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Choices between segmented and unsegmented schedules and the self-control paradigm

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ABSTRACT

A concurrent-chains procedure was used to examine choice between a segmented (two- or three-terminal-link segments schedules) and an unsegmented schedule (simple schedule) in terminal links with equal interreinforcement intervals. In most such experiments, preference for the unsegmented schedule has been found, but in a recent study with humans (Alessandri et al., 2010) a reversal in preference was found when, in the segmented schedule, the terminal link segmenting stimulus was presented briefly and closer to food delivery such that the early terminal link stimulus was temporally closer to the food delivery. In Experiment 1, an attempt to replicate this latter effect with pigeons was unsuccessful but this outcome was consistent with an account in terms of a self-control contingency involving conditioned reinforcers. According to this account, the unsegmented alternative consisted of an immediate, smaller presentation of a conditioned reinforcer (i.e., the impulsive, and thus usually the preferred, option in several experiments) and the segmented schedule led to a delayed, larger conditioned reinforcer (i.e., the self-control option). In Experiment 2, a reversal of preference toward the segmented schedule was found when a delay was added to both terminal links between the reinforced initial-link response and the onset of the corresponding terminal link stimulus. This result is consistent with a similar effect found with primary reinforcers in the self-control literature suggesting the utility of self-control as an account of preferences for unsegmented terminal links of concurrent chains schedules.

1. Introduction

The effect on choice of segmentation has been investigated using the concurrent chains procedure, where the first response meeting the scheduled contingency on either of the operanda results in an exclusive presentation of the terminal link associated with that initial link. In the case of segmentation, one of the terminal links is *segmented* – it is divided into two or more segments associated with distinct stimuli. The other terminal link is *unsegmented* – the stimuli in it are homogeneous for its duration. In the segmented terminal link, the *early stimulus* is the first-presented stimulus and the *segmenting stimulus* the second-presented stimulus.

In several previous experiments, on the one hand, pigeons (Duncan and Fantino, 1972; Leung and Winton, 1986, 1988) and humans (Leung, 1989, 1993) preferred the unsegmented terminal link. These preferences varied in degree from 55 to 99% of the total responses in the initial link associated with the unsegmented terminal link. On the other hand, Alessandri et al. (2010) found preference for segmented vs. unsegmented terminal links (the average preference for this alternative as measured by the allocation of initial link responses to the operandum associated with it ranged from 50 to 100% for the 14 subjects) in humans after making two procedural changes in the segmented schedule relative to the procedures in the aforementioned studies. First, the segmenting stimulus appeared temporally closer to reinforcement (after 80% of the terminal link duration had elapsed *versus* the 50% typically studied heretofore). Second, the change in the segmenting stimulus was brief (4-s), reinstating the early stimulus prior to reinforcement.

Preference for the unsegmented terminal link conflicts with a prediction of Fantino's (1969) delay-reduction theory (DRT), which suggests that the effectiveness of conditioned reinforcers depend on the reduction in the delay to food that they signal relative to the absence of such a signal. Thus, in the case of segmented vs. unsegmented terminal links, DRT predicts a preference e for the segmented link because the terminal-link segmenting stimulus is closer to food delivery than the stimulus associated with

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the unsegmented terminal link. This finding is consistent with Alessandri et al., but not with the other experiments described in the preceding paragraph.

The concurrent chains procedure for assessing segmented/unsegmented terminal link preferences is similar to Rachlin and Green's (1972) self-control paradigm, but with conditioned instead of food reinforcers. In that paradigm, subjects choose between a larger, more delayed reinforcer (the self-control choice) and a smaller, less delayed reinforcer (the impulsive choice). The unsegmented terminal link resembles the impulsive choice, in which a less-effective conditioned reinforcer (as it is correlated with less reduction in the delay to food reinforcement) is delivered immediately. The segmented terminal link resembles theself- control choice, in which a conditioned reinforcer correlated with greater reduction in the delay to food reinforcement is delivered after a delay from the terminal link onset. Using primary reinforcers, this procedure generally results in a preference for the impulsive choice in both nonhumans (for a review, see Logue, 1988) and humans (Kirk and Logue, 1997) alike. Two experiments comprised the present analysis of the segmentation effect. Because the Alessandri et al. findings were counter to much of the extant literature on the segmentation effect, it was of interest in Experiment 1 to attempt a replication using pigeons. Alessandri et al.'s results were not replicated, but the Experiment 1 results are consistent with both the general findings on segmentation and an interpretation based on the self-control analysis presented above. Experiment 2 then was conducted to further assess the utility of self-control as an account of preferences for unsegmented terminal links of concurrent chains schedules.

