (Hively, 1962; Morse & Skinner, 1957). Although this is the mechanism by which a desirable spread of effect may occur, it is also the culprit that can limit the extent of generalized effects. This can be true even in the case of relatively simple, well-controlled experimental environments. The basic experimental literature is replete with examples of behavior coming under the control of stimuli neither specified nor desired by the resarcher (e.g., Blough, 1963; Cumming & Berryman, 1965; Ferster & Hammer, 1966; Iverson, Sidman, & Carrigan, 1986; Rand, 1977; Ray & Sidman, 1970; Sidman, 1969; Skinner, 1965; Stoddard & McIlvane, in press; Stoddard & Sidman, 1971). Even the simplest of stimuli can prove sufficiently complex that unplanned correlation occurs between some component of the stimulus and reinforced responding (e.g., Touchette, 1969). Thus, the desired behavior may not be obtained in all target settings, despite explicit efforts to establish stimulus control to an experimenter-defined stimulus present in all those settings. Generalization may be less than that desired because the subject's responding has come under the control of some limited aspect of the experimenter-defined stimulus. Moreover, all aspects of the stimulus controlling the subject's behavior may not be contained within the experimenter-defined stimulus presented during generalization assessments (e.g., Rincover & Koegel, 1975). For example, if the experimenter who trained the red-green color discrimination assessed generality of the discrimination by moving the subject to another room where the buzz never occurred, the subject would respond only on the left key. The experimenter would note 50% responding to the red key and conclude the response did not generalize to the new setting.

To summarize, three basic points are important to recognize: First, stimuli that acquire control over responding may not exert that control in all contexts due to conditional controlling relationships between the stimuli and behavior. Second, stimuli not defined by the experimenter may come to control behavior through unintended correlation with reinforced responding. And third, even apparently simple stimuli consist of a number of dimensions or components that may control behavior separately or in combination and, therefore, the first two limitations specified above can be easily and inadvertently produced.

Classes of Generalization Failure

The inadvertent establishment of inappropriate stimulus control can result in failures to obtain desired generality of effects—failures that may fall into two general classes. In the first class, the stimuli that control the behavior are absent or only occasionally present in the settings where the behavior is desired. The controlling stimuli might be absent if the experimenter fails to specify the stimuli appropriate for controlling the response or fails to ensure that the controlling stimuli are present in all the settings of interest. Controlling stimuli also may be absent if the stimuli specified by the experimenter as the controlling stimuli are not, in fact, the controlling stimuli. In the second class, the experimenter-specified stimuli may be present in all settings of concern, but these stimuli may also acquire control that is conditional on other stimuli that are absent or only occasionally present in the target settings.

To be successful, generalization programming procedures must avoid the failures described above. For applied behavior analysts, this conceptualization of generalization has three implications. First, all settings where the behavior is desired should be examined prior to training so as to identify the various antecedent events (i.e., stimulus classes) that would be appropriate to set the occasion for the behavior. Training should then be planned to establish those stimulus control relations. Second, applied researchers should consider the possibility that stimuli present in the training setting, but absent in the generalization settings, may enter into a controlling relation with behavior. The training environment should then be arranged in ways that attempt to avoid this control. Finally, if generalization is not sufficient after training, the applied researcher should examine the situations where the behavior occurs and the situations where it does not occur and try to identify failures of transfer that are due to (a) the absence of the controlling stimulus in the novel setting, or (b) the inadvertent establishment of a conditionally controlling relation.

STIMULUS CONTROL TACTICS

The procedures used in stimulus control research can be organized around the three major variables that are manipulated when programming stimulus control: the S+; the extraneous stimuli; and reinforcement schedules. Six tactics for manipulating these variables have been identified.

Treatment of the S+

(1) *Repeatedly present supplemental stimuli.* The first tactic is to repeatedly present members of a class of stimuli desired for control (e.g., Ray & Sidman, 1970). These stimuli are *supplemental* in the sense that they are introduced into the environment by the experimenter as a matter of convenience. In using this tactic, the experimenter arranges for a high positive correlation between the stimuli desired for control and reinforced responses. The experimenter first identifies the stimuli he or she wants to control the behavior, then repeatedly presents those stimuli and reinforces correct responding. For example, if red lights and horizontal lines are the desired S+'s, the training procedure involves presenting red lights and horizontal lines repeatedly. Different stimuli might be presented simultaneously or sequentially, depending on whether the experimenter intends to establish control by a single combined stimulus complex (e.g., horizontal lines on a red light) or by a number of different stimuli (e.g., horizontal lines on white background and red lights alone).

