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PROMOTING RESPONSE VARIABILITY AND STIMULUS GENERALIZATION IN MARTIAL ARTS TRAINING

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The effects of reinforcement and extinction on response variability and stimulus generalization in the punching and kicking techniques of 2 martial arts students were evaluated across drill and sparring conditions. During both conditions, the students were asked to demonstrate different techniques in response to an instructor's punching attack. During baseline, the students received no feedback on their responses in either condition. During the intervention phase, the students received differential reinforcement in the form of instructor feedback for each different punching or kicking technique they performed during a session of the drill condition, but no reinforcement was provided for techniques in the sparring condition. Results showed that both students increased the number of different techniques they performed when reinforcement and extinction procedures were conducted during the drill condition, and that this increase in response variability generalized to the sparring condition.

DESCRIPTORS: extinction, martial arts, response variability, stimulus generalization

Martial arts training, similar to other athletic activities, involves the acquisition of specific technical skills during structured training exercises with the objective of generalizing those skills to naturalistic contexts (Harding, 1993). One approach to improving the performance of specific skills involves the use of instructional feedback and differential positive reinforcement. These procedures have been used to increase the correct execution of skills across a variety of sports, including inline skating (Anderson & Kirkpatrick, 2002), tennis (Buzas & Ayllon, 1981), swimming (Koop & Martin, 1983), gymnastics (Allison & Ayllon, 1980), basketball (Kladopoulos & McComas, 2001), soccer (Brobst & Ward, 2002), and football (Ward & Carnes, 2002). For example, Kladopoulos and McComas demonstrated the effects of instruction and immediate feedback on foul-shooting performance for 3 college basketball players. The participants received descriptive praise pertaining to proper form during foul-shooting practice. The results showed that all 3 participants improved their form and the percentage of shots made during intervention. Similar in-

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tervention effects were demonstrated on the performance of correct relay tags during practice with inline speed skaters (Anderson & Kirkpatrick). Participants received verbal praise immediately following correct relay tags and prescriptive feedback following each intervention session. The results of these and other previous investigations suggest that differential reinforcement procedures may prove useful in improving technical skills related to the performance of athletic maneuvers.

Although a number of studies have demonstrated the efficacy of behavioral programs for improving performance during practice sessions, it is also important to consider the extent to which improved performance during practice generalizes to other relevant contexts (i.e., competition). For example, Ward and Carnes (2002) showed that a public-posting procedure applied to a selection of football skills (e.g., tackling) increased the players' performance during both practice and game sessions. Generalization of improved accuracy in foul shooting in basketball from intervention sessions to game situations was also reported by Kladopoulos and McComas (2001). Brobst and Ward (2002) evaluated the effects of an intervention program that included public posting, goal setting, and oral feedback on 3 female soccer players' performance across three important soccer skills (e.g., ball movement). Results showed that the program was effective in improving performance during practice, but generalization of improved performance to game sessions was limited for two of the three skills targeted for intervention.

In martial arts training, stimulus generalization is an important consideration in preparing the students to use their skills in a self-defense situation. With respect to promoting the generalization of behavior, Stokes and Baer (1977) noted the importance of including salient stimuli across training and generalization contexts. This approach to programming common stimuli is fundamental to martial arts training. Beginning students are typically taught a technique or a chain of techniques as a response to a specific designated attack. For example, in response to an opponent's hooking punch, the student is first taught how to avoid the punch and then learns a selection of counterstrike options. Defensive and counterstrike maneuvers against the hooking punch are practiced repeatedly, with the objective that the hooking punch will acquire a discriminative function that will control the student's responding in an actual self-defense situation.

Another component of martial arts training involves teaching the student to generate diverse adaptive responses across stimulus conditions. An expanded repertoire of skills enables students to adjust their behavior in response to an opponent's behavior and other environmental variables. As discussed by Stokes and Baer (1977), behavioral changes must often occur over a variety of stimulus conditions (e.g., persons, settings), and the effects should sometimes spread to a variety of related behaviors. With respect to the latter objective, these authors suggested the application of programming procedures with the specific intent of teaching the individual "to generalize" (p. 362).