2. Experiment 1

This experiment was, procedurally, a systematic replication of Alessandri et al. (2010) with pigeons rather than humans. Using pigeons was of interest because the putative terminal reinforcer used by Alessandri et al. was somewhat atypical (access to preferred pictures) and it is not known whether it is functionally equivalent to more typical reinforcers like food in pigeons or money in humans (e.g., Leung, 1993).

2.1. Materials and methods

2.1.1. Subjects

Three male White Carneau pigeons were maintained at 80% of their free-feeding body weights by mixed grain obtained during the experimental session and provided by the experimenter immediately following the session. They were housed individually, with free access to water and health grit, in a colony room with a 12 h:12 h light:dark cycle. Each had a history of responding under a variety of reinforcement schedules.

2.1.2. Apparatus

Two plywood operant chambers for pigeons (30 cm long × 32 cm wide × 38 cm high) were used. The front wall was an aluminum panel with three 2-cm diameter Gerbrands Co. response keys, 9 cm apart (center to center) and with their lower edge 25 cm from the floor. The left and right keys were used and each was operated by a minimum force of 0.15 N and could be transilluminated white, red or green. General illumination was provided by a white houselight located in the lower right corner of the aluminum panel. A food hopper was located behind a 6 cm wide by 6.5 cm high rectangular aperture was located on the midline of the panel, with its base 8 cm from the floor. The aperture allowed access to mixed grain when the hopper was raised. A 28-V DC clear bulb illuminated the aperture and all other lights were dark during the 3-s presentations of the hopper that defined reinforcer deliveries (5 s for Pigeon 691). White noise and a ventilation fan in each chamber masked extraneous sounds. Programming of conditions and data recording were accomplished by using MED-PC® interfacing (MED Associates, Inc. & Tatham, 1991) and software and a microcomputer located in an adjacent room.

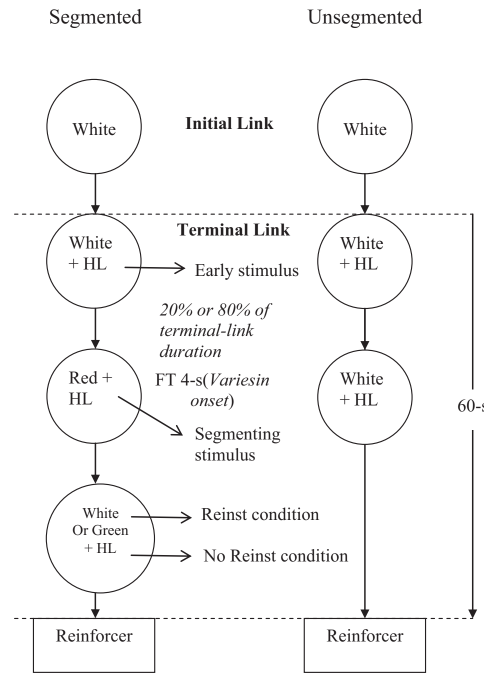

Fig. 1. Schematic diagram of the procedure in Experiment 1. The left portion of the figure shows the segmented terminal link and indicates the sequence of events when it was in effect following a response on the initial link key associated with this terminal link. The right portion shows the unsegmented schedule and indicates the sequence of events when a terminal link was entered following a reinforced response on the initial link key associated with this terminal link.

