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Human Risky Choice: Delay Sensitivity Depends on Reinforcer Type

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The present study was designed to help bridge the methodological gap between human and nonhuman animal research in delay-based risky choice. In Part 1, 4 adult human subjects made repeated choices between variable-time and fixed-time schedules of 30-s video clips. Both alternatives had equal mean delays of 15 s, 30 s, or 60 s. Three of 4 subjects strongly preferred the variable-delay alternative across all conditions. In Part 2, these 3 subjects were then provided pairwise choices between 2 variable-time schedules with different delay distributions. Subjects generally preferred the variable-delay distributions with a higher probability of short-reinforcer delays, consistent with accounts based on nonlinear discounting of delayed reinforcement. There was only weak correspondence between experimental results and verbal reports. The overall pattern of results is inconsistent with prior risky choice research with human subjects but is consistent with prior results with nonhuman subjects, suggesting that procedural differences may be a critical factor determining risk-sensitivity across species.

Keywords: risky choice, distributional characteristics, delay sensitivity, video reinforcement, adult humans

There is ample evidence that choice patterns are sensitive to variance in reinforcer variables (e.g., Bateson & Kacelnik, 1995; Kacelnik & Bateson, 1996; Mazur, 1984, 1986). Some of the most direct evidence comes from experiments involving choices between reinforcer delays. In choices between a fixed (constant) reinforcer delay and a variable reinforcer delay of equal mean to the fixed option, animals consistently prefer the variable option (e.g., Herrnstein, 1964; Killeen, 1968; Mazur, 1984, 1986). Such preference for variable delays is a clear and robust phenomenon, occurring across a range of procedural variations, including choices between fixed-interval (FI) and variable-interval (VI) schedules (e.g., Herrnstein, 1964; Killeen, 1968), fixed-time (FT) and variable-time (VT) schedules (e.g., Bateson & Kacelnik, 1995; Mazur, 1984, 1986), and fixed-ratio (FR) and variable-ratio (VR) schedules (e.g., Mazur, 1986).

This preference for variability in reinforcer delays is observed across a wide range of species inside and outside the laboratory, including pigeons, rats, and starlings (see review by Kacelnik & Bateson, 1996). Much less is known about choice between fixed versus variable reinforcer delays in humans. The few studies that do exist on the topic (Kohn, Kohn, & Staddon, 1992; Weiner, 1966) have produced results strikingly at odds with those reported in studies with nonhuman subjects. In the Kohn et al. study, for example, adult humans were given repeated choices between fixed and variable delays to reinforcement (symbols presented on a computer screen), arranged as FT and VT schedules. In one experiment, the variable schedule was a VT 5 s with a bivalued distribution of reinforcer delays (i.e., 1 s or 9 s, with equal probability). Across groups of subjects, the FT option was either equal to, greater than, or less than, the arithmetic mean of the VT schedule. On average, subjects preferred the FT to the VT schedule when the FT was equal to or less than the VT schedule. Only when the FT was greater than the mean value of the VT was the variable option preferred. In another experiment, mean preferences favored FT 10 s over VT 10 s (1 s and 19 s delays) and FT 2 s over VT 2 s (1 s and 3 s delays).

Such species differences are important because they suggest discontinuities in the determinants of choice in humans and other animals. The most widely held interpretation of preference for variable over fixed delays is that individual reinforcers are weighted differentially with respect to delay, with the occasional shorter delays comprising the variable distribution exerting disproportionate influence on preference (Herrnstein, 1964; Killeen, 1968; Mazur, 1984). Although the specific averaging rule by which such differential sensitivity occurs is still in doubt, there is little question that animals' choices are strongly influenced by reinforcer delay (Mazur, 1984, 1986). That such effects are not consistently observed with humans under laboratory conditions may suggest a fundamental difference between human and nonhuman animal sensitivity to reinforcer delays.

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Another possibility is that species differences in delay sensitivity reflect differences in the procedures used to study choice in humans and other animals. The present study was undertaken to explore this latter possibility by using procedures with humans that are more typically used in choice studies with other animals. First, subjects were given extensive exposure to the procedures, such that choices were well-informed by direct experience with the programmed contingencies, and experimental conditions remained in place until choice patterns were stable. These are standard practices in animal studies, but not in prior human studies in this realm. In the Kohn et al. (1992) study, for example, subjects were studied for a single brief (20–25 min) session and were given clear prompts each time conditions changed. A second and perhaps even more critical factor concerns the nature of the reinforcer. Past studies with nonhumans have used real outcomes, typically food, whereas past studies with humans have used hypothetical or instructed outcomes (points or symbols, which subjects were asked to regard as reinforcers). In the Weiner (1966) study, for example, subjects were paid a flat rate for participation; the points that served as putative reinforcers were not exchanged for money or other reinforcers. Instead, subjects were instructed to "get as high a score as possible."