(2) *Repeatedly present members of a naturally occurring stimulus class.* Although this tactic is similar in execution to the tactic described above, here we make an important distinction based on the type of stimuli the experimenter defines as desirable for antecedent control. In the second tactic the stimuli are *naturally occurring* in the subjects' environments (i.e., they are the stimuli that seem to set the occasion for the behavior when the natural community provides reinforcement), rather than supplemental stimuli introduced by the experimenter as a matter of convenience. This distinction between arbitrary and naturally occurring discriminative stimuli is peripheral to basic research considerations, but gains relevance when we consider practical issues in producing generality across settings. If a subject's behavior is not under the control of naturally occurring

stimuli, the applied behavior analyst must specifiy a means to ensure that the arbitrary stimuli controlling the behavior occur whenever and wherever the behavior is desired. These considerations are similar to concerns expressed by Ayllon and Azrin (1968, pp. 49–53) regarding the "relevance of behavior rule." Ayllon and Azrin suggested that applied researchers should teach only behaviors that will receive reinforcement from a natural community after training. We are suggesting that antecedent stimuli should also be present in the natural community after training, and if they are not, their presence must be arranged.

Treatment of the Extraneous Stimuli

Successful use of one of the two tactics for manipulating the S+ involves incorporating tactics for manipulating the extraneous stimuli (cf. Engelmann & Carnine, 1982).

(3) *Vary extraneous stimuli.* In this tactic, the experimenter varies stimuli extraneous to the stimulus class desired for control (e.g., Ray & Sidman, 1970). This reduces the correlation between extraneous stimuli and reinforced responding relative to the correlation between the stimuli desired for control and reinforced responding. Thus, this tactic reduces the likelihood that extraneous stimuli (i.e., stimuli that are not present in all settings where generalization is required and, therefore, not desired for control) enter into a simple or conditional controlling relation with behavior. For example, key position typically is not one of the stimulus features desired for control; therefore, the experimenter typically randomizes presentation of the S+ over all key positions to reduce the likelihood that position enters into the controlling relation.

(4) *Maximize common stimuli.* In this tactic, the experimenter arranges for stimuli that are not desired for control to be constant in both training and target settings (cf. Skinner, 1938, p. 55). For example, in basic nonhuman research, the probes for generalization are conducted in the same operant chamber in which training occurred. This tactic maximizes common stimuli and serves two functions. First, it reduces the possibility that conditional control will develop in such a way as to limit generalization of the behavior. Second, it increases the probability that stimuli that do enter into the controlling relationship will be present in the target settings.

Reinforcement Schedules

Establishing the desired stimulus control involves more than the manipulation of the S+ and extraneous stimuli. Careful scheduling of reinforcement contingencies is important as well. This has been a consideration in basic research of stimulus control.

(5) *Alter the training schedule of reinforcement.* After employing a continuous reinforcement schedule to establish behavior under the control of particular antecedent stimuli, experimenters often employ intermittent schedules (e.g., Guttman & Kalish, 1956; Nevin, 1973; Skinner, 1950; Terrace, 1966). This reduces the possibility that the reinforcer itself will function as a discriminative stimulus for further responding. If the reinforcer did serve such a function, responding would quickly undergo extinction during tests for generalization, where reinforcement often is not presented.

(6) *Arrange reinforcement in the generalization settings.* In basic research in stimulus control, this tactic involves intermixing training and probe trials. Like the tactic mentioned above, this procedure reduces the probability that the reinforcer will become a discriminative stimulus for further responding and that extinction will quickly occur.