2.1.3. Procedure

Because subjects were experienced, training commenced immediately on the concurrent-chains schedule diagrammed in Fig. 1. During the initial link, the two side keys were transilluminated white and responding on either key occasionally produced the respective terminal-link schedule, correlated with illumination of the houselight, while the selected key remained white and the other key was darkened. A single variable-interval (VI) 30-s schedule was in effect on both response keys in the manner described by Stubbs and Pliskoff (1969). This procedure was used to ensure that the scheduled and obtained number of reinforcers for the two keys were identical. An initial-link response was reinforced by terminal link entry provided that (a) an interval selected from a VI 30-s schedule had elapsed; (b) the response was to the preselected key; and (c) a 2-s changeover delay (COD) was satisfied (i.e., at least 2-s had elapsed following a changeover to the side on which the terminal-link entry was arranged). For one alternative terminal-link responses were reinforced according to a tandem VI VI (unsegmented) schedule, and in the other alternative responses were reinforced according to a chained VI FT 4-s VI (segmented schedule). The sum of the different terminal-links values were equal to those of the tandem schedule on the other key. The mean overall terminal link duration was 60 s (based on 12 intervals ranging from 25-s to 150-s selected randomly without replacement). In the unsegmented terminal link, the same key color was present until reinforcement delivery (i.e., white + houselight). In the segmented terminal link, the key color changed from white to green (for Pigeon 567) or red (for Pigeons 691 and 775) for 4-s after 20%

Table 1
Order of conditions and the number of sessions (in brackets) per condition. The first number is the number of sessions during the initial presentation and the number preceded by a "+"is the number of sessions during the replication.

	Subjects		
	775	567	691
20% no reinst	4 (17)	2 (44)	4 (14)
20% reinst	1 (17 + 9)	1–5 (14 + 8)	1 (23)
80% no reinst	3 (15)	3 (16)	2 (24)
80% reinst	2 (19)	4 (20)	3 (19)

or 80% of the terminal link duration elapsed, according to the condition in effect. Then, depending on the condition, the light either turned back to white (the *reinstatement* condition) or to a different color (the *nonreinstatement* condition) (i.e., red for Pigeon 567, and green for Pigeons 691 and 775) for the remainder of the terminal link. In all conditions, the segmented alternative was presented on the left key for two pigeons (567 and 775) and on the right key for the other (691).

Table 1 provides the sequence of conditions and the number of sessions at each for each pigeon. Each pigeon was studied at each combination of the temporal location of the brief stimulus (20% or 80% of the terminal-link duration) and the reinstatement of the original terminal link stimulus following the brief segmenting stimulus offset (described hereafter as *reinstatement* or *nonreinstatement* conditions). The order of the conditions differed between subjects. The next condition was introduced when the mean choice proportion of the last five sessions did not differ by plus or minus 7% from that of the previous five sessions. Each session terminated after 60 min. The last condition for Pigeons 567 and 775 was in effect respectively for only eight and nine sessions because of a time constraint on terminating the experiment.

2.1.4. Results and discussion

The choice proportion data for the segmented terminal link (i.e., the number of responses on the segmented initial link key divided by the total number of responses during initial links) in each condition are shown in Fig. 2. Preference for the segmented schedule was greater (albeit modestly so for Pigeon 691) when the early terminal link stimulus, the white key color, was reinstated after the brief stimulus change in the segmented terminal link. Fig. 3 shows, for each pigeon, the choice proportions on the segmented key as a function of the reinstatement or not of the early terminal link stimulus and the effect of the temporal placement of the segmenting stimulus. Contrary to the prediction of delay-reduction theory (Fantino, 1969), preference for the segmented schedule decreased slightly when the segmenting stimulus was temporally closer (i.e., the 80% conditions) to the food presentation. In fact, preference for the segmented alternative did not occur in most conditions, particularly in the critical reinstatement condition, in which the early terminal link stimulus was reinstated such that the segmenting stimulus was presented closer to food delivery (the "80% reinst" condition). Except for Pigeon 691, which preferred the segmented alternative in 3 of 4 conditions, and for Pigeon 567 in the 20% reinst condition, the general finding was a preference for the unsegmented terminal link even if it sometimes was slight. This finding is consistent with the results of most other studies on segmentation (e.g., Duncan and Fantino, 1972; Leung, 1989, 1993; Leung and Winton, 1986, 1988), but it is inconsistent with the extensive literature on the role of delay reduction on preference (cf. Fantino, 2008) and with the results of Alessandri et al. (2010). The latter inconsistency considered in the general discussion.