Reinforcement for response variability combined with extinction for invariant responding has been shown to increase variability in response topography with porpoises (e.g., Pryor, Haag, & O'Reilly, 1969) and with humans (Duker & van Lent, 1991; Goetz & Baer, 1973; Lalli, Zanolli, & Wohn, 1994; Lee, McComas, & Jawor, 2002; Miller & Neuringer, 2000). For example, Goetz and Baer taught 3 preschool children to increase the number of novel block forms during block-building play. The children were given descriptive social reinforcement (e.g., "Oh, that's very nice—that's different!") contingent on the initial creation

of a form that had not appeared previously during the session. Experimental control was demonstrated via a second condition in which reinforcement was provided only for forms that had already appeared during the session. The results showed that each child displayed increases in form diversity when reinforcement was provided for the creation of different forms during a session. Lalli et al. showed the effects of positive reinforcement combined with extinction on increased response variability in 2 young children's toy play. Previous research suggests that variability in response topography may be viewed as an operant dimension of behavior that is amenable to basic behavioral procedures (e.g., reinforcement, extinction) in applied settings.

The purpose of the current investigation was to determine whether a combination of reinforcement for response variability and extinction for invariant responding would result in an increase in the diversity of techniques displayed by martial arts students during a training drill. Specifically, following a baseline condition, the instructor provided descriptive performance feedback only for each different technique displayed by the student during each session of the training drill. A second purpose was to evaluate whether response variability would then generalize across a second, more realistic training context in which no performance feedback was provided, but in which the relevant discriminative stimuli were present.

METHOD

Participants and Setting

Two adults with graduate degrees who were beginning students in the Kenpo system of martial arts gave consent to participate in the investigation. Both students had received approximately 100 hr of training over an 8-month period prior to the study. Angie, aged 40 years, had received no previous martial arts training. Andre, aged 33 years, had previous martial arts training that was limited to a brief exposure to jujitsu (grappling) as a teenager. The instructor (first author) was a black belt in Kenpo with 25 years of experience in teaching martial arts. All sessions were conducted in the students' regular training area. Sessions were conducted over a 3-week period for Andre and a 5-week period for Angie. Both students continued to attend regular classes during the course of the investigation. Students and the instructor wore protective equipment that included padded coverings over the head, body, shins, hands, and feet during all sessions. All sessions were videotaped for subsequent data collection and analysis.

Response Definitions

An event recording system was used to measure student and instructor behavior. Student behavior consisted of seven hand techniques and seven foot techniques. For the purposes of this article, hand techniques are referred to as punching and foot techniques as kicking. *Punching techniques* included the forefist punch, hooking punch, uppercut punch, vertical punch, backfist strike, hooking elbow strike, and driving elbow strike. Each punching technique was further classified with respect to whether it was delivered with the right or left hand, and whether it was directed to the opponent's head (high) or body (middle). Thus, there were 28 possible punching techniques that could be recorded as distinct techniques. *Kicking techniques* included the front kick, hooking kick, side kick, crescent kick, soccer kick, front knee strike, and hooking knee strike. Each kicking technique was further classified with respect to whether it was delivered with the right or left leg, and whether it was directed to targets below the opponent's waist (low) or above the opponent's waist (middle). For kicks, there were 26 pos-

sible techniques that could be recorded as distinct techniques, because the soccer kick is typically used only against low targets (e.g., opponent's shin, knee). *Technique execution* was defined as the performance of a technique with correct form and delivery (e.g., balance, target focus, and speed). Each technique was rated as either *incorrect* (0) or *correct* (1).

Two instructor behaviors were recorded. *Counterstrike* was defined as the delivery of a middle right-hand forefist punch to the student's body following the performance of a student's punch or kicking technique. *Feedback* was defined as the instructor's identification of the punching or kicking technique that the student had just performed and any comments regarding the correct or incorrect execution of the technique. For operational definitions of student and instructor behaviors, please contact the first author.

Interobserver Agreement

The first author and a second martial arts instructor with a similar number of years of teaching experience independently scored the occurrence of student and instructor behavior from the videotapes using an event recording system. An assessment of interobserver agreement was done on a trial-by-trial basis across randomly selected sessions. For example, during the drill condition, each of the instructor's punches was followed by a student response and, during Phase 2, instructor feedback. This series constituted one trial. The observer recorded the specific technique that was used in the response, rated the execution of the technique (correct or incorrect), and recorded if instructor feedback occurred. During the sparring condition, each student technique was considered a discrete trial. As in the drill condition, the observer recorded the specific technique that was used and rated the execution of the technique.