GENERALIZATION PROGRAMMING METHODS

We now proceed to examine each of the generalization programming procedures identified by Stokes and Baer (1977) in accord with the foregoing analysis. For each procedure, a description and example will be given, followed by a theoretical analysis of how the procedure might be conceptualized in terms of the stimulus control tactics mentioned above. This analysis clarifies the relationships between principles of stimulus control and the present technology of generalization by identifying the stimulus control tactics that are explicitly suggested in the nine procedures. In any given application of a procedure, however, a number of tactics that were not specifically identified by Stokes and Baer may nonetheless be functioning. The analysis of any particular application, therefore, may be incomplete with respect to tactics that are implicit; that is, not specifically suggested by the generalization programming procedure, but probably operative. The tactics explicitly and implicitly suggested in each of the nine procedures are summarized in Table 1.

Train Loosely

In this generalization programming procedure, training is conducted with relatively little consistency in the stimuli presented. All stimulus dimensions of the setting that are practically manipulatable are varied during training (Baer, 1982a; Stokes & Baer, 1977). Stimuli that are "practically manipulatable" would include those that are convenient to manipulate and those that are not desired to set the occasion for the behavior.

Campbell and Stremel-Campbell (1982) successfully utilized a train-loosely procedure to teach two language-delayed children appropriate use of the words "is" and "are." The training procedure took place in the context of training a wide variety of self-help and academic skills, and a wide array of stimulus events was allowed to set the occasion for the behavior. Teachers sometimes prompted responses by removing training materials, asking questions, or making comments to the subject. Also, the subject could initiate a language response based on naturally occurring stimulus events. The irrelevant stimuli varied in this training procedure included training materials, statements made to the child in the form of questions or prompts, and particular syntactic structure (e.g., "wh" questions, yes-no questions, and statements were introduced in a multiple baseline design). Although a wide array of irrelevant stimuli was varied, target responses were reinforced only when emitted under specific conditions. For example, when the subjects were presented with two objects of the same stimulus class (e.g., two pencils, two cups, two apples), the response "are" was consistently reinforced; similarly, the reponse "is" was consistently reinforced when one object from a stimulus class was presented (e.g., one pencil, one cup, one apple). Generality was assessed by recording appropriate use of "is" and "are" in a nontraining free play setting.

Stimulus control analysis. The focus of this procedure is on the systematic variation of the extraneous stimuli. As mentioned previously, varying extraneous stimuli should reduce the probability of establishing undesirable stimulus control. Although many features of the stimulus complexes presented by the experimenter during training may be different from each other, these complexes are likely to have a number of common features. If the behavior is to occur in all situations where it is desired, then these common features need to acquire stimulus control. Presentation of this set of stimuli should therefore be consistent from occasion to occasion, while irrelevant stimulus features are varied randomly. Therefore, although the train-loosely method explicitly identifies the stimulus control programming tactic of varying extraneous stimuli, one result of the procedures should be the repeated presentation of naturally occurring stimuli that are members of a stimulus class appropriate for control. Repeated presentation of a stimulus class is an example of a tactic not explicitly suggested, but probably operative.

Indiscriminable Contingencies

The method of indiscriminable contingencies has been conceptualized as a way of scheduling contingencies so as to obscure the stimulus complexes that set the occasion for the behavior being reliably

TABLE 1

Implicit and Explicit Stimulus Control Tactics in Generalization Programming Procedures

	Generalization programming procedures								
Stimulus control tactics	**Train loosely**	**Indiscriminable contingencies**	**Program common stimuli**	**Mediate generalization**	**Train sufficient exemplars**	**Sequential modification**	**Train and hope**	**Introduce to natural maintaining contingencies**	**Train to generalize**
Treatment of S+ stimulus class									
Repeatedly present naturally occurring members	I		X		X		I	I	I
Repeatedly present supplemental members			I	X			I		I
Treatment of extraneous stimuli									
Vary extraneous stimuli	X				I				I
Maximize common features		I	I						
Reinforcement schedules									
Alter training schedule		X	I						
Arrange reinforcement in generalization settings					X	X	I	X	X

Note. X = Tactic is explicitly suggested in the generalization procedure. I = Tactic is implicit (i.e., not explicitly suggested, but probably operative).

followed by reinforcement (Baer, 1982a; Stokes & Baer, 1977). In implementing the indiscriminable contingencies procedure, the experimenter often uses intermittent or delayed reinforcement delivery. Sometimes stimuli in the training or transfer settings are adjusted to eliminate or reduce elements that make the training setting distinctive.

