# On Terms

## On Distinguishing Progressively Increasing Response Requirements for Reinforcement

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Several different arrangements have been described for increasing the response requirements for reinforcement using the label *progressive-ratio schedule*. Under the original progressive-ratio schedule, the response requirement is increased after each reinforcer. Subsequently, arrangements have been used in which the number of required responses increases following multiple reinforcers at a single response requirement or between sessions. Following an assessment of the different types of contingencies that result from such progressive response requirements and the labels used to describe them, a set of descriptive labels is suggested for these different types of progressively increasing response requirements.

*Key words:* progressive-ratio schedules, terms, dissemination, taxonomy

Science attempts to achieve a balance between making useful distinctions among aspects of the subject matter and finding common ground where there is diversity. In the case of schedules of reinforcement, finding commonalities among different schedules has greatly advanced behavior analysis, but this advancement has not been achieved by ignoring important differences in the way behavior is controlled by the different scheduling arrangements. The purpose of this review is to consider the similarities and differences among different scheduling arrangements that all carry the label *progressive-ratio schedule* and to make suggestions concerning the descriptions of such arrangements.

The analysis of how progressive changes in requirements for reinforcement affect behavior has been a topic of interest in behavior-analytic research and application (e.g., the experimental analysis of behavior, behavioral pharmacology, and applied behavior analysis). These arrangements have been used, for example, in basic behavioral research to assess the relative efficacy of different reinforcer magnitudes (Hodos, 1961) and intensities (Hodos, 1965), in drug self-administration studies to examine the relative abuse liability of drugs (see Stafford, LeSage, & Glowa, 1998, for a review), and by applied behavior analysts to identify stimuli to be used as reinforcers in function-based treatments (e.g., Roane, Lerman, & Vorndran, 2001). These latter two applications have resulted in the development of other progressively increasing arrangements that deviate from the schedules originally investigated in basic research.

One result of all of this research has been to apply the label *progressive ratio* (PR) to a number of different procedures that have in common a response requirement for reinforcement that increases over time. A synthetic view is to consider all of these procedures, and indeed, perhaps all schedules involving ratio requirements, similarly (cf. Killen,
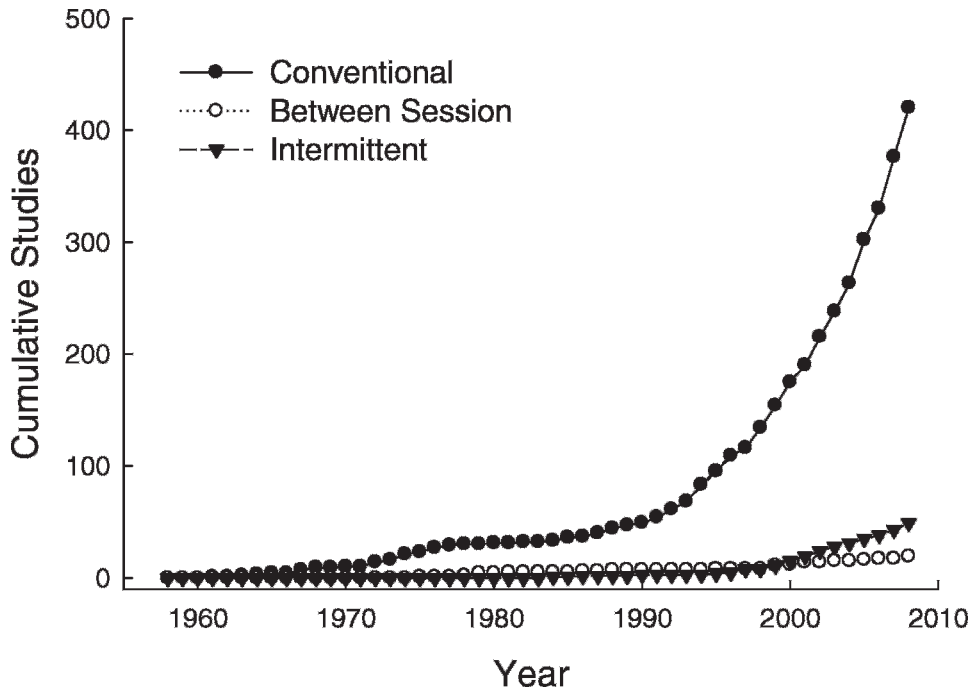
Figure 1. Cumulative research articles published using progressive-ratio schedules from 1960 to 2008 as indexed by PsycINFO. Filled circles represent articles that report the use of conventional PR schedules, open circles represent those that use between-sessions schedule progressions, and filled triangles represent those that use intermittent PR schedules.

