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MULTIPLE SCHEDULES IN PRACTICAL APPLICATION: RESEARCH TRENDS AND IMPLICATIONS FOR FUTURE INVESTIGATION

Valdeep Saini, **Scott A. Miller**, and **Wayne W. Fisher**

THE UNIVERSITY OF NEBRASKA MEDICAL CENTER'S MUNROE-MEYER INSTITUTE

Abstract

Researchers began studying multiple schedules in basic laboratories, but recent advances have extended research on multiple schedules to a wide variety of socially significant applications, especially during the last decade. Applied researchers have used multiple schedules (a) to promote stimulus control over high-rate appropriate behaviors, (b) to thin the schedule of reinforcement following functional communication training, and (c) to obtain stimulus control over problem behaviors maintained by automatic reinforcement. In the current paper, we reviewed 31 studies with 147 applications identified through a search of the applied literature on multiple schedules. Using these studies, we (a) reviewed the empirical literature on multiple schedules, (b) recommended multiple-schedule procedures that serve as best practice guidelines for applied behavior analysts, (c) identified the generality and boundaries of current knowledge about the effectiveness of multiple schedules, and (d) critically analyzed the literature to provide directions for future multiple-schedule research.

Keywords

discrimination training; multiple schedules; reinforcement-schedule thinning; reviews; stimulus control

A multiple schedule is a compound schedule in which two or more component schedules of reinforcement, extinction (EXT), or punishment alternate based on the passage of time; each component is correlated with a unique stimulus (e.g., a fixed-ratio [FR] 1 schedule correlated with a green stimulus alternated with an EXT schedule correlated with a red stimulus; Barlow, Nock, & Hersen, 2009; Ferster & Skinner, 1957). Historically, researchers have used multiple schedules to study basic behavioral phenomena, such as stimulus control (e.g., Buzzard & Hake, 1984; Herrick, Myers, & Korotkin, 1959), response persistence (e.g., Nevin, 1974, 1992; Nevin, Tota, Torquato, & Shull, 1990), and response variability (e.g., Denney & Neuringer, 1998; Tatham, Wanchisen, & Hineline, 1993).

Multiple schedules are a highly effective arrangement for demonstrating the development of stimulus control (i.e., when each stimulus [and associated contingency] change in a multiple

Address correspondence to Valdeep Saini (; Email: valdeep.saini@unmc.edu) or Wayne Fisher (; Email: wfisher@unmc.edu), Munroe-Meyer Institute, University of Nebraska Medical Center, 985450 Nebraska Medical Center, Omaha, Nebraska 68198

schedule produces an immediate, reliable, and clear change in responding). In a multiple schedule in which an FR 1 reinforcement schedule is correlated with a green stimulus (S^D) and EXT is correlated with a red stimulus (S^Δ), each change from the red to the green stimulus should produce a rapid and reliable increase in responding, and each change from the green to the red stimulus should produce a rapid and reliable decrease in responding after stimulus control has been established. *Stimulus control* in this sense refers to a change in behavior following the initial presentation of the antecedent stimulus change. If the probability of a response immediately increases with the introduction of the S^D and immediately decreases with the introduction of the S^Δ, this change can be more readily attributed to stimulus control rather than to the associated contingency because the change (in the probability of the response) occurred before the response contacted the contingency (or the absence of a contingency in the case of EXT). In contrast, *contingency control* in a multiple schedule refers to a change in target responding only when the response contacts the scheduled contingency in each component of the multiple schedule. By comparison, the change from FR 1 to EXT without correlated stimuli (i.e., a mixed schedule) would not produce an immediate shift in responding, thus demonstrating the influence of the programmed stimuli in controlling the occurrence of behavior.

Although multiple schedules have been commonly used in basic research since the 1950s, they rarely appeared in applied literature until the turn of the 21st century. Since that time, there has been a large increase in their use to gain stimulus control over behavior that is considered socially desirable in some contexts and undesirable in other contexts. That is, in addition to arranging periods in which reinforcement for a target behavior is available and unavailable (i.e., EXT), researchers have associated these periods with a variety of salient environmental stimuli to promote stimulus control. In particular, multiple schedules have been used (a) to promote stimulus control over high-rate appropriate behaviors (e.g., frequent requests for adult attention) in typically developing children (Cammilleri, Tiger, & Hanley, 2008; Tiger & Hanley, 2004, 2005; Vargo, Heal, Epperley, & Kooistra, 2014), (b) to teach individuals with intellectual disabilities who engage in severe problem behavior to request the putative reinforcer maintaining problem behavior only when the S^D is present and to gradually tolerate longer periods in which the S^D is absent (Betz, Fisher, Roane, Mintz, & Owen, 2013; Fisher, Kuhn, & Thompson, 1998; Hagopian, Toole, Long, Bowman, & Lieving, 2004; Hagopian, Contrucci Kuhn, Long, & Rush, 2005; Hanley, Iwata, & Thompson, 2001; Rooker, Jessel, Kurtz, & Hagopian, 2013), and (c) to signal periods of punishment in the treatment of severe problem behavior maintained by automatic reinforcement displayed by individuals with intellectual disabilities (Anderson, Doughty, Doughty, Williams, & Saunders, 2010; Doughty, Anderson, Doughty, Williams, & Saunders, 2007; Rollings & Baumeister, 1981).

The extension of multiple schedules from basic behavioral research to areas of social importance may be an indication of a maturing science as stimulus-control procedures become refined and increasingly sophisticated for more socially relevant target behaviors. However, the manner in which these procedures have been translated from basic research to application has varied across studies (e.g., stimuli arranged during each component, strategies for promoting the development of stimulus control, the initial and terminal durations of components, and if and how those component durations are faded). Moreover,

no studies have examined the potential side effects of including EXT components in a multiple-schedule arrangement in which the target response is exposed to periods of nonreinforcement. Exposure to EXT can sometimes lead to a temporary increase in the frequency, duration, intensity, or magnitude of the target response (Lerman & Iwata, 1995), and it remains unknown whether EXT-induced side effects are more or less common in a multiple-schedule arrangement than when EXT is implemented in isolation without a schedule-correlated stimulus.

In addition, resurgence is a phenomenon that involves the reemergence of a response (e.g., problem behavior) that had been previously reduced through the delivery of alternative reinforcement (e.g., functional communication training; FCT) when the alternative reinforcement is discontinued (i.e., EXT) or rapidly thinned (Epstein, 1983, 1985; Lieving, Hagopian, Long, & O'Connor, 2004; Lieving & Lattal, 2003; Pritchard, Hoerger, Mace, Penney, & Harris, 2014; Volkert, Lerman, Call, & Trosclair-Lasserre, 2009; Wacker et al., 2011, 2013). In clinical settings, resurgence can result in treatment relapse in which problem behavior reemerges when an alternative, appropriate response (e.g., functional communication response; FCR) is exposed to periods of EXT (Pritchard, Hoerger, & Mace, 2014; Volkert et al., 2009; Wacker et al., 2011, 2013). Resurgence is primarily a function of the contingency between the discriminative stimulus and the reinforcing consequence (stimulus–stimulus pairings; Nevin & Grace, 2000). Therefore, signaling periods of EXT in the context of a multiple schedule may have the potential to mitigate resurgence of problem behavior, because reinforcement is never delivered in the presence of the S^{Δ}, thereby precluding any stimulus–stimulus pairings (see Betz et al., 2013, for results consistent with this hypothesis).

Given these variations and limitations, a comprehensive review of the application of multiple schedules was warranted. We conducted a review of the applied literature on multiple schedules that focused specifically on obtaining stimulus control over practically relevant target responses in typically developing children and individuals with intellectual and developmental disabilities (e.g., high-rate requesting, severe problem behavior, and FCRs). This review attempts to address the diverse literature base of multiple schedules in practical applications and discusses considerations and strategies for implementing multiple schedules. The purpose of this review is (a) to provide a coherent summary of existing literature, (b) to recommend best practices that may be useful for behavior analysts, (c) to identify the generality and boundaries of knowledge about the effectiveness of multiple schedules, and (d) to critically analyze the literature as a guide for identifying areas of future multiple-schedule research.