Interobserver agreement on occurrence was calculated based on direct comparisons of the data-recording sheets in which the number of agreements was divided by the number of agreements plus disagreements and multiplied by 100%. Interobserver agreement for both student and instructor behavior was assessed for 23% of sessions across both students. Interobserver agreement for combined punching and kicking techniques ranged from 89% to 100% (M = 94%). Interobserver agreement for instructor counterstrikes and feedback ranged from 95% to 100% (M = 98%). Interobserver agreement for technique execution ranged from 75% to 100% (M = 87%).

Procedural Integrity

A measure of procedural integrity on the correct delivery of instructor feedback was evaluated via an analysis of instructor accuracy in providing feedback for the performance of different techniques during all drill conditions. Integrity was defined as the occurrence of feedback for a technique that had not been previously performed within each session and the nonoccurrence of feedback for a technique that had been previously performed within each session. Procedural integrity was calculated by dividing the number of correct feedback deliveries by the number of incorrect plus correct feedback deliveries and multiplying by 100%. Procedural integrity ranged from 84% to 95% (M = 89%) across sessions.

Experimental Design

The results for each participant were evaluated within a two-tiered multiple baseline design (across punching and kicking techniques). A multielement design (across drill and sparring conditions) was embedded within the multiple baseline design as a measure of generalization during sparring sessions.

Procedure

The investigation was conducted in two phases. A series of three to eight sessions was conducted immediately after the student's regular training class. Session duration during the course of the study averaged 96 s. Following each session, the student was given a brief break (2 to 3 min) to reduce the effects of fatigue and to enable the instructor to explain the next condition.

Phase 1: Baseline drill and sparring conditions. The purpose of this phase was to evaluate the diversity of the student's techniques during a training drill and during a more realistic sparring exercise. During the baseline drill condition, the instructor performed 20 high right-hand forefist punches (i.e., 20 trials per session). The student was directed to perform a defensive maneuver (e.g., block or evasion), and then to perform a single counterstrike in response to each of the instructor's punches. The student was told that he or she could use any of the punching or kicking techniques included in the response definitions. He or she was also instructed to use different techniques in performing the counterstrike. The student was allowed direct light contact to the instructor's body and legs, but was requested to avoid direct contact to the instructor's head. The student was allowed 3 s to perform both the defensive and the counterstrike techniques, at which time the instructor delivered another punch (i.e., it was possible for the student to miss an opportunity to counterstrike during a trial if he or she did not respond quickly). During this phase, no verbal feedback was provided for any of the student's responses.

During the sparring condition, the student was allowed to use any of the techniques described in the response definitions, in any number, sequence, or combination. Each session continued until the student had performed 20 techniques (i.e., 20 trials per session). The student was allowed direct light contact to the instructor's body and legs, but was requested to avoid direct contact to the instructor's head. The instructor performed two techniques during this phase. The same high right-hand forefist punch used during the training drill (i.e., the discriminative stimulus) was delivered intermittently during the session without contact to the student. The instructor also performed a middle right-hand forefist punch to the student's body intermittently during the sparring session following an average of four techniques (range, three to seven techniques across sessions) performed by the student. The purpose of the punches to the student's body was to add another element of realism to the training exercise, in that the student experienced intermittent contact in the process of performing their techniques. No verbal feedback was provided to the student at any time during the session. The sparring condition was conducted in the same fashion across both phases of the investigation.

Phase 2: Differential reinforcement (DRA) plus extinction. The first purpose of this phase was to evaluate whether providing verbal feedback following the performance of each different technique would serve to reinforce (and thus increase) the number of different techniques the student performed during the training drill. To further enhance reinforcement effects, previously performed techniques during a session were ignored (i.e., placed on extinction). The second purpose was to evaluate whether increases in the number of different techniques the student performed during the training drill would generalize to the sparring condition, in which no verbal feedback was provided. As described in Phase 1, the student was told to use any of the punching and kicking techniques included in the response definitions and was instructed to try different techniques. The student was informed that the objective of the drill was to increase both the

diversity and the correct execution of the techniques.