The immediate consequence of responses in the initial link, when the variable interval lapsed, was to produce a stimulus light correlated with the terminal link. In the case of the segmented terminal links, another stimulus occurred for 4 s somewhat later in the interval, after either 20% or 80% of the interval had lapsed. According to delay reduction theory, because this stimulus reduced the delay to food delivery, it should be preferred. That it was not can be accounted for by considering the segmentation procedure in terms of the self-control paradigm, as outlined in the introduction. Thus, the pigeons are faced with a choice between a stimulus that is correlated with the reinforcer that occurs immediately on the criterion response, and a stimulus which should be, according to delay reduction theory, a more potent conditioned reinforcer (because it reduces the delay to primary reinforcement) after either 20% or 80% of the interval lapses. This suggests, then, that this and the other instances of preferences for the unsegmented terminal links in studies of the segmentation effect in fact preferences for a more immediate over a more delayed conditioned reinforcer.

Otherwise, in comparing the *reinstatement* and *no reinstatement* conditions, in general, preferences for the segmented schedule were closer to indifference, or even with preferred, in the former condition compared to those in the latter. Thus, when the white light was reinstated prior to reinforcement, are the pigeons were more indifferent in their preferences than when it was not reinstated. That is, when the white light was paired with food at the end of the terminal link, it was a more effective conditioned reinforcer early in the link, leading to greater impulsive choice of the immediately available conditioned reinforcer.

3. Experiment 2

One variable that reverses preference in the self-control paradigm is the addition of a same delay to both alternatives between the choice response and the delivery of the reinforcer (e.g., Green et al., 1981). To further investigate a functional similarity between the self-control paradigm and preference in the segmentation procedure studied in the first experiment, 90-s delays to both alternatives were introduced between the reinforced initial link response and the production of the corresponding terminal link stimulus. In addition, in this experiment the terminal-link segmenting stimulus was presented until food delivery. This was done (a) so that the contingency would more closely resemble the standard two-stimulus segmented terminal-link used in all prior studies on segmentation and (b) in an effort to further equate the present procedure with the self-control procedure by placing the segmenting stimulus contiguous with food delivery while separating the early terminal-link stimulus further from food delivery.

3.1. Materials and methods

3.1.1. Subjects and apparatus

Pigeons 567 and 775 from Experiment 1 were used in this experiment (the other pigeon was not used because it showed persistent response bias toward one of the side keys in another experiment). The apparatus was the same as in Experiment 1.

3.1.2. Procedure

The procedure was as in Experiment 1, with the following exceptions. In the segmented schedule, as noted above, the segmenting stimulus was no longer presented briefly but remained on until food delivery. The overall terminal link mean duration was 30 s (based on 12 intervals ranging from 12.5-s to 75-s). For Pigeon 567, the segmenting stimulus appeared after 80% of the terminal link duration had elapsed and for Pigeon 775, it appeared, depending on the condition, either after 20% or 80% of the terminal link had lapsed. The critical manipulations were the presence and absence of a 90-s blackout between the reinforced initial link response and the onset of the corresponding terminal link stimulus. An ABA reversal