Posadas-Sanchez, Johanson, & Thrailkill, 2009). Although there is certainly value in such integration, it also seems valuable to analyze how differences in progressive scheduling arrangements might differentially influence behavior.

## VARIETIES OF PROGRESSIVE CONTINGENCIES

A review of the psychological literature since 1960 reveals that at least three different arrangements have been investigated under the label *progressive ratio*. Figure 1 shows the frequency with which these three different arrangements have appeared in articles found using the key word *progressive ratio* in Psyc-INFO from 1960 to 2008.[1]

The earliest of the three arranged increases in the response requirement with each successive reinforcer. Sessions typically progressed until responding ceased for a specified period. The last-completed ratio before this period elapses was labeled the *breaking point* (Hodos, 1961) or, more commonly, *break point* (e.g., Lattal, Reilly, & Kohn, 1998). Research reported prior to 1975, and a majority of the research on progressive arrangements to date (see Figure 1), has involved this arrangement. Beginning in the mid-1970s, a second arrangement appeared in which the response requirement in-

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[1] All articles found using the search term *progressive ratio* in PsycINFO were included in Figure 1. Articles were scored by reading the methods section of each article to determine if the ratio always progressed after each reinforcer (i.e., conventional), the ratio sometimes progressed after multiple reinforcers (i.e., intermittent), or if the ratio increased across sessions (i.e., between sessions). The number of each articles of each type was then compiled, and a cumulative total of each type of article is shown.

creased between rather than within sessions. A third arrangement appeared in the 1990s. With it, the ratio requirement was static for several successive reinforcers before it progressed to the next higher ratio requirement. Thus, the ratio requirement increased intermittently. The data in Figure 1 show that, since its inception, this arrangement has been used in a few investigations each year.

## SIMILARITIES AND DIFFERENCES AMONG THESE PROCEDURES

Future research will reveal more about how these different arrangements function and relate to one another. Undoubtedly, there are common factors that underlie all types of progressive contingencies of reinforcement. Not considering or analyzing the potential differences, however, may deprive behavior analysis of useful data. All ratio and interval schedules share common features, but they also have important formal differences that have been shown to yield myriad behavioral differences among the schedules. The taxonomy of interval and ratio schedules has, to some extent, been important heuristically in aiding the identification of features of these schedules that might differentially affect behavior. Thus, the fact that fixed- and variable- ratio schedules have been distinguished has stimulated research than might not have occurred had all ratio schedules been considered together.

The sort of differences described in the preceding paragraph can be found along either functional or structural lines. At this point, there is insufficient research to allow strong conclusions with respect to functional similarities and differences among the different arrangements. It is possible, however, to identify structural differences among the arrangements that might lead to the discovery of poten-

tial functional differences among the procedures.

Two factors are considered here in assessing similarities and differences among the arrangements. The first is the potential contingencies of reinforcement that result from the different arrangements. The second is that of distinguishing between different contingencies and different parameters of the schedule itself.

### Contingencies That Underlie PR Performance

In the first arrangement above, a conventional PR schedule, responding has three consequences: (a) A reinforcer is delivered when the ratio requirement is completed; (b) earning a reinforcer increases the response requirement for the next reinforcer; and (c) each response extends the session. On the one hand, both reinforcer delivery and session extension may strengthen responding. Extending the session may be viewed as either maintaining the opportunity for reinforcement or avoiding time-out from positive reinforcement (Baer, 1960; D'Andrea, 1971; DeFulio & Hackenberg, 2007), but in either case the functional outcome is to maintain responding. On the other hand, increasing the response requirement has been associated with increased pausing (Baron, Mikorski, & Schlund, 1992; Perone & Courtney, 1992), other escape behavior such as self-imposed time-outs (Dardano, 1973, 1974), and responding to reset the ratio requirement (Findley, 1958; Hurwitz & Harzem, 1968). The break point therefore can be considered as the point at which schedule-specified contingencies no longer provide sufficient reinforcement to maintain responding.