The drill plus feedback condition was identical to the baseline drill condition, except that the instructor provided brief verbal feedback immediately following the performance of each different technique the student used within a session. For example, following the first time the student performed a high right-hand forefist punch during a session, the instructor would identify the technique (e.g., "High right-hand forefist punch") and comment briefly on the execution of the technique (e.g., "You did that with good form"). Repetitions of a technique during each session received no verbal feedback.

For Andre, feedback was initially provided only for different punching techniques used during the drill (i.e., no feedback was provided for kicking techniques). Following an increase in the number of different punching techniques performed during the drill, feedback was then provided for each different kicking technique performed during the drill. For Angie, feedback was initially provided only for different kicking techniques performed during the drill (i.e., no feedback was provided for punching techniques). Following an increase in the number of different kicking techniques performed, feedback was then provided for each different punching technique performed during the drill. The initial decision to reinforce punching techniques first for Andre was arbitrary. For Angie, the order of techniques subject to reinforcement was reversed from Andre's to rule out order effects.

RESULTS

The results for Andre are shown in Figure 1. During Phase 1 (baseline), the number of different punching techniques performed in each session averaged 3.5 during the drill condition and 6.75 during the sparring condition. The number of different kicking techniques performed in each session averaged 1.28 during the drill condition and 1.16 during the sparring condition. During Phase 2 (DRA plus extinction), the number of different punching techniques performed in each session increased during both the drill (M = 8.57) and the sparring (M = 9.40) conditions. The number of different kicking techniques performed in each session also increased across the drill (M = 7.0) and the sparring (M = 3.0) conditions.

The results for Angie are shown in Figure 2. During Phase 1 (baseline), the number of different kicking techniques performed in each session averaged 6.4 during the drill condition and 3.75 during the sparring condition. The number of different punching techniques performed in each session averaged 2.77 during the drill condition and 3.42 during the sparring condition. During Phase 2 (DRA plus extinction), the number of different kicking techniques performed in each session increased during both the drill (M = 8.62) and the sparring (M = 5.42) conditions. The number of different punching techniques performed in each session also increased across the drill (M = 7.25) and the sparring (M = 4.75) conditions.

Changes in technique execution were also evaluated across experimental conditions (Table 1). Correct execution was calculated by adding the ratings separately across punches and kicks, and then dividing the sum by the number of punches and kicks performed in each condition and multiplying by 100%. These results suggested that improvement occurred for the class of techniques that was rated relatively low at baseline. For example, Andre's correct kicking techniques during baseline were rated at 27% and 28%, respectively, during the drill and sparring conditions. Following the DRA procedure, the ratings increased to 77% and 83%. Punching techniques, which were rated relatively high during baseline (drill =