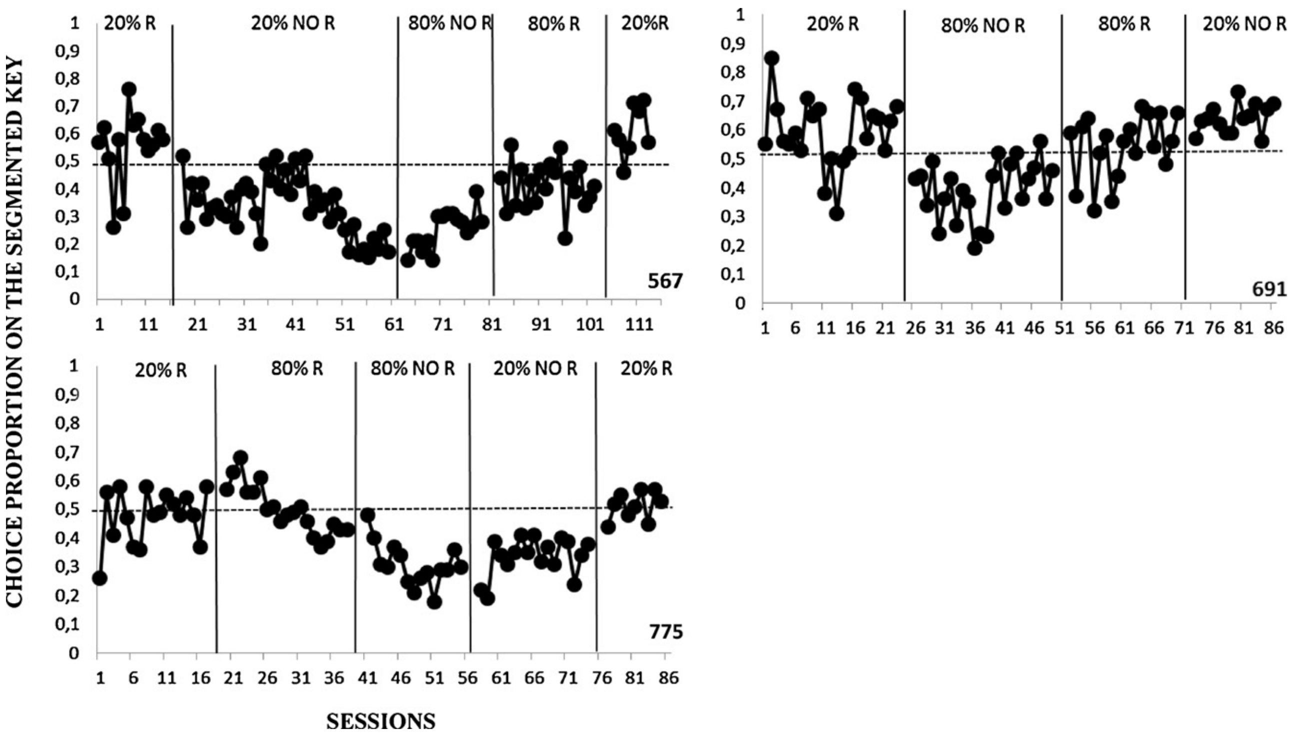

Fig. 2. Choice proportions for each pigeon in Experiment 1 on the segmented alternative during each session as a function of the reinstatement or not of the early terminal link stimulus following the segmenting stimulus presentation and of the temporal placement of the segmenting stimulus (after 20% or 80% of the terminal link duration).

design was used for Pigeon 567 with A as the no delay condition and B as the delay condition and an ABB'A' design was used for Pigeon 775, where A was the no delay 80% condition, A' was the no delay 20% condition, B was the delay 80% condition, and B' was the delay 20% condition. A condition with a shorter delay to the segmenting stimulus subsequently was studied with Pigeon 775 because of the failure to systematically reverse the preference in favor of the segmented outcome in the B condition, to examine the contribution to this reversal failure of the longer delay to the segmenting stimulus for this pigeon.