METHOD

Article Identification

We identified empirical investigations of multiple-schedule studies through a search of *PsycINFO*, *ERIC*, *PubMed*, *Medline*, *EBSCOHost*, and the *Journal of Applied Behavior Analysis* using the key words *multiple schedule*, *mixed schedule*, *schedule thinning*, *reinforcement thinning*, *functional communication training*, *multiple-schedule training*, and *multiple-schedule teaching* between 1957 and 2014. Furthermore, we examined the

reference section of each obtained article to identify additional studies that were not identified during the initial search.

Inclusion and Exclusion Criteria

We included studies that met all of the following criteria: (a) The study enrolled human participants; (b) it addressed a socially important behavior (e.g., communication, problem behavior) as opposed to simple operant responses (e.g., card touching or button pressing); (c) it used direct observations of the primary dependent variable collected in vivo or video recorded for subsequent scoring under naturalistic or analogue conditions; (d) it used single-case research designs; (e) it included one or more compound schedules that met Ferster and Skinner's (1957) definition of a multiple schedule; and (f) it used a multiple schedule as an intervention rather than as an assessment (thereby excluding all studies that used multiple-schedule or multielement designs, such as those used during a functional analysis; Hanley, Iwata, & McCord, 2003). We excluded studies that failed to meet one or more of the above criteria. It should be noted that the application of multiple schedules has been extended to other socially important problems beyond what met the inclusion criteria and what is presented in the current review (e.g., Cividini-Motta & Ahearn, 2013; Hantula & Crowell, 1994; Lanovaz, Fletcher, & Rapp, 2009; Parry-Cruwys et al., 2011; Pastrana, Rapp, & Frewing, 2013; Simmons, Smith, & Kliethermes, 2003; Smaby, MacDonald, Ahearn, & Dube, 2007).

Two independent raters examined each study that was obtained using the initial search criteria to determine whether each study met the inclusion or exclusion criteria. We calculated interrater agreement by dividing the number of agreements by the number of agreements plus disagreements and converting the resulting proportion to a percentage. The raters reviewed a total of 5,110 studies and agreed that 31 (0.6%) should be included and 5,078 (99.4%) should be excluded. Raters agreed on 100% of studies for inclusion and exclusion.

Data Collection

We collected data on individual applications of multiple schedules within and across studies. We defined an *application* as the use of a multiple schedule for one target response in one setting. Therefore, if a study used a multiple schedule for one participant's target behavior across two settings, we considered and analyzed this as two applications (e.g., Álvarez, Call, & Lomas Mevers, 2014, first applied a multiple schedule in a padded therapy room and then in a treatment facility that served as the generalization context). We also delineated applications by the function of each target response. For example, if a single target response (e.g., aggression) was maintained by access to adult attention and escape from academic instructions and a multiple schedule was used to address each function independently, we considered this to be two applications. We examined, quantified, and evaluated the applications along the following dimensions.

Participant and setting characteristics—We collected data on participants' ages and diagnoses as well as the settings in which the multiple-schedule evaluations were conducted. We grouped participants as young children (birth to 3 years old), children (4 years old to 12

years old), adolescents (13 years old to 18 years old), or adults (19 years old and older). We categorized settings as either clinical (e.g., conducted in therapy or session rooms at a clinic or university-based setting) or typical (e.g., naturally occurring conditions such as in the participant's home or in their regular classroom environment).

Response topography—We collected data on the topography of behaviors evaluated. For many applications, although the primary concern was problem behavior such as self-injurious behavior (SIB) or aggression, the dependent variable that was evaluated using a multiple schedule was an FCR or other appropriate behavior (e.g., requesting teacher attention). Therefore, we categorized response topographies as FCR (i.e., an alternative communicative response taught during FCT; e.g., Fisher et al., 1998; Hanley et al., 2001), socially appropriate behavior (i.e., an existing appropriate response that occurred at high rates or at inappropriate times; e.g., Tiger & Hanley, 2004, 2005), or problem behavior if the investigators included a specific problem behavior in the multiple-schedule evaluation (e.g., Anderson et al., 2010).

Response function—We collected data on the identified function of the target behavior reported for each application. We categorized response functions as social-positive reinforcement (e.g., access to adult attention, access to tangible items), social-negative reinforcement (e.g., escape from task demands), or automatic reinforcement (e.g., behaviors that persisted in the absence of social consequences).

Data were collected based on the results of a functional analysis reported by the authors of each study. If a functional analysis was not conducted, conclusions regarding the function of the target behavior were adopted from assumptions made by the authors of those studies (e.g., with typically developing children, teacher attention likely served as a reinforcer for high-rate requesting in classrooms; Tiger & Hanley, 2004). If a functional analysis was not conducted or the authors did not provide assumptions regarding function, this was scored as unidentified or not reported.

Component number—We collected data on the number of different components included in each multiple-schedule evaluation. A *component* was defined as a session or portion of a session during which a distinct stimulus was correlated with a specific reinforcement, EXT, or punishment schedule. Some applications reported the use of multiple-component multiple schedules, but two of the components were identical with respect to schedule of reinforcement and schedule-correlated stimulus (e.g., Component 1: EXT, Component 2: FR 1, Component 3: EXT). Therefore, we reported multiple-schedule arrangements as containing more than two components only if the multiple schedule had multiple distinct stimuli correlated with multiple distinct contingencies (e.g., FR 1 when the therapist wore a blue shirt, EXT when the therapist wore a green shirt, FR 1 punishment when the therapist wore a red shirt).

Component schedules—We collected data on the reinforcement, EXT, or punishment schedule that was associated with each component of the multiple schedules. We will express multiple schedules with each schedule component separated by a forward slash (e.g., mult FR 1/EXT).

Component durations—We collected data on the duration of each component of the multiple schedule. If an application reported several component durations (as typically occurs during schedule thinning), we collected data on the initial and terminal schedule. In some applications, participants experienced different initial and terminal component durations; therefore, in those cases we collected data on the range of initial and terminal component durations.

Schedule-correlated stimulus—We categorized schedule-correlated stimuli as (a) colored cards (including posters) or clothing (e.g., shirts and wristbands), (b) the presence or absence of activities or materials, (c) typical stimuli (e.g., caregiver turns away and is "busy" or the presence and absence of individuals), or (d) other stimuli that did not fall into any of these categories (e.g., illuminated lights; Rollings & Baumeister, 1981).

Effects of EXT—For several applications, EXT of the target behavior was implemented during one component of a multiple schedule. Data were collected on whether an EXT burst occurred based on visual inspection of the results using the criteria described by Lerman, Iwata, and Wallace (1999). An *EXT burst* was defined as an increase in responding in the EXT component of the multiple schedule during any of the first three treatment sessions above all of the last five sessions of the previous non-multiple-schedule phase (or all of the sessions of the previous non-multiple-schedule phase if there were fewer than five).

For applications in which a multiple schedule was implemented for an FCR, we collected data on resurgence of problem behavior during the EXT component. We used visual inspection to determine whether rates of problem behavior increased above stable treatment levels when the FCR was exposed to EXT. We defined *resurgence* as the occurrence of problem behavior at a rate that exceeded levels observed during the prior non-multiple-schedule phase in at least one of the following 10 sessions. This definition is similar to the one used by Volkert et al. (2009) to define resurgence following FCT.

Two independent raters examined 28.1% of the studies that met inclusion criteria. The raters created independent data tables using each characteristic item above (e.g., response function, response topography, etc.) for each article. Each rater evaluated a given study and independently scored each item (e.g., each rater input the setting for a given article independent of the other rater's evaluation). After these independent evaluations of each article, item-by-item agreement was assessed by comparing data tables generated for each study by the two raters. We calculated interrater agreement by dividing the number of agreements by the number of agreements plus disagreements and converting the resulting proportion to a percentage for each study, resulting in a mean interrater agreement of 99.6% (range, 95% to 100%) across studies.