Fowler and Baer (1981) used indiscriminable contingencies to teach a variety of behaviors to preschool children. Contingencies were in effect for only a 10- to 15-minute training period during the first half of the school day, but reinforcers earned during this period were not delivered until just prior to dismissal. Target periods consisted of another 10- to 15-minute period that was scheduled at a different time of day. In addition to reinforcement delay, as many stimuli as possible were kept constant between the training and target periods. Training periods, target periods, and reinforcement delivery all took place in the same room.

Stimulus control analysis. This feature focuses on using a schedule of reinforcement that reduces the possibility that reinforcement delivery produces a discriminative stimulus for behavior (e.g., Baer, Williams, Osnes, & Stokes, 1984; Fowler & Baer, 1981; Schwarz & Hawkins, 1970). There are two ways that reinforcement delivery is frequently arranged in applied settings. Both arrangements can lead to the development of undesirable stimulus control. In the first arrangement, reinforcement for a target behavior is delivered consistently at the end of a training session and subsequent responding is on extinction. Given this arrangement, presentation of the reinforcing stimulus may function as an S- for further target responses. In the second arrangement, reinforcement is presented throughout the training session after short intervals of target responding. At the end of the session the reinforcer (or stimuli associated with the reinforcer) is removed and further target responding is on extinction. In this arrangement the removal of the reinforcing stimulus may function as an S- for further target responses. Even if the reinforcer were not consistently visible during training, occurrence of longer intervals of target responding without presentation of the reinforcer may serve as an S-. Altering the training schedule of reinforcement by delaying delivery of the reinforcer reduces the likelihood that undesirable control will develop in these ways.

Another component of this method is the maximization of common features of the training and transfer settings. Fowler and Baer (1981) achieved this not only by arranging for the reinforcers to be absent from both settings, but also by conducting contingent and generalization periods in the same room. As mentioned previously, the tactic of keeping many stimuli constant serves two functions. First, it reduces the possibility that conditional control will develop in such a way as to limit generalization of the behavior, and second, it increases the probability that stimuli that do enter the controlling relation will be present in the generalization settings.

Program Common Stimuli

The third method, program common stimuli, involves introducing "salient" stimuli from the target settings into the training setting. Sometimes these stimuli are introduced into the training setting so that they are likely to be correlated with reinforced responding and develop discriminative function. Sometimes they are simply placed in the training setting without any systematic arrangement regarding responding and reinforcement delivery (Baer, 1982a; Stokes & Baer, 1977).

Koegel and Rincover (1974) used this procedure to establish generalization of academic responding from a training setting with two children present, to a classroom setting with eight children present. While intermittently reinforcing correct responding, they gradually introduced additional children (i.e., the common stimuli) into the training setting until the final class size of eight was reached. After eight children were introduced into the training setting, academic responding generalized to the classroom.

Stimulus control analysis. Of all the generalization-promoting methods, program common stimuli most clearly parallels the logic of a stimulus control approach. The careful choice of "salient" stimuli involves a deliberate identification of antecedent stimuli that may be arranged to produce desirable generalization. Although Stokes and Baer explicitly prescribe identifying "salient" stimuli that are naturally occurring in the generalization setting and establishing them as S+'s during training, they also cite examples that involved introducing supplemental stimuli into all settings of interest to the experimenter (e.g., Walker & Buckley, 1972). In addition, no clear distinctions are made among "salient" stimuli that are (a) those desired for stimulus control (i.e., S+'s), or (b) those in the generalization setting that could inhibit generalization by becoming discriminative for incompatible responses (i.e., extraneous stimuli) or by establishing undesirable conditional stimulus control (e.g., Rincover & Koegel, 1975).

Thus, although this generalization procedure explicitly suggests repeatedly presenting naturally occurring stimuli during training, two additional manipulations of antecedent stimuli are implied: (a) repeated presentation of supplemental stimuli, and (b) maximization of common features. The program-common-stimuli procedure, when used by Koegel and Rincover (1974), was probably successful for one or both of the following reasons. First, including additional children in the training setting maximized common features and could have eliminated the two children's function as conditional stimuli that prevented control by other stimuli common to the training and generalization settings. Second, the addition of the children to the training setting may have established them as supplemental (nonconditional) discriminative stimuli for responding. Note also that Koegel and Rincover altered the training schedule of reinforcement to an intermittent schedule before programming the common stimuli—another possible variable.