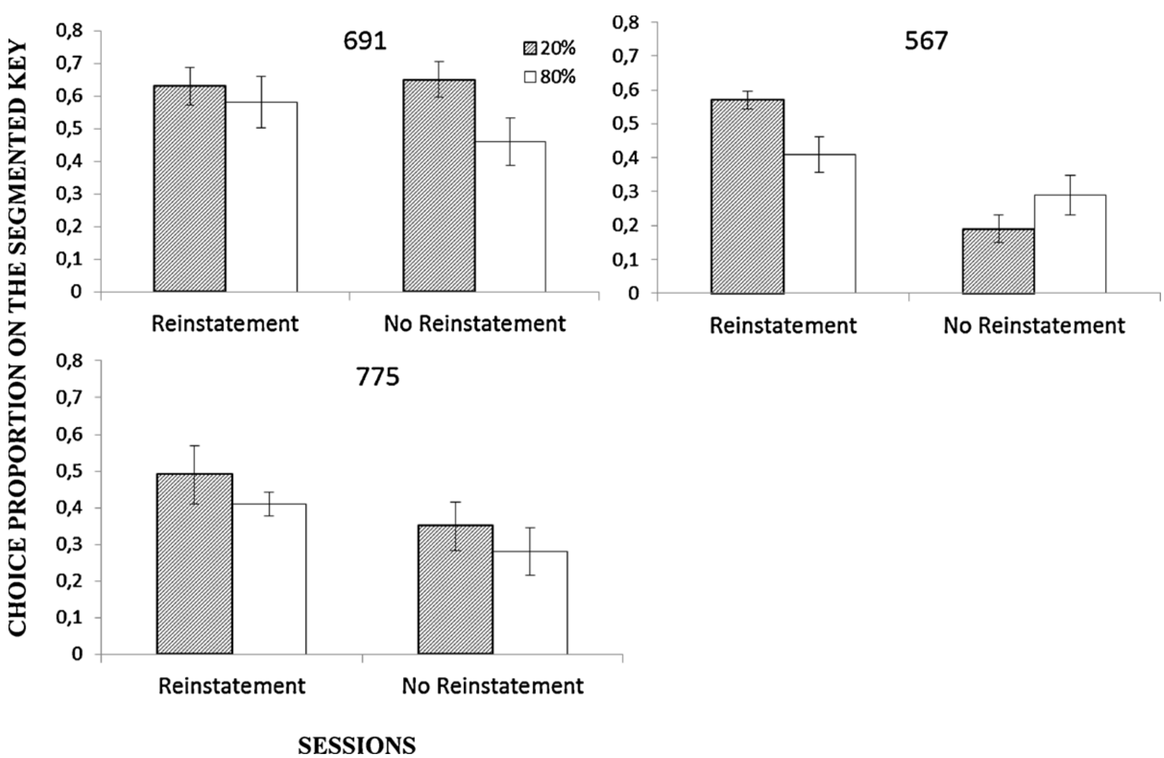

Fig. 3. Mean choice proportions and standard deviations calculated over the last 5 sessions for each pigeon in Experiment 1 on the segmented initial link alternative (means of the two reinstatement and no reinstatement conditions) as a function of the temporal placement of the segmenting stimulus and of the reinstatement variable.