RESULTS

We identified 147 applications of multiple schedules in 31 empirical studies. Figure 1 shows a general increasing trend of published studies in applied behavior analysis that have included at least one application of a multiple schedule as an intervention. These results suggest that the use of multiple schedules is becoming more prevalent in clinical assessment

and treatment studies. The last 5 years alone have produced more studies using multiple schedules than the previous decade (14 studies between 2010 and 2014; 13 studies between 2000 and 2009). It is reasonable to expect that this trend will continue and that the use of multiple schedules applied to problems of social importance will become more commonplace both in applied laboratories and in routine clinical practice.

Multiple schedules have been applied with young children (2.7%), children (83.6%), adolescents (4.7%), and adults (8.8%). About half of these applications were with individuals with intellectual and developmental disabilities (52.3%) and half with individuals of typical development (47.6%); these studies have taken place in both clinical (56.4%) and typical (43.5%) settings.

Multiple schedules have been shown to be an effective treatment component for high-rate appropriate social behaviors (55.1%; Grow, LeBlanc, & Carr, 2010; Sidener, Shabani, Carr, & Roland, 2006; Tiger & Hanley, 2004, 2005; Tiger, Hanley, & Heal, 2006; Tiger, Hanley, & Larsen, 2008) and a variety of problem behaviors (44.9%) including perseverative speech (Fisher, Rodriguez, & Owen, 2013), aggression (Zanolli, Daggett, Ortiz, & Mullins, 1999), SIB (Hagopian et al., 2004), disruptive behavior (Rooker et al., 2013), and stereotypy (McGonigle, Rojahn, Dixon, & Strain, 1987; Rollings & Baumeister, 1981).

Applications across Response Function

Multiple schedules have been combined with treatment interventions (e.g., FCT) to treat problem behavior maintained by access to adult attention (Fisher et al., 1998; Rooker et al., 2013), access to tangible items (Betz et al., 2013; Hagopian et al., 2005), access to edible items (Jarmolowicz, DeLeon, & Contrucci Kuhn, 2009), interruption of ritualistic behavior (Rispoli, Camargo, Machalicek, Lang, & Sigafoos, 2014), escape from academic instruction (Álvarez et al., 2014), and problem behavior maintained by automatic reinforcement (Anderson et al., 2010; Doughty et al., 2007).

Most investigators have used multiple schedules primarily when the target behavior was maintained by social-positive reinforcement (87.0%) rather than social-negative reinforcement (5.4%) and automatic reinforcement (4.7%). This is somewhat surprising given the higher prevalence of problem behavior maintained by social-negative reinforcement reported in the functional analysis literature (Beavers, Iwata, & Lerman, 2013).

In a review of schedule-thinning procedures following FCT, Hagopian, Boelter, and Jarmolowicz (2011) suggested that multiple schedules may be limited in their effectiveness for use in cases of social-negative reinforcement and that chained schedules may be a better alternative (Berg, Wacker, Harding, Ganzer, & Barretto, 2007; Day, Horner, & O'Neill, 1994; Fisher et al., 1993; Hagopian, Fisher, Sullivan, Acquisto, & LeBlanc, 1998; Lalli, Casey, & Kates, 1995; Mildon, Moore, & Dixon, 2004; Peck Peterson et al., 2005; Perry & Fisher, 2001). For example, Fisher et al. (1993) taught an individual with an intellectual disability to comply with a gradually increasing number of tasks before the FCR produced escape. This type of chained schedule, sometimes referred to as *demand fading*, has been an

effective procedure for maintaining compliance with academic tasks, maintaining low rates of problem behavior, and providing breaks contingent on appropriate behavior.

CONSIDERATIONS IN ARRANGING MULTIPLE SCHEDULES

Establishing the Target Response

Multiple schedules, as treated by the research in this review, have focused on obtaining stimulus control over the occurrence and nonoccurrence of a target response. In some cases, that response existed before participants' inclusion in the study (e.g., bids for social attention, Tiger & Hanley, 2004); however, in many studies that response was established as part of the individual's study participation. For instance, Hanley et al. (2001) taught novel requests (via FCT) before they arranged the availability of reinforcement for those requests into a multiple schedule. It is important to acknowledge that no study that established the target response during the experiment did so in the context of a multiple schedule. That is, each study that taught a novel target response did so in the context of a consistent, predictable FR 1 schedule and subsequently exposed that response to alternating schedules of reinforcement during the multiple schedule. Presumably, the novel target response would not be acquired, or at least would be acquired more slowly, if exposed to periodic EXT conditions. We highlight this simply to state that multiple schedules are most appropriate when the target response is already firmly established in the repertoire (e.g., request for teacher attention) or after the response exists at a certain level of strength (e.g., high rate).

Including Discriminative Stimuli

Several studies have examined the necessity of schedule-correlated stimuli in the effectiveness of multiple schedules by directly comparing multiple schedules to mixed schedules of reinforcement. Mixed schedules represent an ideal control condition for testing the effects of schedule-correlated stimuli because they are identical to multiple schedules except that schedule-correlated stimuli are absent.

Hanley et al. (2001) compared mixed and multiple schedules with two participants, each with an intellectual disability, who displayed severe SIB (Jake and Julie) and aggression (Julie only) and whose exposure to FCT resulted in low levels of problem behavior and elevated levels of an FCR. Problem behavior remained low during both the mixed and multiple schedules for both participants. However, Jake showed highly discriminated FCRs in the multiple schedule but not in the mixed schedule, with FCRs occurring almost exclusively in the reinforcement component of the multiple schedule by the end of the analysis. Julie showed a similar response pattern.

Betz et al. (2013) compared mixed and multiples schedules and delivered contingency-specifying rules before each mixed- and multiple-schedule session. Results indicated that the multiple schedule combined with contingency-specifying rules produced highly discriminated responding (with FCRs occurring almost exclusively in the reinforcement component), whereas the mixed schedule combined with contingency-specifying rules did not.

Finally, Jarmolowicz et al. (2009) compared the effectiveness of mixed schedules with three variations of multiple schedules: (a) when the reinforcement component only was signaled by a specific schedule-correlated stimulus, (b) when the EXT component only was signaled by a specific schedule-correlated stimulus, or (c) when both the reinforcement and EXT components were signaled by different, specific, schedule-correlated stimuli. The results of this study suggested that signaled components were always more effective than mixed schedules; however, signaling both reinforcement and EXT did not produce significantly better effects than signaling reinforcement only.

Thus, results of several studies that have evaluated the necessity of schedule-correlated stimuli have concluded that (a) multiple schedules result in better stimulus control over behavior than mixed schedules (Betz et al., 2013; Tiger & Hanley, 2004); (b) the effectiveness of multiple schedules may not be substantially reduced by signaling only periods of reinforcement (Jarmolowicz et al., 2009; Tiger et al., 2006); (c) the effectiveness of multiple schedules may not be substantially reduced by signaling only periods of EXT (Grow et al., 2010; Rispoli et al., 2014); however, (d) during initial implementation of the multiple schedule, signaling periods of reinforcement may be important; and (e) during schedule thinning, it may become increasingly important to signal the EXT component (Jarmolowicz et al., 2009).

Selecting Discriminative Stimuli

When multiple schedules are programmed, schedule-correlated stimuli should be given special consideration, because these are the environmental variables that are assumed to acquire stimulus control over the target response. Table 1 describes the various multiple-schedule-component characteristics. The most common schedule-correlated stimuli reported in the existing literature is the use of arbitrary stimuli such as colored clothing or cards (72.1%). For example, Jarmolowicz et al. (2009) used a green card to signal periods of reinforcement and a red card to signal periods of EXT during schedule thinning with one girl with autism. The cards acquired discriminative control over an FCR in this study, and similar stimuli have been sufficient to produce stimulus control over target responding in both clinical and typical environments (Álvarez et al., 2014; Cammilleri et al., 2008; Fisher et al., 1998, 2013; Hagopian et al., 2004; Hagopian, Bruzek, Bowman, & Jennett, 2007; Heald, Allen, Villa, & Oliver, 2013; Luczynski & Hanley, 2014; Sidener et al., 2006; Tiger & Hanley, 2004, 2005; Vargo et al., 2014). Contrived stimuli such as colored cards offer the advantage that they are unlikely to have been associated with previous contingencies or idiosyncratic learning histories. In addition, contrived stimuli may have salient novel features that are readily discriminable in the typical environment. For example, Heald et al. (2013) used a brightly colored jacket to signal the availability of therapist attention and the absence of the jacket to signal the unavailability of attention with four children with Angelman syndrome. These types of stimuli might be useful because they are often significantly different and visually distinct from other, more typical stimuli that are present in the environment. Further, individuals may more easily see stimuli that are noticeably different from typical environmental stimuli from any visible location. For example, it is likely that the brightly colored jacket used by Heald et al. could be seen from any angle.