In the second aforementioned arrangement—a between-session increase in the response requirement for reinforcement—reinforcer delivery is the only consequence for completing individual ratio require-

ments (e.g., Griffiths, Findley, Brady, Dolan-Gutcher, & Robinson, 1975; Johnson & Bickel, 2006). Therefore, ratio completion may not be influenced by the same interactive contingencies as those that operate when the ratios progress within the session. A fundamental procedural difference between the first and the second arrangements involves break-point determination. In the between-sessions arrangement, the break point often is defined as the ratio value at which the organism fails to earn a specified number of reinforcers (cf. Griffiths et al.; Johnson & Bickel), making session duration defined by the experimenter. Hence, the variables that control the break point are not necessarily the same in the two arrangements. Furthermore, these two different arrangements, both labeled PR schedules, also generate different patterns of responding, with the conventional PR schedule associated with higher response rates and lower break points than the between-sessions arrangement (Foster, Temple, Cameron, & Poling, 1997). In addition, the two arrangements produce only superficially similar demand curves (Foster et al.). Comparing the results of Madden, Smethells, Ewan, and Hursh (2007), who used a conventional PR schedule, to those of Johnson and Bickel, who used an arrangement in which response requirements increased between sessions, reveals that the two procedures produce break points that differ in their relation to behavioral economic measures such as $P_{max}$ (the point on the demand curve at which the slope of the demand curve becomes $-1$ or lower) and $O_{max}$ (the level of response output at $P_{max}$). With these procedural and behavioral differences, using the same label for both procedures is potentially confusing and misleading.

The third progressive arrangement resembles the conventional PR schedule in that the response requirement increases within individual sessions.

In the conventional PR schedule, however, the ratio requirement increases after each reinforcer (what might be called a continuous progression), whereas in this third arrangement the increases are intermittent. Thus, a response requirement of $x$ might be in effect for a block of five reinforcers, at which point the response requirement would increase to $x + 5$, and after five reinforcers to $x + 10$, and so forth. Responding extends the session duration in both arrangements. As a result, the break point measures the effects of the same contingency as described for the PR schedule. The result is that the increasing response requirement occurs more gradually than it does in the conventional PR schedule. As a result, the contingencies differ from reinforcer to reinforcer in the two arrangements. Perhaps analogous to the differences observed when transitioning from a continuous (i.e., fixed-ratio [FR] 1) to an intermittent (e.g., FR 5) schedule of reinforcement (e.g., Ferster & Skinner, 1957) or to the differences between sudden and gradual introduction of a negative discriminative stimulus (Terrace, 1963), differences in responding have been reported between continuous and intermittent ratio progressions. For example, in comparison to conventional PR schedules, the third arrangement has been associated with shorter postreinforcement pauses (Li, He, Parrish, Delich, & Grasing, 2003) and more completed ratios (Li et al.; Stafford, LeSage, & Glowa, 1999; Timberlake, 1984) but lower break points (Stafford et al.).

The preceding material describes how different progressive arrangements involve not only different configurations of concurrently operating contingencies but also, in many cases, different behavioral outcomes. Even if no difference in outcome were observed between these different arrangements, the negative results would not necessarily constitute evidence of similar controlling variables.

A failure to consider such contingency differences limits the applicability of both procedures and findings.

### Contingencies versus Parameters

The contingency differences outlined above can be contrasted with parametric variations within a single progressive arrangement. Specifically, with parametric variation, the underlying contingencies are not altered, whereas the differences outlined above represent a fundamental alteration of the contingencies that maintain responding. For example, altering the schedule value or the duration of pause defining session termination could be considered parametric variations. Thus, behavioral differences would be expected if the value of the PR were 2 or 12, or if the criterion for session termination were a pause in responding of 2 min or 6 min. The differences, however, would not be attributed to changes in the underlying contingencies or schedule structure, as described in the preceding section. Different taxonomic labels are appropriate, however, in cases in which the contingency structure does differ, as in the progressive arrangements discussed here.