Baer (1982a) suggested that the major unsolved problems of this approach were (a) the development of strategies for assessing which stimuli are likely to be "salient" (cf. Stokes & Baer, 1976, relative to Stokes, Doud, Rowbury, & Baer, 1978), and (b) the appropriate arrangement of antecedent stimuli and consequences in the training setting. As mentioned previously, the stimulus control literature is replete with examples of behavior coming under the control of stimuli not specified by the researcher. Thus, the basic experimental literature has also faced the problem of identifying all the components necessary to establish controlling (or salient) antecedent stimuli.

Mediate Generalization

The method of mediate generalization is similar to the program-common-stimuli method in that both procedures introduce stimuli into the training setting. Unlike the method of program common stimuli, however, in mediate generalization the stimuli introduced into training are not necessarily "salient" stimuli from the generalization settings. Instead, stimuli are chosen because they will be easy for the subjects to carry from setting to setting (Baer, 1982a; Stokes & Baer, 1977).

In the mediate-generalization method, these easily transported stimuli (e.g., counters, recording devices, written instructions) are usually introduced into the training setting so that they are likely to be correlated with reinforced responding and develop discriminative function. Sometimes, however, the subjects are simply given the stimuli to transport to the generalization settings. In these instances, the stimuli chosen are assumed to have been correlated with reinforced responding at some time in the subject's history (e.g., written instructions; Glynn & Thomas, 1974).

Stimulus control analysis. At least two situations exist in which mediate generalization might establish desirable stimulus control of responding. First, if the desired behavior involves a complex sequence of responses and the sequence is not already established as a behavioral chain, the mediating response may produce supplemental discriminative stimuli for each step in the chain. An example of this type of mediate-generalization procedure was provided by Baer (1982b) in a discussion of the use of an algorithm for extracting square roots. In training this skill, the trainer first gives the students the algorithm, which is a series of step-by-step instructions for deriving the square root. Memorizing the algorithm involves establishing a complex sequence of verbal responses, but all the stimuli in this sequence remain constant from trial to trial. The natural number from which the square root is to be extracted varies from trial to trial, changing many stimuli in the chain, thus making the chain of number manipulation more difficult to establish. Recitation of the algorithm during the derivation of the square root, then, may provide supplemental discriminative stimuli enabling the student to execute the response.

In the second situation, mediate generalization can facilitate responding by supplementing the environment with a series of publicly observable stimuli that can become discriminative for responses that are already established but occur at a lower rate than desired. A device for self-recording may serve such a function if it is established as a discriminative stimulus during training in self-recording (e.g., Holman & Baer, 1979). Having the subject carry a device that is discriminative for a low-rate behavior into the generalization settings should supplement the number of discriminative stimuli for the low-rate behavior relative to the number of stimuli discriminative for other behavior. Thus, an increase in the rate of responding might be produced and generalization of the behavior might then be considered sufficient.

In both examples, mediate generalization probably facilitates responding by providing supplemental discriminative stimuli. As noted in Table 1, this tactic is explicitly identified in the generalization programming procedure.

Sequential Modification and Train Sufficient Exemplars

Baer (1982a) described training sufficient exemplars as "nearly a nonmethod" (p. 201) because it sometimes degenerates into sequential modification. (Sequential modification is considered a "nonmethod"; that is, it is not an example of programming for generality because it involves arranging reinforcement delivery in all settings and therefore requires as much intervention as training.) Because these procedures are closely related and employ similar methods, they are discussed together.