However, stimuli should also be selected based on their practicality for use in typical environments. Contrived stimuli (e.g., cards, wristbands, poster boards, and colored clothes) might need to be transported and continuously presented by the caregiver, whereas some stimuli may be impractical or cumbersome to present (e.g., large poster boards) or more likely to break (e.g., wristbands), resulting in a cost to families. Further, all of the potential downfalls with using contrived stimuli may potentially lead to decrements in treatment integrity.

Despite the effectiveness of contrived stimuli to acquire stimulus control over target responding in a multiple schedule, transfer of stimulus control to more common stimuli (items commonly found in the individual's typical environment) is warranted if the presentation of those stimuli are salient and discriminative control over the target response can be established relatively easily. To date, only a small proportion of studies have used such typical-environment stimuli (6.8%) such as using caregiver behavior to signal the availability or unavailability of reinforcement (Kuhn, Chirighin, & Zelenka, 2010; Leon, Hausman, Kahng, & Becraft, 2010).

The use of typical-environment stimuli may be an attractive alternative to schedule-correlated stimuli that are added to the environment by the behavior analyst, which may call undue attention to the individual and be perceived negatively by others. For example, Kuhn et al. (2010) taught one child with autism and one child with cerebral palsy to request attention based on whether their caregiver engaged in a busy (e.g., talking on the phone) or nonbusy (e.g., reading a magazine) activity. After teaching, both participants displayed the FCR primarily when caregivers engaged in nonbusy activities. Leon et al. (2010) and Fragale and O'Reilly (2011) extended these results by demonstrating that discriminative control can be maintained using typical-environment stimuli in novel settings and with novel therapists.

It may be adventitious for behavior analysts to teach individuals to refrain from emitting the target response when typically occurring stimuli signal that emitting the response would be socially inappropriate (e.g., two adults conversing serve as the S for requests for attention) and to engage in the response when it is socially appropriate to do so (e.g., two adults not conversing with each other serve as the S^D). One obvious advantage of this approach is that typical-environment stimuli are always present in the environment, whereas caregivers may lose or fail to present and switch contrived stimuli (e.g., colored cards, wristbands). In addition, it is possible that typical-environment stimuli may facilitate generalization in some cases, because the individual is frequently exposed to these stimuli across a variety of typical contexts (e.g., a caregiver who is busy cleaning a bathroom displays many similar behavioral characteristics to that same caregiver who is busy cleaning the bedroom or even cooking in the kitchen). However, because of the few applications of multiple schedules with typical-environment stimuli, the extent to which these stimuli facilitate transfer and generalization of stimulus control remains unknown.

The use of typically occurring stimuli in a multiple schedule should be selected with some caution. Typical-environment stimuli are often associated with an uncontrolled history of correlated consequences for the individual's behavior. This may be undesirable because such

stimuli are likely to have stimulus control over other (and possibly problem) behavior. For example, Kuhn et al. (2010) programmed "talking on the phone" to signal the unavailability of reinforcement. In the typical environment, such stimuli may have historically functioned as discriminative or motivating stimuli that occasion or evoke problem behavior and thus compete with the early stages of the treatment process. In addition, typical-environment stimuli may, at times, be more subtle and more difficult to establish discriminative control with than those evaluated in the Kuhn et al. (2010) and Leon et al. (2010) studies (e.g., looking at a friend's Facebook page on a computer vs. completing one's taxes on the same computer). In these circumstances, it may be important to teach the individual a precursor response, such as asking the caregiver, "Are you busy?," which was done to good effect with one participant in the Kuhn et al. (2010) study. Further research in this area is clearly warranted.

A more practical alternative to physical stimuli (whether contrived or typical) involves briefly signaling the start of each component via a verbal statement made by the therapist or caregiver. For example, Tiger et al. (2008) found that briefly signaling both the S^D and S^Δ components with verbal statements ("It's your time," "It's my time") produced discriminative control over social-approach responses for three of four preschool-aged children at levels comparable to studies that used continuously present physical discriminative stimuli (e.g., Cammilleri et al., 2008). The fourth child showed highly discriminated social-approach responses only when continuously available physical stimuli were used to signal the two components of the multiple schedule. Additional research is needed to evaluate brief verbal versus continuous physical discriminative stimuli with other populations (e.g., those with developmental disabilities and severe problem behavior).

Strategies to Promote Discrimination

Some studies have demonstrated difficulty with establishing discriminated responding across multiple-schedule components. For example, one participant in Hanley et al. (2001) engaged in high rates of the FCR in the presence of both the S^D and S^Δ during initial multiple-schedule sessions. Jarmolowicz et al. (2009) observed a similar pattern of initially high rates of the FCR in the presence of the S^Δ with one participant. Further, Tiger and Hanley (2004) did not observe discriminated responding until contingency-specifying rules about requests for attention were introduced. These failures in discrimination may have been the result of (a) participants not attending to the relevant multiple-schedule stimuli, (b) attending to other non-multiple-schedule stimuli, or (c) the multiple-schedule stimuli were not sufficiently salient to engender discriminated responding. All of these factors may preclude the establishment of stimulus control over behavior.

Surprisingly, we identified few studies that explicitly attempted to remediate multiple-schedule discrimination failures when schedule-correlated stimuli showed limited discriminative control of the target response following initial discrimination-training procedures. That is, when multiple-schedule arrangements failed to produce clear discriminated responding, researchers have attempted alternative strategies (e.g., response restriction; Fisher, Greer, Querim, & DeRosa, 2014) or have added contingency-specifying

rules (e.g., Betz et al., 2013; Tiger & Hanley, 2004) as opposed to identifying and then addressing the operant mechanism responsible for limited stimulus control.

One method to determine whether the target response is under stimulus control or contingency control is by conducting within-session analyses using procedures similar to those described by Doughty et al. (2007), Tiger and Hanley (2004), and Vollmer, Iwata, Zarcone, Smith, and Mazaleski (1993b). A minute-by-minute analysis that examines when a target response occurs may reveal whether changes in responding reliably occur immediately after changes in the discriminative stimuli (from the S^D to the S^Δ and vice versa), which would be indicative of stimulus control. Alternatively, these within-session analyses may reveal that changes in responding are more closely correlated with reinforcer deliveries, which would be indicative of contingency control. Persistent responding in both the S^D and S^Δ components that does not reliably change with changes in either the discriminative stimuli or reinforcer deliveries may be due to stimulus–reinforcer pairings between other (nonprogrammed) stimuli in the training environment and reinforcer deliveries. Determining whether the target response is under stimulus control or contingency control via within-session analyses may engender methods to facilitate discriminated responding; however, this requires further research.

Although few studies have attempted to remediate multiple-schedule discrimination failures, several teaching strategies that might facilitate discriminated responding between schedule components are worth considering and evaluating in future research.

Maximizing contingency contrast and minimizing the number of schedule components—Researchers have primarily used a two-component FR 1/EXT multiple schedule when conducting discrimination training, which is the most common multiple-schedule arrangement reported in the literature (94.5%). This may be because contrasting contingencies (i.e., FR 1 and EXT) facilitate discriminative control more readily than component schedules in which reinforcement is similar across components (Long, 1962). It is possible that as the two (or more) components of a multiple schedule become increasingly similar, failures to discriminate across components also increase (Davison & Jenkins, 1985; McIlvane & Dube, 2003).