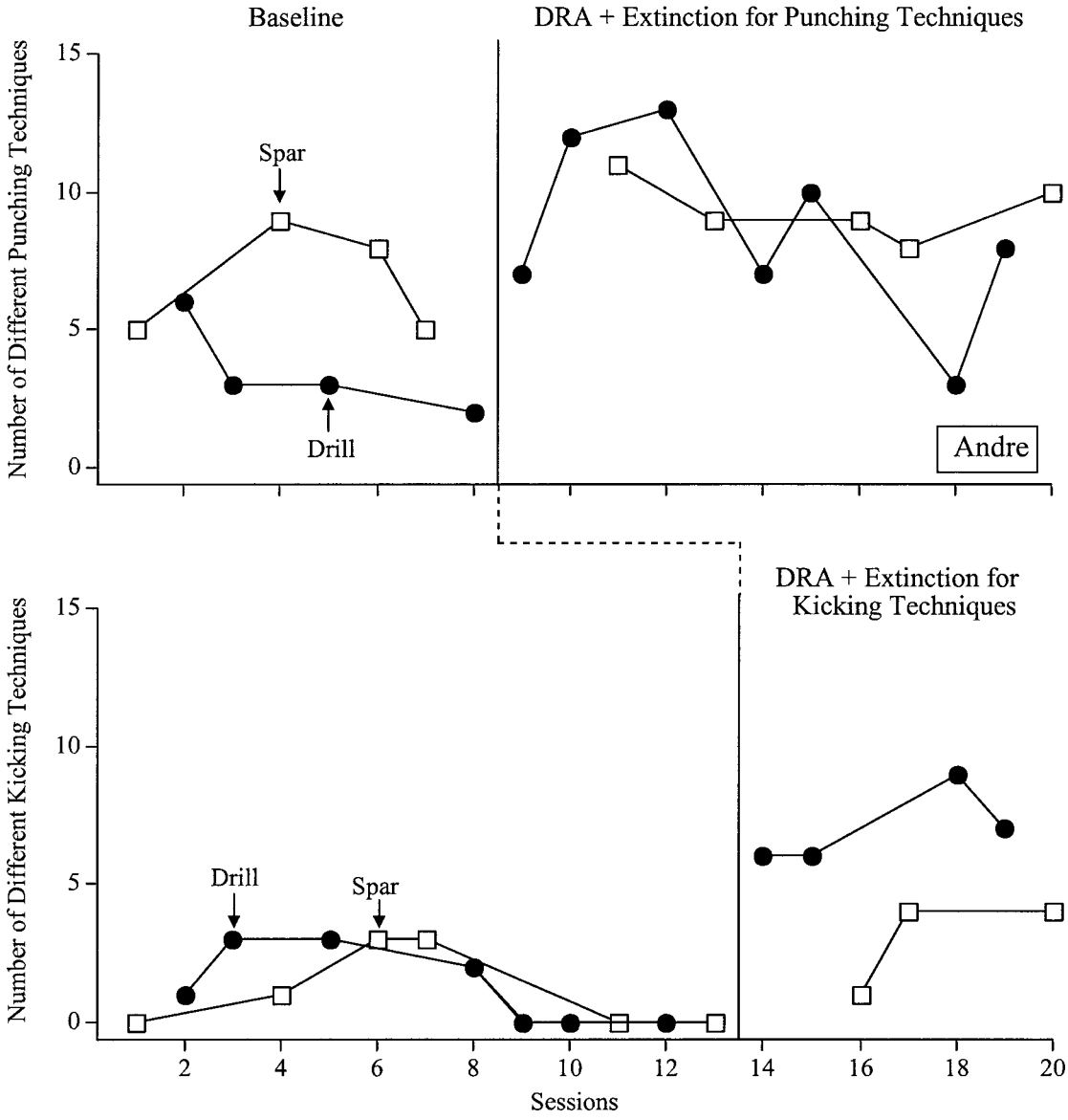

Figure 1. Number of different punching techniques (top panel) and different kicking techniques (bottom panel) for Andre across drill and sparring conditions.

93%, sparring = 75%), maintained their high rating (drill = 95%, sparring = 75%). For Angie, punching techniques during baseline were rated at 65% and 16%, respectively, during the drill and sparring conditions. Following the DRA procedure, the ratings increased to 83% and 57%. Kicking techniques, which were rated relatively high during baseline (drill = 84%, sparring = 77%), maintained their high rating (drill = 86%, sparring = 79%).

DISCUSSION

This investigation demonstrated that reinforcement and extinction procedures increased the response variability of techniques performed by 2 martial arts students during