In these procedures, a behavior is trained in fewer settings than the total number of interest. Responding is then measured in the untrained settings. At this point, the absence of desired responding in these settings is handled differently by each of the two methods. In sequential modification, training is introduced into all remaining settings. In train sufficient exemplars, however, training is introduced into one of the previously untrained settings, then responding is again measured in all remaining settings. If the desired response still has not generalized sufficiently, training is introduced into yet another setting, and the remaining settings are again measured. This cycle of training in one setting, then measuring in the remaining settings is repeated until the desired response is occurring in all situations of interest (Baer, 1982a; Stokes & Baer, 1977). If responding never generalizes to the remaining settings, then all settings are exhausted by this process and the sufficient-exemplars procedure becomes very similar to sequential modification.

Stokes et al. (1974) used the train-sufficient-exemplars procedure to establish appropriate greeting responses in retarded children. It was considered desirable for the children to emit this response upon the approach of any person in the institution. Sufficient exemplars were trained by having a new trainer reinforce the children's greeting responses. New trainers were added one at a time until the children appropriately greeted any approaching person.

Stimulus control analysis. As Stokes and Baer (1977) explicitly noted, the method of sequential modification deals with insufficient generalization by introducing reinforcement in all the remaining settings. However, the method of sufficient exemplars was explicitly described as a more systematic introduction of reinforcement and as a method involving repeated presentation of new exemplars. These new exemplars would probably constitute a stimulus class desired for control (e.g., Anderson & Spradlin, 1980; Stokes et al., 1974), although this was not a condition Stokes and Baer specified. In instances where insufficient generalization occurs because extraneous stimuli have come to control behavior, this tactic may lead to elimination of the extraneous control (e.g., Garcia, 1974; Griffiths & Craighead, 1972). When stimuli desired for control are embedded in a stimulus complex, repeated presentation of new exemplars results in variation of extraneous features of the stimulus complex while the stimulus features desired for control remain constant. Thus, in addition to specifying a feature of the exemplars, a stimulus control analysis suggests that the method of sufficient exemplars implies the tactic of varying extraneous stimuli.

Repeated presentation of new trainers in Stokes et al. (1974) resulted in variation of extraneous individual characteristics (e.g., eye color, hair color, clothing), while features that all people have in common (e.g., basic form of head and face, arms, legs, and torso) were presented repeatedly. In instances where an insufficient number or variety of stimuli have come to control responding, the repeated presentation of new exemplars may provide additional and varied controlling stimuli. If the exemplars trained involve stimuli that are in the same stimulus class as other untrained stimuli, generalization will occur to those untrained stimuli (e.g., Anderson & Spradlin, 1980; Dixon, 1978; Dixon & Spradlin, 1976; Dixon, Spradlin, Girardeau, & Etzel, 1974; Sidman, 1971; Sidman, Cresson, & Willison-Morris, 1974; Sidman & Tailby, 1982; Spradlin & Dixon, 1976). If none of the stimuli belong to the same stimulus class, and during training no stimulus classes are established, it is likely that all exemplars will have to be trained and the method will become sequential modification.

For example, MacDonald (1983) taught children the concepts "fruit" and "vegetable" by training appropriate within-class matching and identification of a variety of fruit and vegetable stimuli. Children were first trained to match two exemplars (e.g., blueberry and melon), after which new exemplars (e.g., plum) were added to the matching task, one at a time. Teaching occurred in a systematic order designed to establish new stimulus classes. Appropriate labeling of fruits and vegetables was found to generalize to untrained stimuli within the established stimulus classes. Thus, once the children were taught that blueberry is a fruit, they were able to point appropriately to a plum when they were asked to find "fruit," even though they had not been directly taught that a plum is a fruit.[3]

NONMETHODS

In addition to sequential modification, Stokes and Baer (1977) considered three other procedures to be steps toward assessing generality, but not examples of programming to produce it. Baer (1982a) called these procedures "nonmethods" because they required direct provision of training or reinforcement in the other settings. The additional procedures were: (a) train and hope, (b) introduce to natural maintaining contingencies, and (c) train to generalize. Interpretation of the procedures in terms of stimulus control suggests that all of the procedures considered to be methods involve arrangements of the S+ and/or the extraneous stimuli, or, in the case of indiscriminable contingencies, explicitly suggest arranging the reinforcer so as to avoid establishing undesirable antecedent control. Some of the methods involve manipulating the reinforcement contingencies, in addition to arranging antecedents. Nonmethods, however, only involve manipulating reinforcement contingencies, if any intervention is suggested at all. Arrangements of the S+ and/or extraneous stimuli are not considered.