Furthermore, a two-component multiple schedule requires a simple successive discrimination (a positive stimulus that signals reinforcement is alternated with a negative stimulus that signals EXT; Spradlin & Simon, 2011), and adding additional components (especially those that share similar schedule requirements) might increase the complexity of the discrimination. This is likely why the use of multiple schedules with more than two components has been uncommon in the applied literature (2%). Although minimizing the number of schedule components and maximizing the contrast between components is a practical recommendation to facilitate discriminated responding, further research is warranted on whether two-component multiple schedules are advantageous in this respect.

Contingency-specifying rules—Some studies have shown that contingency-specifying rules facilitate discrimination between S^D and S^Δ components in children and adults with relatively proficient vocal-verbal repertoires (i.e., telling the individual that the target

response will produce reinforcement in the presence of the S^D but not in the presence of the S^Δ; Betz et al., 2013; Cammilleri et al., 2008; Grow et al., 2010). Vargo et al. (2014) examined the efficacy of a multiple schedule combined with contingency-specifying rules to decrease high-rate hand raising in kindergarten classrooms. The authors found that providing contingency-specifying rules before multiple-schedule teaching sessions facilitated discriminated responding between the S^D and S^Δ components in all three classrooms. In total, 46 children learned that the classroom teacher would provide attention for hand raising only in the presence of the S^D and not in the presence of the S^Δ. Moreover, the children displayed highly discriminated responding after just a few sessions in all classrooms, underscoring the strength of contingency-specifying rules to facilitate stimulus control over target responding in a multiple-schedule arrangement.

Response prompts—An additional strategy that has been used to facilitate discriminated responding in combination with contingency-specifying rules has been the use of response prompts. Tiger and Hanley (2004, 2005) combined rules with presession response prompts in the presence of each schedule-correlated stimulus in order to expose participants to the consequences associated with those rules. Similarly, Luczynski and Hanley (2014) combined response prompts and rules in the context of presession role-plays to evoke discriminated responding. Although combining response prompts with rules produced discriminated responding in both studies, it is unclear whether stimulus control was facilitated through prompts, rules, or the combined presession exposure. However, the use of prompts alone may be a viable strategy to promote discriminated responding during initial multiple-schedule teaching, especially with individuals who have limited communication skills or receptive language deficits. Future studies could investigate the degree to which response prompts alone facilitate discriminated responding when prompts are (a) used only to emit the target response in the presence of the S^D, (b) used only to expose the target response to EXT in the presence of the S^Δ, or (c) used during both components of the multiple schedule.

Alternatively, researchers might prompt alternative appropriate behavior during the S^Δ component (e.g., engaging with tangible items or completing work tasks) as a method to minimize EXT period responding. With two participants, Fisher et al. (1998) reinforced requests for toys during the S^Δ interval of a multiple schedule (called alternative communication) and ignored requests for the putative reinforcer that maintained problem behavior (i.e., functional communication). This method was effective at maintaining low levels of problem behavior and low levels of functional communication in the presence of the S^Δ. Although Fisher et al. did not explicitly prompt alternative communication, this response was taught before they introduced the multiple schedules in a manner similar to FCT. Conceivably, prompting and reinforcing alternative appropriate behavior in the presence of the S^Δ may also facilitate discriminated FCRs, although further research is warranted.

In contrast to response prompting, researchers might consider the effects of response blocking as a strategy to evoke discriminated responding during initial multiple-schedule teaching. Blocking the target response in the presence of the S^Δ may facilitate discriminated responding via an EXT or punishment mechanism (Lerman & Iwata, 1996b; Smith, Russo, & Le, 1999).

Response restriction—A common type of discrimination failure that occurs in the treatment of problem behavior following FCT is when schedule-correlated stimuli fail to produce discriminated FCRs (i.e., FCRs continue to occur during the EXT component of a multiple schedule; Fisher et al., 2014). Fisher et al. (2014) conducted a study with individuals for whom a multiple-schedule arrangement failed to produce discriminated responding across schedule components during schedule thinning and investigated a modified multiple-schedule procedure called *response restriction* (Fyffe, Kahng, Fittro, & Russell, 2004; Hagopian, et al., 2004; Roane, Fisher, Sgro, Falcomata, & Pabico, 2004).

During response restriction, the therapist eliminates the opportunity to engage in the FCR during the EXT component by removing response materials (Hagopian et al., 2011; Roane et al., 2004). For example, Fisher et al. (2014) first taught four children to engage in an FCR (touching a small laminated card) to request breaks from preacademic and academic instructions. Response restriction was introduced following a demonstration of failed discriminated card touching in a multiple-schedule arrangement (i.e., high, consistent rates of FCRs during the S^{Δ} component). To prevent further incorrect responding, the therapist removed the FCR card during the scheduled S^{Δ} period, thus preventing the child from engaging in the response. The FCR card was represented during the S^{D} condition.

Hagopian et al. (2011) enumerated several potential limitations of the response-restriction procedure. Response restriction does not allow the individual to experience periods of nonreinforcement for the FCR. Fisher et al. (2014) partially addressed this limitation by including an FCR card and a control card during the reinforcement component of the multiple schedule. Touching the FCR card produced reinforcement, and touching the control card produced no consequence (i.e., EXT). All of the participants showed clear discriminative responding by touching the FCR card almost exclusively.

It should be noted that the procedure used by Fisher et al. (2014) required a simultaneous discrimination, and a concurrent-operants arrangement is not indicative of discriminated responding in a successive multiple-schedule arrangement. Therefore, response restriction may not necessarily facilitate the development of stimulus control in a typical multiple schedule. Nonetheless, the procedure used by Fisher et al. was a practical modification that was effective at maintaining low rates of problem behavior when response materials were removed, while high, stable rates of FCRs were maintained in the S^{D} component.

Response restriction may be an alternative to a traditional multiple-schedule procedure; however, its use is currently limited to cases in which the FCR can be removed. For vocal FCRs (e.g., saying “Play with me” to access adult attention), response restriction would be impossible. One possible modification to response restriction would be to require that the individual emit the vocal response while simultaneously exchanging a corresponding picture card. If the vocal request selected as the FCR never produced reinforcement in the absence of the card exchange, excessive vocal requests during EXT might be less likely. However, the use of combining a card exchange with a vocal FCR has not been investigated. This possible modification of response restriction might be the focus of future research with children with competent vocal-verbal repertoires who display severe problem behavior and who frequently request reinforcement in the presence of the S^{Δ}.

Additional strategies that require further research—Strategies to facilitate discriminated responding that might be attempted in addition to those discussed include (a) increasing the saliency of the differences between the S^D and S^Δ (e.g., using vibrant colored stimuli or enlarged stimuli), (b) introducing the S^Δ gradually and using systematic errorless training procedures (e.g., Terrace, 1963), (c) introducing a momentary differential reinforcement contingency (i.e., withholding contingency changes and presentation of schedule-correlated stimuli until a period of time elapses without the target response to prevent adventitious reinforcement at the end of the component interval; Barton, Brulle, & Repp, 1986), (d) requiring a specific differential observing response when schedule-correlated stimuli are presented (Koegel, Dunlap, Richman, & Dyer, 1981), and (e) using a blocking procedure similar to the one developed by Saunders and Spradlin (1990) for training conditional discriminations. Each of these procedures have been used to good effect in similar training contexts but have not been used with multiple-schedule procedures. Therefore, their usefulness for remediating limited stimulus control or discrimination failures in multiple schedules remains unknown and should be examined in future research.

Selecting Initial and Terminal Reinforcement Schedules and Schedule Fading

The most common strategy for implementing multiple schedules as a schedule-thinning procedure following FCT has been to arrange brief periods of EXT that alternate with longer periods of reinforcement and then gradually fading those schedules so that reinforcement is available for a brief time and EXT is progressively increased for longer durations. This type of schedule thinning occurred in 52 of the 147 (35.4%) multiple-schedule applications.

Hagopian et al. (2004) compared the efficacy of a gradual fading procedure to one that presented the multiple schedule at its terminal delay value (1 min of reinforcement and 9 min of EXT; termed a *fixed-lean procedure*). Their results showed that discriminated responding was achieved more quickly during the fixed-lean procedure, but that levels of problem behavior were significantly higher during the initial stages of exposure. Thus, the gradual fading procedure may be more desirable to minimize the occurrence of problem behavior when a multiple schedule is first introduced.