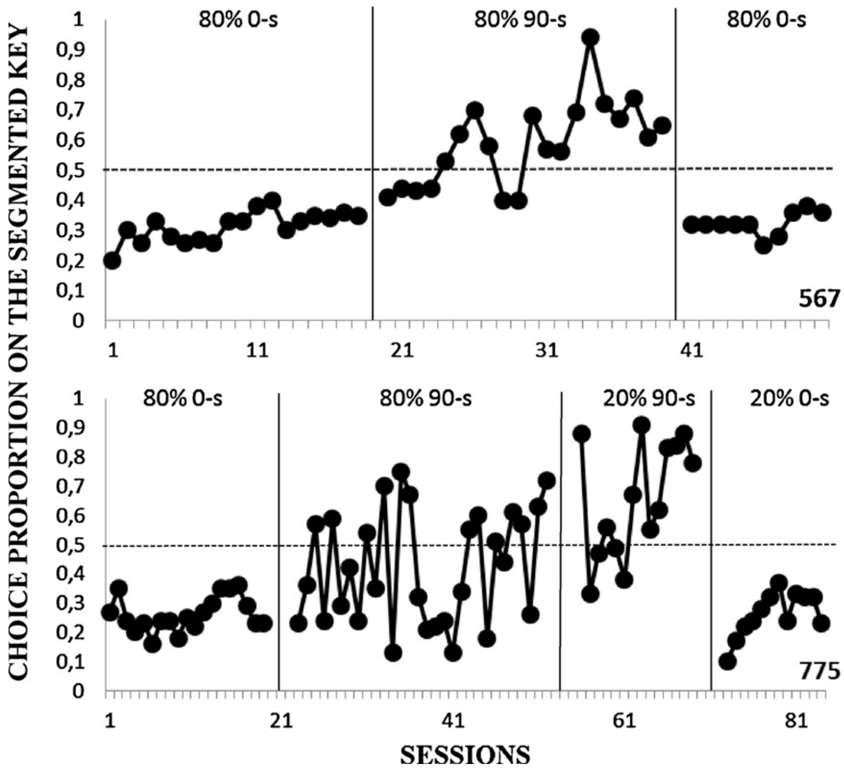

Fig. 4. Mean choice proportions for each pigeon in Experiment 2 on the segmented alternative during each session as a function of the presence or absence of a 0-s blackout between the reinforced initial link response and the production of the corresponding terminal link stimulus and for Pigeon 775 as a function of the temporal placement of the segmenting stimulus (after 20% or 80% of the terminal link duration).

3.2. Results and discussion

Choice proportions are shown in Fig. 4. In the absence of the delay, preference favored the unsegmented terminal link, but when the 90 s delay was imposed, this preference reversed in favor of the segmented terminal link for both pigeons. This effect occurred with both pigeons when the segmenting stimulus occurred after 80% of the terminal link had transpired; however, for Pigeon 775 the reversal was in terms of an upward trend and increasing preference for the segmented terminal link, but with considerable session-to-session variability (median of 0.39 for the 90-s condition *versus* median of 0.24 for the 0-s condition). For Pigeon 567, the reversal of preference was absolute in that greater than 0.50 of the initial link responses were to the initial-link key associated with the segmented terminal link (median of 0.6 for the 90-s delay condition *versus* median of 0.32 for the 0-s delay condition). When a 20-s delay replaced the 90-s one with Pigeon 775, preference for the segmented terminal link increased markedly, but still with variability (median of 0.65 for the 90-s condition *versus* median of 0.26 for the 0-s condition). Removing the delay resulted in a reversal of preference favoring the unsegmented terminal link.

This reversal of preference was similar to that observed with self-control studies involving primary reinforcers (e.g., Logue, 1988). Green et al. (1981), for example, found that the preference for the longer, more delayed reinforcer increased systematically as a function of delay value within the range of 2–28 s. A related change in preference in the present experiment when the delays were imposed suggests that the absence of preference for the segmented terminal link component, despite the presentation of a stimulus that, according to DRT, should function as the more potent conditioned reinforcer, is a result of the temporal discounting of the segmenting stimulus (cf. Mazur, 1987). In the same way, the increase in level of preference for the segmented outcome in the 20% 90-s condition compared to the 80% 90-s condition was similar to the observed inverse relation between the delay to the reinforcer and the degree of preference for the self-control option (for a review, see Logue, 1988).

4. General discussion

The present findings suggest that the choice between segmented and unsegmented schedules in terminal links of concurrent chains schedules resembles the choice between impulsive and self-control alternatives in the self-control paradigm (e.g., Rachlin and Green, 1972). In Experiment 1, pigeons preferred the unsegmented alternative even when the early terminal link stimulus was contiguous with food delivery and when the segmenting stimulus was temporally closer to reinforcement. This result is consistent with previous findings using pigeons and humans, where the unsegmented schedule was systematically preferred (Duncan and Fantino, 1972; Leung, 1989, 1993; Leung and Winton, 1986, 1988). It also extends the finding by showing that it occurs when the segmenting stimulus appears at times other than the 50% temporal point in the terminal link. It was suggested at the end of Experiment1 that preference for the unsegmented alternative occurred because it provided immediate access to a conditioned reinforcer even though, according to delay reduction theory (Fantino, 1969), the unsegmented stimulus should be a less potent conditioned reinforcer than the segmenting stimulus in the segmented schedule. A parallel finding has been observed consistently in the self-control paradigm using primary reinforcers (e.g., Rachlin and Green, 1972). Furthermore, there was a trend toward lower preference for the segmented schedule in the 80% condition than in the 20% condition. That is, when the delay to the segmenting stimulus was longer, as in the self-control procedure when the delay to reinforcement in the self-control alternative is increased (e.g., Logue, 1988).