Train and Hope

In the train-and-hope procedure, behavioral procedures are implemented in fewer settings than those in which behavior change is desired. Subsequent transfer to other settings is noted anecdotally or is systematically probed. Any transfer that may occur is applauded, but special measures are not taken to enhance the likelihood that it occurs (Baer, 1982a; Stokes & Baer, 1977).

Stimulus control programming tactics are not directly suggested by this procedure. The only direct emphasis is on actual observation or data-based probes for generalization. It is possible that on occasions when this procedure is used and generalization results, some stimuli appropriate for the generalization of behavior have been unintentionally correlated with reinforced responding to a degree sufficient to establish antecedent control (see Halle, Baer, & Spradlin, 1981, for data that suggest unintentional establishment of observers as controlling antecedent stimuli). It should be noted, however, that control by consequences that have not been arranged or planned for by the experimenter may also produce the generalized effects (Catania & Cutts, 1963).

Introduce to Natural Maintaining Contingencies

The procedure of introducing behavior to natural maintaining contingencies involves using the reinforcement contin-

[3] See Sidman and Tailby (1982) for a discussion of the training necessary to establish stimulus classes (i.e., stimulus equivalence). MacDonald (1983) is used as an example because the arrangement of stimuli clearly parallels the train-sufficient-exemplars approach and the choice of fruit and vegetable stimuli make the example more easily understood. The reader should be aware, however, that in order to reduce the influence of previous experience, the fruit and vegetable stimuli used were agricultural symbols rather than pictures or actual fruits and vegetables. Also, the experimental design did not allow MacDonald to determine whether the classes were established through inclusion (e.g., blueberry served as an S+ for melon, and therefore melon was matched with blueberry), or exclusion (e.g., corn served as an S− for melon, and, therefore, melon was matched with blueberry).

gencies in the natural environment to produce responding in untrained situations of interest (Baer, 1982a; Stokes & Baer, 1977). The direct emphasis of this approach is on the arrangement of reinforcement in the generalization settings rather than on the antecedents of behavior.

Although tactics for establishing stimulus control of behavior are not directly considered or arranged, stimulus control of behavior can develop in an appropriate fashion because reinforcement in the natural community is often delivered only when the occasion is appropriate for the behaviors. Thus, stimuli appropriate for control are likely to be correlated with reinforced responding to a degree sufficient for the establishment of stimulus control.

Train to Generalize

Train to generalize may involve two basic procedures. One procedure is to consider generalization to be a response class itself and to place a reinforcement contingency on it (Goetz & Baer, 1973). Under these contingencies, new responses would be reinforced each time they occurred in a new setting, but a second occurrence of the same response under the same conditions would not receive reinforcement (Baer, 1982a). In this sense, the train-to-generalize procedure is similar to other nonmethods in that it arranges reinforcement in the generalization settings and does not specifiy manipulation of S+ or extraneous stimuli.

In instances where responses are reinforced each time they occur in a new setting, a member of a particular stimulus class may be presented repeatedly. Even though the experimenter defines the situations as new, the situations may include stimuli that are functionally the same or equivalent for the subject. Although the stimulus class is presented repeatedly, other stimuli in the new situation would vary. In this case, the arrangement of antecedents in train to generalize becomes logically identical to train sufficient exemplars and train loosely, as Baer (1982a) has suggested.

A second train-to-generalize procedure involves directly instructing the subject to generalize (Baer, 1982a; and by implication of an example, Stokes & Baer, 1977, p. 363). The provision of instructions for emitting a particular behavior may essentially involve the use of supplemental stimuli that have already acquired a discriminative function (e.g., Herbert & Baer, 1972). In this case, train to generalize is logically identical to mediate-generalization procedures that take advantage of stimuli with previously established discriminative functions.