Selecting initial reinforcement schedules—Studies that have used multiple schedules during schedule thinning have often used long reinforcement components and short EXT components during the initial schedule (Hanley et al., 2001; Jarmolowicz et al., 2009; Neidert, Iwata, & Dozier, 2005; Rispoli et al., 2014; Rooker et al., 2013; Sidener et al., 2006). However, selecting the ratio of the initial schedule has varied widely across studies; the ratio has ranged from 10 min of reinforcement and 0 min of EXT (Hagopian et al., 2004) to some equal ratio between reinforcement and EXT components (e.g., 30 s of reinforcement alternating with 30 s of EXT or 1 min of reinforcement alternating with 1 min of EXT; Fisher et al. 1998).

It is possible that initially long reinforcement components alternated with initially shorter EXT components has been adopted to minimize exposure to the establishing operation for the putative reinforcer. Longer exposures to the establishing operation during the S^Δ component when multiple-schedule training commences could potentially evoke problem

behavior (cf. DeRosa, Fisher, & Steege, 2015) or produce resurgence of problem behavior (similar to Volkert et al., 2009). Further, initially short durations of the S^{Δ} component may also minimize the number of incorrect FCRs (i.e., FCRs that occur when reinforcement is unavailable). Therefore, this method might mimic an errorless learning procedure in which opportunities to engage in erroneous responding are minimized (Jones & Eayrs, 1992; Terrace, 1963).

Despite initially long reinforcement components being a general finding in our review of the literature, no studies described or identified how the durations of the initial components were determined. That is, it is unclear whether initial schedules were selected arbitrarily, were based on the intensity, topography, or function of problem behavior, were based on rates of problem behavior during baseline, or were based on the relative rates of the FCR and problem behavior during FCT. Therefore, further research is warranted on the optimal method for determining initial multiple-schedule component durations.

Selecting terminal reinforcement schedules—Hanley et al. (2001) extended the applied research on multiple schedules by introducing progressive schedule thinning, which began with a rich schedule of reinforcer deliveries (i.e., FR 1 for 45 s alternated with EXT for 15 s) and ended with a lean schedule of reinforcer deliveries (i.e., FR 1 for 1 min alternated with EXT for 4 min). This terminal schedule was considerably more practical than those used by Fisher et al. (1998) because it decreased reinforcer deliveries by about 80% and gave caregivers periods of 4 to 8 min in which they could attend to other matters (e.g., two consecutive 4-min S^{Δ} periods could provide a parent with 8 min of uninterrupted time). The terminal schedule used by Hanley et al. was achieved in 31 of the 52 (59.6%) applications of schedule thinning. Although Hanley et al. did not describe the criteria used to establish the terminal reinforcement schedule, reinforcement availability was decreased from continuous reinforcement to one fifth of the time.

The criterion established by Hanley et al. (2001) represents a reasonable endpoint for schedule thinning; however, terminal schedules have varied greatly across studies and may be dependent partly on each individual's specific needs. In the reviewed studies, the ratio of the terminal schedule ranged from 90 s of reinforcement alternating with 30 s of EXT (Rooker et al., 2013) to 1 min of reinforcement alternating with 9 min of EXT (Hagopian et al., 2005).

Ultimately, terminal schedules should be based on each individual's final treatment goals, which should be developed with input from relevant stakeholders (e.g., parents, school personnel) and based on what is practical in the individual's typical environment (Stromer, McComas, & Rehfeldt, 2000). For example, if a child is expected to complete academic tasks for 15 min at a time, it may be practical to design a multiple schedule in which the terminal schedule consists of EXT (or work) periods as long as 15 min. However, it is also important to consider individual differences, because it may be difficult for some preschool-aged children to wait 15 min for caregiver attention. Perhaps more important, the terminal schedule should maintain low to zero levels of problem behavior while it maintains a strong contingency between the FCR and reinforcement in the presence of the S^{D}.

Types of schedule fading—Researchers have thinned the schedule in multiple schedules using either progressive fading (i.e., with multiple fading steps) or abrupt fading (i.e., the transition from the initial to the terminal schedule is done in a single step). The most common method of progressive fading consists of thinning the schedule if problem behavior remains below a prespecified criterion for a certain number of sessions (Hagopian et al., 2005; Hanley et al., 2001; Jarmolowicz et al., 2009; Rooker et al., 2013). For example, Hagopian et al. (2004) moved to the next schedule-thinning step after problem behavior was maintained at levels that were at least 80% lower than baseline for two consecutive sessions.

The percentage reduction criterion should be determined based on practical exigencies of the individual case. For example, for a child who engages in severe aggression toward peers in a classroom setting, a 100% reduction is necessary because an 80% reduction would leave peers at risk for injury. However, in cases of more mild-intensity, high-frequency disruptive behavior, an 80% reduction may be reasonable. A major advantage of the percentage reduction method is that it continually takes into account levels of problem behavior on a session-by-session basis; the schedule is not thinned simply based on time exposed or number of sessions at each schedule requirement. For example, for three of four children in a trial-based multiple-schedule procedure, Heald et al. (2013) increased the ratio of nonreinforcement trials to reinforcement trials after every fifth session, regardless of levels of problem behavior or levels of requests for attention.

When progressive schedule thinning is used, behavior analysts should consider including a fallback criterion in which a denser, previously successful schedule is reinstated if problem behavior reemerges for several sessions or stimulus control over the FCR is weakened (Hagopian et al., 2011). For example, Hagopian et al. (2005) established a percentage reduction criterion and determined that schedule requirements would increase if problem behavior was less than 0.4 instances per minute for two consecutive sessions. However, if problem behavior was greater than 0.4 instances per minute for two consecutive sessions, the investigators reimplemented the previously successful step. A fallback criterion might be helpful during schedule thinning because it ensures that FCRs are exposed to a given schedule of reinforcement for a duration long enough to prevent the reemergence of problem behavior. Establishing a fallback criterion may also safeguard against progressing too quickly through schedule thinning, which may lead to deleterious outcomes if problem behaviors reemerge.

Betz et al. (2013) investigated whether progressive fading was a necessary component of schedule thinning. They found that gradual fading from the initial schedule (1 min of reinforcement alternating with 1 min of EXT) to the terminal schedule (1 min of reinforcement alternating with 4 min of EXT) would not be necessary if participants received extended exposure to the initial schedule and the multiple schedule included contingency-specifying rules to facilitate discriminated responding. Furthermore, participants displayed highly discriminated FCRs and low levels of problem behavior when the terminal schedule was abruptly introduced. However, these results should be interpreted cautiously. The authors noted that they conducted several sessions at the initial schedule and observed low rates of problem behavior and high, stable rates of FCRs before they introduced the terminal schedule. The success of abruptly moving to the terminal schedule

may be compromised when FCRs are not fully under control of the schedule-correlated stimuli and may lead to increases in problem behavior (e.g., Hanley et al., 2001).

Effects of Extinction

In the reviewed literature, 95.9% of all applications of multiple schedules included at least one EXT component. Emotional responding, variability in behavior, and increases in problem behavior at or above baseline levels are sometimes observed when a target behavior is initially exposed to EXT (Kelly & Hake, 1970; Lerman & Iwata, 1995, 1996a; Morgan & Lee, 1996). Extinction-induced side effects may become more probable when EXT is implemented without alternative sources of reinforcement (Vollmer et al., 1998), as is often done in one component of a multiple schedule.