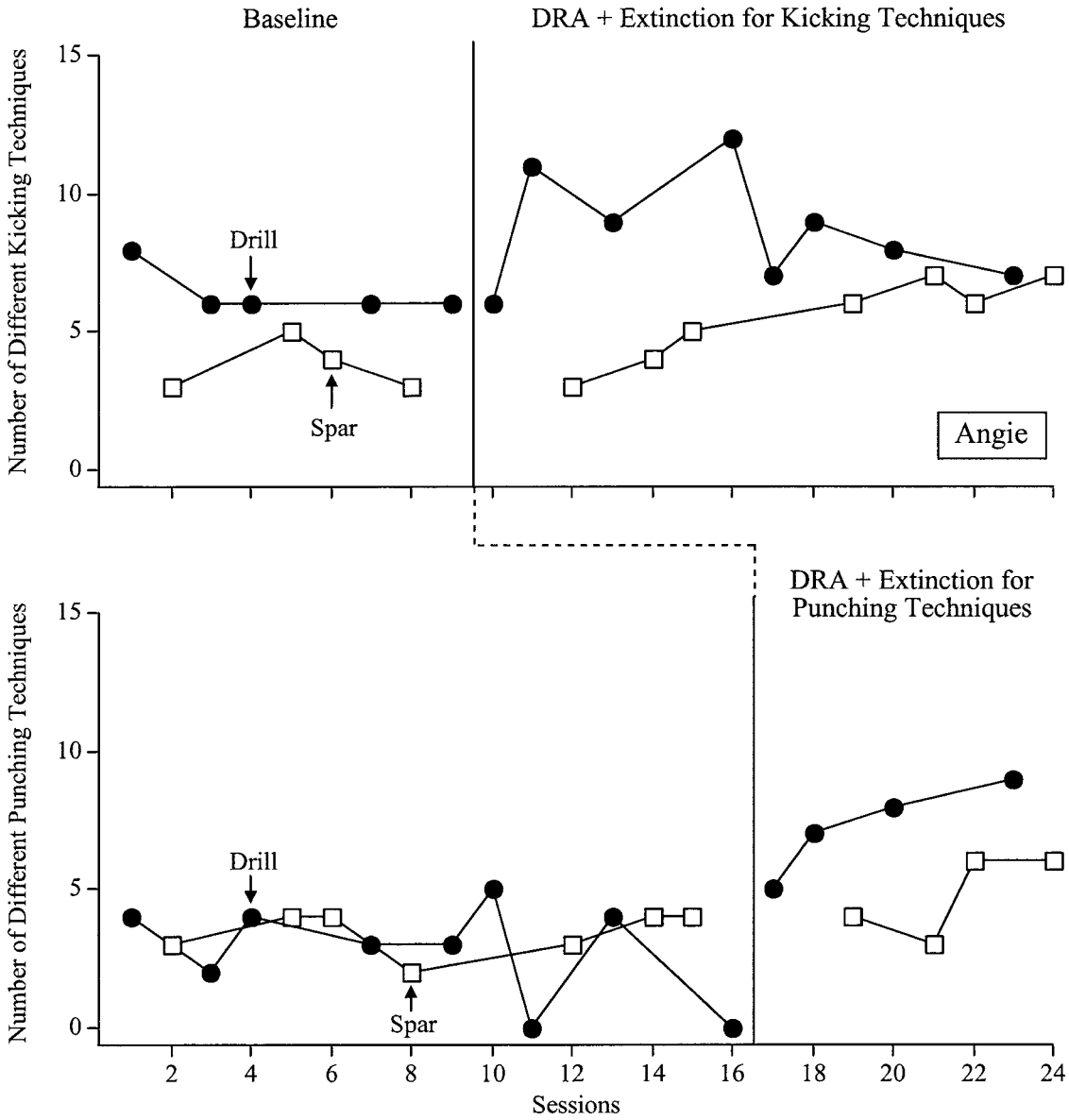

Figure 2. Number of different kicking techniques (top panel) and different punching techniques (bottom panel) for Angie across drill and sparring conditions.

a training drill. In this respect, the study replicated the results of previous applied studies (e.g., Goetz & Baer, 1973; Lalli et al., 1994; Lee et al., 2002) in which response topography variability was shown to be an operant dimension of human behavior. For both participants, an increase in the number of different kicking and punching techniques performed during the training drill appeared to be controlled by the programmed contingencies. Specifically, each student displayed an increase in different techniques both within session and cumulatively across conditions when reinforcement was provided for the performance of different techniques and the repetition of techniques was placed on extinction.

This study contributes to the literature on

Table 1
Average Percentage of Correctly Executed Punching and Kicking Techniques Across Conditions

Conditions	Technique	Baseline	Punches reinforced	Kicks reinforced
Andre				
Drill	Punches	93	95	
Sparring	Punches	75	75	
Drill	Kicks	27		77
Sparring	Kicks	28		83
Angie				
Drill	Punches	65	83	
Sparring	Punches	16	57	
Drill	Kicks	84		86
Sparring	Kicks	77		79

sports training by providing another example of the use of differential reinforcement and descriptive feedback to improve the performance of specific athletic skills (e.g., Anderson & Kirkpatrick, 2002; Kladopoulos & McComas, 2001). In the current investigation, a comparison of student performance was made between the training condition and a sparring condition that more closely resembled a naturalistic context for the application of technical skills. The results suggested that improvements in student performance during the training condition generalized to another stimulus condition.