SUMMARY AND DISCUSSION

A stimulus control interpretation of generalization programming procedures provides support for and elaborates on the technology of generalization that Stokes and Baer (1977) identified. It is consistent with Baer's (1982a) observation regarding procedures that are logically identical (i.e., reinforce generalization, train sufficient exemplars, and train loosely) and identifies additional procedures that may be logically identical (e.g., ask for generalization and mediate generalization). It also is consistent with Stokes and Baer's classification of procedures as methods and nonmethods and adds rationale for this division. The generalization methods explicitly apply tactics that manipulate antecedents to establish stimulus control, whereas nonmethods involve no explicit attention to antecedents.

The stimulus control interpretation extends Stokes and Baer's (1977) review as it clarifies points of similarity and overlap between procedures. Moreover, it identifies features of the procedures that were not explicitly identified in the original work, but may be functioning as a natural consequence of implementing another feature. For example, the train-loosely procedure suggests that all "practically manipulatable" stimuli be varied from trial to trial. The stimulus control interpretation of this procedure suggested that repeated presentation of the stimulus class desired for control is likely to result. In addition, this interpretation suggests a more systematic means for determining: (a) which of the stimuli that could be manipulated should be manipulated carefully (i.e., stimuli that are desired for control should be presented in a manner that is richly correlated with reinforcement, at least initially), and (b) which stimuli may not be easily manipulated, but may nevertheless hinder generalization and, therefore, eventually require attention if the desired generalization is to be achieved.

A stimulus control interpretation also identifies features of generalization programming procedures that were not specified in Stokes and Baer's (1977) analysis, but that are used as an additional (almost incidental) feature in some applications of the procedure and omitted in others. The identification of implicit features in Table 1 may help explain inconsistencies in the success of applications in different studies by drawing attention to important differences in procedure.

Another benefit of translating generalization procedures into tactics for establishing stimulus control is that it may set the occasion for researchers to carefully plan stimulus control for the behavior of interest. To date, research in applied behavior analysis has concentrated heavily on the arrangement of different consequences for a variety of behavior changes (Deitz, 1978), while paying relatively little attention to specifying and arranging for appropriate antecedent control (cf. Etzel, 1987; Marholin & Touchette, 1979; Sidman, 1979).[4]

Attention to principles of antecedent control may explain instances when a generalization training procedure works and when it does not. As previously mentioned, one reason that train sufficient exemplars may not produce generalization is that none of the stimuli desired for generalization have previously been established as members of the same stimulus class during the subject's reinforcement history. If training is not arranged in a manner that leads to the establishment of stimulus classes, new responses to stimuli within a stimulus class cannot emerge. All exemplars will have to be trained and the method will degenerate into the nonmethod of sequential modification. Fortunately, research in stimulus control has led to the discovery of a reasonably reliable means of establishing stimulus classes during training (e.g., Sidman, 1971; Sidman et al., 1974; Sidman & Tailby, 1982). Thus, careful attention to the arrangement of antecedents in accordance with the principles established through stimulus control research should increase the success of producing emergent stimulus-response relations through the procedure Stokes and Baer identified as sequential modification.

Further isolation of principles responsible for the success or failure of generalization training procedures may be an important and fruitful endeavor for applied researchers. Although some applied researchers have approached the problem of generalization from this perspective (e.g., Becker & Carnine, 1981; Becker & Engelmann, 1978; Engelmann & Carnine, 1982; Rincover & Koegel, 1975), much research remains to be done.

Six years ago, Baer (1982a) suggested that generalization research would probably yield a pragmatic technology effective enough for it to be worth learning by practitioners and organized enough to suggest ways to discover new and successful techniques. We would argue that generalization research has already accomplished this, but that another of Baer's suggestions has not been fully explored:

> Perhaps [generalization] is a term for a relatively small number of behavioral processes of considerable generality. In that case, the implicit technology of generalization induced by Stokes and Baer (1977) . . . can through pointed research become an explicit technology based knowingly on basic principle. Thereby, it could achieve power, generality, replicability, and the potential for extending itself from its own principles into still more and perhaps better technology (p. 211).

[4] We do not mean to underplay the importance of consequences in a stimulus control analysis. In fact, it is necessary to consider the reinforcement schedule operating in each context where one wishes to establish stimulus control as some reinforcement is necessary to maintain the stimulus-response unit (cf. Marholin & Touchette, 1979).

We believe that a stimulus control interpretation of generalization provides a path whereupon exploration of this possibility can begin.

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