Extinction burst—Extinction bursts may occur during multiple-schedule arrangements and may be indicative that stimulus control has not been fully established. That is, the target behavior may still be at least partially under contingency control, resulting in continued responding in the EXT component. Extinction bursts could potentially occur when multiple schedules are used to target FCRs, problem behavior, or socially appropriate responses that occur at unacceptably high levels. Therefore, we analyzed the data from all applications for which the data were depicted in a figure with a line graph (n = 111), thereby allowing us to evaluate whether an extinction burst occurred. As previously described, a burst was scored if an increase in responding in the EXT component of the multiple schedule was observed during any of the first three treatment sessions above all of the last five sessions of the previous non-multiple-schedule phase (or all of the sessions of the previous non-multiple-schedule phase if there were fewer than five). In these applications, 11.7% reported or demonstrated bursting. This represents a lesser prevalence of bursting than was reported by Lerman and Iwata (1995), who found bursting in 36% of 113 cases of problem behavior when EXT was implemented alone. This suggests that EXT components can be effectively programmed into multiple schedules and may not increase the likelihood of bursts. However, future research is warranted with respect to potential behavioral contrast effects that may produce increases (or decreases) in target responding during the EXT component (Reynolds, 1961).

Response resurgence—In clinical settings, resurgence may result in a form of treatment relapse in which a destructive response that was previously reduced by the delivery of alternative reinforcement (e.g., FCT) reemerges after introduction of a disrupter (e.g., discontinuation of reinforcement for the FCR; Pritchard et al., 2014). Resurgence may also occur when the duration of the EXT component is increased during reinforcement-schedule thinning. For example, in the case of Participant Matt (FCT EXT-only condition) reported by Hagopian et al. (2005), resurgence of aggression was not observed when the FCR was exposed to 3 min of EXT; however, resurgence did occur when the EXT component was increased to durations of 7 min or greater.

We identified 24 applications of FCT in which the researchers used multiple schedules to signal periods of reinforcement and EXT for the FCR following FCT and for which the researchers displayed the results in graphical form that allowed us to evaluate whether

resurgence occurred. In 13 of these applications (54.2%), we observed resurgence of problem behavior at some point during the multiple schedule.

We examined the data sets for these 24 applications of multiple schedules with FCT in an attempt to identify variables that might contribute to resurgence. First, we examined whether resurgence was related to the initial duration of the EXT component when the investigators initiated the multiple schedule. For seven of the applications, the investigators began with an EXT interval that exceeded 2 min, and in each of these applications we observed resurgence of problem behavior. By contrast, when investigators initiated the multiple schedule with an EXT interval of 2 min or less, we observed resurgence less often (6 of 17 applications; 35.3%), representing a statistically significant difference ($Z = 3.58$; $p < .001$).

We also examined whether resurgence occurred more often during schedule thinning when the EXT interval of the multiple schedule reached a certain duration. We identified 12 applications of schedule thinning for which the researchers displayed the results in graphical form that allowed us to evaluate whether and when resurgence occurred. We observed resurgence in only three of those applications (25%), which occurred when the EXT component reached 1 min, 1.5 min, or 2 min. In each case, resurgence was transitory and typically lasted for just one session. Taken together, these results suggest that behavior analysts should initiate schedule thinning with multiple schedules that start with a brief EXT interval (e.g., 1 min or less).

Failures to suppress problem behavior—Researchers should consider investigating strategies to reduce the likelihood of resurgence that may occur in the EXT component of a multiple schedule during schedule thinning as well as strategies to suppress low levels of problem behavior that continue to occur in the EXT component. One strategy is to provide alternative noncontingent reinforcement or access to alternative activities in the EXT component (Fragale & O'Reilly, 2011; Hagopian et al., 2005; Kuhn et al., 2010). For instance, Hagopian et al. (2005) found that including competing items (i.e., stimuli that produce reinforcement that competes with the reinforcer that maintains problem behavior; Piazza et al., 1998; Shore, Iwata, DeLeon, Kahng, & Smith, 1997) in periods of nonreinforcement during schedule thinning resulted in more rapid reductions in problem behavior and may have prevented resurgence. This was true both when Hagopian et al. implemented delayed-reinforcement schedules (Participants Steven and James) and when they implemented schedule thinning using a multiple schedule (Participant Matt). The investigators gave participants access to the competing stimuli throughout each session (e.g., in both the reinforcement and EXT components conducted with Matt). It is possible that including competing items only during the EXT component of a multiple schedule will produce comparable effects.

If noncontingent access to alternative stimuli fails to suppress problem behavior and all other reinforcement procedures have been exhausted, practitioners might consider implementing punishment in both multiple-schedule components. For example, with two boys who engaged in severe SIB, aggression, and disruptive behavior that were occasioned by interruption of free-operant behavior (i.e., given an instruction that was incompatible with an ongoing activity), Hagopian et al. (2007) arranged a multiple schedule with FR 1

reinforcement for an FCR in one component, EXT of the FCR in the other component, and FR 1 punishment in both components (30-s hands-down procedure for Perry and 1-min exclusionary time-out for Maxwell). An advantage of implementing punishment in both components is that the child is not required to learn an additional successive discrimination for the contingencies for problem behavior. That is, the multiple schedule is in effect only for FCRs while problem behavior in both components contacts punishment, potentially reducing the likelihood of resurgence when the FCR contacts EXT in the S^{Δ} component. It should be noted that in all applications of multiple schedules in which an FCR was exposed to EXT, a punishment component was added in only 3.8% of them, suggesting the necessity of punishment might be restricted to exceptionally difficult cases. In all applications in which investigators implemented punishment, it was either faded completely or moved to a less intrusive form (e.g., a card that signaled the loss of preferred activities; Hagopian et al.).

Considerations When Implementing Multiple Schedules in the Typical Environment

Perhaps the greatest utility of multiple schedules comes from the ability of schedule-correlated stimuli to maintain stimulus control over clinically significant target behaviors when behavioral interventions are implemented in the individual's typical environment. In this review of the literature, 43.5% of the applications were conducted in natural environments including classrooms (e.g., Vargo et al., 2014) and participants' homes (e.g., Sidener et al., 2006). Two additional considerations relevant to the implementation of multiple schedules in the typical environment are social validity and the possibility of treatment-integrity failures.

Social validity—Establishing social validity is a key feature of applied behavior analysis (Wolf, 1978); therefore, measures should be taken to ensure that individuals, as well as caregivers, find the use of multiple schedules in the natural environment acceptable, generalizable, and practical (Álvarez et al., 2014). Moreover, it may be valuable to establish preferences for multiple schedules over alternative schedules of reinforcement for long-term positive outcomes.

Tiger et al. (2006) evaluated preschoolers' preferences for different multiple-schedule arrangements of social approaches using a modified concurrent-chains arrangement (Hanley, Piazza, Fisher, Contrucci, & Maglieri, 1997). Participants selected between multiple-schedule arrangements that consisted of (a) a unique stimulus correlated with the reinforcement component and another unique stimulus correlated with the EXT component, (b) a stimulus associated only with the reinforcement component and no stimulus associated with the EXT component, and (c) no stimuli associated with either component (i.e., a mixed schedule). They found that three of seven children preferred the arrangement in which both components were signaled, and four of seven children preferred the arrangement that signaled only the reinforcement component. Based on the latter finding, the investigators suggested that some children might develop an aversion to schedule-correlated stimuli associated with EXT because responding is continually unreinforced. This may account for some children's preference for multiple schedules in which only the reinforcement component is signaled.

More recently, Luczynski and Hanley (2014) evaluated children's preferences for multiple schedules in comparison to yoked, time-based (noncontingent) schedules and to yoked, delayed-reinforcement schedules. They found that three of four children preferred multiple schedules to yoked, time-based schedules and two of two children preferred multiple schedules to yoked, delayed-reinforcement schedules. Taken together, results of these studies (Luczynski & Hanley, 2014; Tiger et al., 2006) support the social validity of multiple schedules by showing that typically developing children often prefer discriminative stimuli that signal when requests will produce reinforcement. In addition, the absence of signals for periods of EXT does not necessarily reduce preferences for, or effectiveness of, multiple schedules (Tiger et al., 2006).

Although typically developing children may prefer multiple schedules to alternative schedules, no studies to date have evaluated caregiver preferences. Establishing caregiver preference may be just as important as child preferences because caregivers often implement the multiple-schedule arrangement. One potential method of evaluating caregiver preferences is to demonstrate the multiple-schedule arrangement alongside other procedures (e.g., delayed-reinforcement schedules) and subsequently evaluate preference using procedures similar to Hanley, Piazza, Fisher, and Maglieri (2005).