This study extends previous applied research by demonstrating that the effects of programmed generalization during the training drill resulted in an increase in response variability in a different context (i.e., sparring). This effect of differential reinforcement has been demonstrated in football skills (e.g., Ward & Carnes, 2002) following a public-posting procedure, but in that study the focus was to improve the performance of a selection of specific skills (e.g., tackling) rather than to increase the variability of responses. In the current study, response variability occurred across training situations, showing that the procedures produced both stimulus and response generalization, although the generalization effects during sparring were more modest than during the training sessions.

It is likely that instructor feedback served multiple functions. The identification of different techniques during the drill plus feedback condition appeared to function as a reinforcer for response variability. The feedback on technique execution addressed both correct and incorrect elements of performance. Thus, corrective performance feedback may have served to reinforce specific aspects of a technique (e.g., "good speed") while weakening others (e.g., "Don't put all of your weight on your front foot when you punch; stay balanced").

There are a number of limitations to the current investigation that warrant discussion. First, it is notable that there were some instances of overlapping data between baseline and intervention for both participants. For example, the number of different punching techniques decreased to baseline levels during intervention sessions for both Andre and Angie. In Andre's case, a decrease in different punching techniques appeared to be part of a downward trend. However, these decreases in different punching techniques should be considered in relation to the concurrent increase in the number of different kicking techniques that occurred during the same sessions. Given the fixed number of trials per session, as diversity for one class of techniques (e.g., kicking techniques) increased due to reinforcement, there would be fewer opportunities for the occurrence of the second class of techniques (e.g., punching techniques). Similar findings occurred for Angie with respect to the relation between kicking and punching techniques during intervention. Second, the conditions were relatively limited with respect to the instructor's behavior. The instructor performed only one punching technique during the training drill and added only one additional punching technique during the sparring exercise. In an

actual competition or self-defense situation, the student's opponent may display at least the same degree of response diversity as the student. Variability in opponent behavior must be considered as a potential influencing factor in the performance and diversity of student responding. Third, although generalization of response variability was observed during the sparring condition, we did not conduct a direct analysis of the variables that produced generalization to this context. Also, generalization across other stimulus conditions—such as different opponents, training drills, and settings outside the regular training area—remains to be investigated. Finally, it is unknown whether the students would have maintained a similar level of response variability over time without programmed reinforcement.

With respect to these limitations, it should be recognized that the participants in the current study were novices. The training curriculum in their martial arts system is designed to guide the students in the systematic development of effective self-defense responses. Drills and sparring exercises as described in the current study are used to acquire technical proficiency at specified levels (e.g., belt ranks) before moving on to more complex maneuvers and realistic training. In addition, the techniques described in the response definitions represent a subset of the techniques that are practiced during the students' regular class.

As discussed by Stokes and Baer (1977), the most practical position for behavior analysts is to assume that generalization will not occur without some form of programming. Such a position is certainly relevant to martial arts training. Although it is desirable for students to acquire and be able to demonstrate technical proficiency in a training situation, systematic programming is typically needed to extend these technical skills across other conditions. The current investigation offers some preliminary evidence that such programming can be used to enhance response variability and stimulus generalization. Future investigations will be needed to evaluate the critical variables that function to promote the generalization of diverse adaptive responding across behaviors, environmental stimuli, and time.

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STUDY QUESTIONS

1. Describe the student responses that were of interest to the investigators.
2. How were the student responses scored?
3. How was procedural integrity assessed, and why was it important to do so?
4. What contingencies were in effect for varied and invariant responding during baseline and treatment?
5. Summarize the results obtained in the study.
6. How might the experimental situation have influenced relative rates of the two target responses, and what effect might this have on the data?
7. How would one empirically determine the extent to which extinction was an important component of the intervention?
8. What feature of the presession procedures may have enhanced the effects of the consequence-based intervention (DRA plus extinction) on response generalization?

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