### A STARTING POINT?

Overly fine discriminations and overly coarse generalizations are equal sins in any science, including behavior analysis. Slicing the cake too thin wastes time on the inconsequential, and not slicing it at all obfuscates the analytic task of isolating controlling variables. The material in the previous section suggests that there are procedural distinctions among the different arrangements all labeled *progressive ratio*. These differences invite further experimental analysis, of course. We suggest that they also warrant further taxonomic distinction. It may turn out that some of the structural differences are unimportant in terms of behavioral outcomes; however, it also may be that some of the distinctions are important behaviorally and thus cannot be dismissed. In either case, it is premature to consider all progressive arrangements interchangeable, as adopting a common label for them might be taken to imply. Use of the unqualified label *progressive ratio* to describe all of the contingencies outlined above may result in some confusion regarding the procedures used in a given study. It is with an eye toward both facilitating the exploration of behavioral differences and increasing procedural clarity that we propose distinguishing different types of progressive arrangements.

### DISTINGUISHING PROGRESSIVE CONTINGENCIES

The term *progressive ratio* seems most logically reserved for schedules in which the response requirement is advanced within a session and in which the break point is defined as the highest ratio completed prior to a pause of a prespecified duration. This is consistent with the original (e.g., Findley, 1958; Hodos, 1961) and most frequent (see Figure 1) use of the term. It is usual for the step size to be included after the schedule label; thus, a PR 5 indicates that the ratio requirement increases by five following each reinforcer. This practice also is consistent with the conventions of other ratio schedules.

The arrangement in which the response requirement intermittently increases was described by Killeen et al. (2009) as a *basis x* PR schedule, where *x* refers to the number of ratios completed at each successive response requirement. For example, a schedule in which the ratio requirement is increased by one following every two reinforcers is labeled a Basis 2 PR 1. It is logically consistent to use this system to refer to a PR schedule in which the ratio requirement increases for successive rein-

forcers as a Basis 1 PR $x$ schedule; however, a basis of one could be considered the default and would not require additional notation. Intermittent increases to this point have involved periodic increases in the response requirement (e.g., after every fourth reinforcer), but aperiodic progressions are possible (e.g., after, on average, four reinforcers). Precision dictates that the algorithm for increasing the response requirement be specified (see Li et al., 2003).

We propose a different designation when the response requirement increases between sessions because (a) the contingencies it generates seem potentially different from those of the original within-session PR schedule, and (b) some investigators refer to this arrangement as a PR schedule and others do not. The latter virtually assures that any electronic database search will miss references that may be relevant. This arrangement could be labeled a *progressive fixed-ratio* (PFR) schedule, which would ensure its inclusion in electronic searches of PR arrangements while still distinguishing it from other arrangements. The number of sessions at each ratio value also could be specified. For example, if the ratio requirement increased every two sessions by 20 responses, the schedule could be identified as a Basis 2 PFR 20.

Parameters of the progressive contingency also need to be identified. For example, responding and persistence are affected by such variables as the break-point criterion (Stafford & Branch, 1998), step size (Hodos & Kalman, 1963; Stafford & Branch), and step type (e.g., geometric, logarithmic, or arithmetic; Killeen et al., 2009). In addition, progressively increasing response arrangements that end after a specified period of time rather than after a break-point criterion have become common in conjunction with each of the three arrangements discussed here. This operation needs to be distinguished from one of terminating a session at the break point. It could be described as a *time-limited* PR schedule or as a time-limited basis $x$ PR schedule.

## CONCLUSION

There are both scientific and practical reasons for being cautious in applying the singular label *progressive ratio* to the different arrangements discussed herein. Scientifically, there is an insufficient database to conclude that the different arrangements affect behavior sufficiently similarly to warrant a nondiscriminative label. Practically, the taxonomic suggestions herein could increase the precision with which progressively increasing response requirements are described and, perhaps, used. Because of the pivotal role of key words and abstracts in the indexing and searching of scientific literature, increased precision in taxonomic labels could facilitate scientific communication.

Although we have limited our suggestions to descriptions of progressively increasing response requirements, many of the suggestions are applicable to other types of progressively changing arrangements, such as progressively increasing delays to reinforcement (e.g., Reilly & Lattal, 2004) or progressively increasing time requirements for reinforcement (e.g., Dougherty, Cherek, & Roache, 1994; Leinenweber, Nietzel, & Baron, 1996).

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