Treatment integrity—Multiple schedules typically add to the complexity of function-based treatments like FCT; therefore, this complexity could potentially contribute to problems of treatment integrity in the typical environment. Side effects of EXT may be of concern in typical settings when problem behaviors or FCRs are abruptly exposed to relatively long periods of EXT. These side effects (e.g., bursting or resurgence of problem behavior) may be difficult for caregivers to tolerate, which may result in treatment-integrity errors (e.g., delivery of the functional reinforcer after problem behavior). However, without additional research on multiple schedules in typical environments with routine caregivers, the extent to which multiple schedules contribute to treatment-integrity errors remains unknown. Therefore, further research is needed to examine strengths and limitations of multiple schedules when they are implemented in the typical environment by caregivers over long periods of time.

It should be noted that integrity errors with multiple schedules should be considered relative to the alternatives (e.g., mixed schedules, contingency-specifying rules for verbally competent individuals, delay-to-reinforcement schedules, etc.). It may be that treatment interventions that involve schedules that require more frequent reinforcer deliveries might be implemented with less integrity (e.g., noncontingent reinforcement typically produces more reinforcer deliveries than do interventions such as differential reinforcement of other behavior; Britton, Carr, Kellum, Dozier, & Weil, 2000; Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993a). Further, it may be the case that certain schedules in the natural environment might be more likely to weaken the response–reinforcer contingency and result in resurgence of problem behavior (e.g., delay schedules; Fisher, Thompson, Hagopian, Bowman, & Krug, 2000). However, the effect of treatment complexity as it relates to multiple schedules remains uncertain, in that no studies published in the applied literature have directly manipulated treatment integrity in a multiple-schedule arrangement. Further, researchers have yet to compare the treatment complexity of multiple schedules and other

schedules of reinforcement or stimulus-control procedures, and additional research is warranted to address these gaps in the literature.

CONCLUSION

The utility of multiple schedules is evident across a variety of settings, response topographies, and clinical populations (including individuals with and without developmental disabilities). A review of the applied literature indicates that researchers are using multiple schedules with greater frequency, and multiple schedules have proven to be effective for establishing stimulus control over clinically meaningful target behaviors, including (a) high-rate socially appropriate behavior in classroom settings, (b) socially appropriate alternative responses taught to individuals with intellectual and developmental disabilities, and (c) problem behaviors maintained by automatic reinforcement.

Our review of the literature suggests that multiple schedules have increased the practicality of function-based treatments like FCT without significantly increasing negative side effects such as extinction bursts (although additional research is warranted to further reduce the risk of these side effects). This review also identified several areas in which additional research is clearly warranted (especially in determining methods to facilitate discriminated responding within a multiple schedule) and the strengths and limitations of these procedures when implemented in the typical environment by routine caregivers.

Although the recent literature on the use of multiple schedules in applied settings has been fruitful, further refinements of multiple-schedule methods are needed to enhance practicality, efficacy, and generality. These refinements may assist in understanding how factors such as reinforcement history, schedules of reinforcement, and behavioral contrast affect the desirable and untoward effects of multiple schedules. For instance, behavior that occurs during programmed multiple schedules may be susceptible to carryover effects in which manipulations in one condition affect behavior in the other (e.g., behavioral contrast). Nevin and Shettleworth (1966) reported transient behavioral contrast effects in two-component multiple schedules with pigeons when they programmed variable-interval schedules in each component. It is possible that such effects may have implications for applied contexts when multiple schedules deviate from the typical FR 1/EXT arrangement. Nevertheless, the current (and apparently growing) body of research on multiple schedules suggests that these procedures are often useful in applied settings and that research that evaluates the validity of these methods is likely to continue to expand for the foreseeable future.

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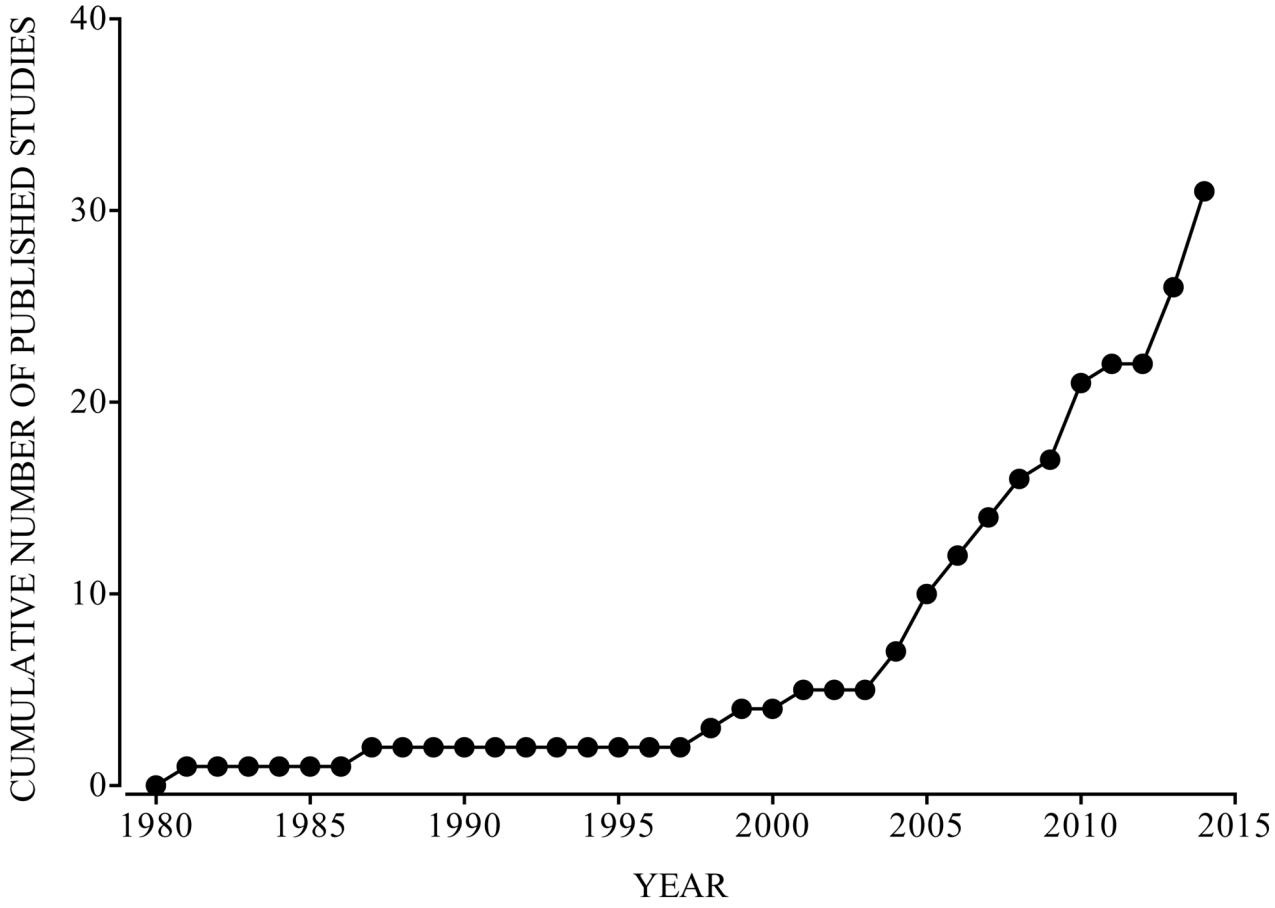

Figure 1.
The cumulative number of studies that have used at least one application of a multiple schedule between 1980 and 2014, based on the 31 studies included in the present review.

Table 1

Multiple-Schedule Component Characteristics

		Number of applications	Percentage of sample
Schedule-correlated stimuli	Colored cards or clothing	106	72.1
	Presence or absence of materials (e.g., activities)	22	14.9
	Typical-environment stimuli	10	6.8
	Other	5	3.4
	Not described	4	2.7
Component schedule	FR 1/EXT	139	94.5
	Other	8	5.4
Number of components	2	144	97.9
	3 or more	3	2.0