In Experiment 2 there was a reversal of preference in favor of a larger, more delayed conditioned reinforcer (segmented schedule) over a smaller, immediate conditioned reinforcer (unsegmented schedule) when an equivalent delay was added to both alternatives between the choice response and the delivery of the smaller conditioned reinforcer. This effect also has been observed in the self-control procedure (e.g., Green et al.,1981).

The similarity between the segmentation and self-control procedures and outcomes could resolve the apparent paradox of preference for an option that leads to what delay reduction theory would identify as a less effective conditioned reinforcer (Fantino, 1969; Mazur, 2001). From the standpoint of both delay reduction theory and Mazur's (2001) HVA model, the segmenting stimulus of the segmented schedule should be the more potent conditioned reinforcer than the terminal link stimulus of the unsegmented schedule. Preference for the segmented schedule, however, did not develop because of the more delayed presentation of the segmenting stimulus, resulting in it being discounted over time. As in the self-control procedure, there is a trade-off between conditioned reinforcement resulting from delay reduction and delay of conditioned reinforcement.

This latter variable has been found to influence choice (Ohta, 1988). Also, regarding the tendency of decreasing choice for the segmented alternative when the delay of conditioned reinforcement increased (Experiment 1), the present findings support the idea that conditioned and primary reinforcers share the same sensitivity concerning delay of reinforcement. This extends the results of other studies in which the rate of responding decreased when the delay, between the response and delivery of a conditioned reinforcer, increased (Bermúdez et al., 2012; Royalty et al., 1987). In effect, the evidence that delay to a conditioned reinforcer contributed to preference was: (a) the increase in preference for the segmented schedule during the 20% condition (Experiments 1 and 2 for Pigeon 775), and (b) the increase in preference for the segmented schedule when a 90-s delay was added prior to the terminal link (Experiment 2).

As was noted, these results are contrary to those recently found in humans in which preference for the segmented schedule was found when the segmenting stimulus appeared following 80% of the terminal link duration and the early stimulus reappeared (Alessandri et al., 2010). It seems unlikely that species difference is the reason for this discrepancy because preference for unsegmented schedules was found previously in humans (Leung, 1989, 1993). The reason for this discrepancy might be the difference in the nominal reinforcers used. Alessandri et al. used access to preferred pictures. Not only was this an atypical stimulus to use a reinforcer with humans, but it also may be the case that relative preference does not predict how well the preferred items will function as reinforcers in more absolute terms. Another procedural difference between the present experiments and human operant research is the use of FR 1 schedules during initial links in Alessandri et al. In studies of percentage reinforcement, initial preference for the reliable alternative (probability of reinforcement of 1), when initial links were variable-interval schedules, reversed when FR 1 schedules were arranged in the initial-links (Dunn and Spetch, 1990). This variable invites investigation in future experiments to assess its potential contribution to the differences in preference for the segmented schedule between Alessandri et al. and the other experiments described herein.

Several experiments, including the present ones, attest to the deleterious effect on choice of segmenting a stimulus ultimately leading to reinforcement. These deleterious effects can be overcome by providing conditioned reinforcement early in the chain as, for example, in Experiment 2 (Pigeon 775, Fig. 4). More generally, this can be achieved by adding an identical delay between the response and stimulus change to both alternatives. When this is done, the procedure parallels the self-control paradigm, inviting further experimental analyses of the potential functional similarities between segmentation and self-control procedures.

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