Perhaps the lack of delay sensitivity in humans reflects the use of weak reinforcers (if indeed, the consequences functioned as reinforcers at all). What is needed for a comparative analysis are studies with human subjects that use actual and meaningful reinforcers. Therefore, in the present study humans' choices produced access to video clips. Prior research has shown that video access functions as an effective reinforcer for both children (e.g., Doggett, Gans, & Stein, 2000) and adults (Hackenberg & Pietras, 2000; Navarick, 1996, 1998). Moreover, unlike token and other monetary reinforcers typically used with human subjects, which accumulate and are later exchanged for other reinforcers, video reinforcers are "consumed" as they are earned. In this way, video reinforcers are more akin to consumable reinforcers such as food and water typically used with other animals. Together with extended direct experience with the contingencies, providing real consequences for choices narrows the methodological chasm separating human from animal studies, permitting more balanced species comparisons. If procedural differences are responsible for past human–animal disparities reported in the literature, then bringing the procedures into closer alignment should yield more comparable results across species, specifically, greater preference for variable reinforcer delays in human subjects.

Another objective of the present study was to assess sensitivity of choices to distributional characteristics. In most previous studies with humans, the form of the variable distribution has been severely constrained, mainly bivalued distributions with one short and one long delay. There has been little empirical work examining sensitivity to delay-based distributional variables per se. In Part 1 of the present study, subjects were given choices between two alternatives, each of which provided access to a 30-s video clip: a certain (fixed) delay and an uncertain (variable) delay drawn from a bivalued distribution (one short and one long delay with equal probability). In Part 2, choices were examined across four distribution types: bivalued, rectangular, normal, and exponential (positively skewed) distributions. Each distribution type was used to construct two variable schedules with the same arithmetic mean, arranged concurrently. Subjects were given pairwise choices between variable reinforcer delays comprised of different delay distributions.

All distributions had the same arithmetic mean (30 s), minimum value (1 s) and maximum value (59 s; with the exception of the exponential distribution, with a maximum value of 100 s; see Appendix A for delay distribution details). Although the overall mean delay, computed in standard arithmetic form, of each distribution is equivalent to the fixed delay (30 s), past research with nonhumans has shown that the arithmetic mean is not the most appropriate statistical characterization of the delay distribution (e.g., Killeen, 1968). Indeed, the disproportionate influence of shorter delays on preference suggests that averaging principles with delay-based differential weighting may fare better than the equal weighting of elements implied by the arithmetic mean. For example, Mazur (1984, 1986) proposed the following averaging rule, based on differential weighting of elements comprising the variable distribution,

$$V = \sum_{j=1}^{n} p_j \left(\frac{1}{1 + KD_j} \right), \tag{1}$$

where V, the value of a variable schedule, is determined by the sum of the reciprocals of each delay interval, D, plus 1 s, with each delay weighted by its probability of occurrence, P. K is a free parameter representing the rate of discounting. (A K value of 1.0 provides a reasonable fit to risky-choice data using titrating procedures; Mazur, 1984, 1986, and will therefore be used in the present analyses involving Equation 1.)

Applying Mazur's (1984, 1986) nonlinear averaging rule to the distributions used in the present study would yield the following rank order: bivalued, exponential, rectangular, normal. Thus, although all distributions have the same arithmetic mean, they differ with respect to the delay-based averaging metric, yielding predictable choice patterns. If choices are sensitive to distributional characteristics, then we should not only see preference for variable over fixed reinforcer delays (Part1) but also more extreme preference for the distribution types with a higher proportion of short delays (Part 2).

Method

Subjects

Four adult human men between 19 and 21 years of age were recruited through advertisements in a local university newspaper. Subjects were selected randomly from an applicant pool based on schedule compatibility and lack of experience in behavioral psychology. Subjects participated in one 45-min session per day, Monday through Friday, for which they received a flat wage of \$1.50, plus a bonus of \$4.00 per session if the experiment was completed in its entirety. All subjects completed the experiment, and received approximately \$7.30 per hr. All procedures were approved by the University of Florida Institutional Review Board.

Apparatus

Subjects were seated in a cubicle measuring 2.21 m high, 1.21 m wide, and 1.25 m deep, facing a white, aluminum panel 74 cm high and 44.5 cm wide. The upper portion of the panel contained 3 rows of 12 lights (28-V), with each row spaced 8 cm apart (not used in the present study). Three 2.5 cm diameter response keys, horizontally aligned 8.2 cm from one another at approximately eye level, were mounted 8.2 cm below the lowest row of lights. A force of approximately .6 *N* was required to operate the response keys. A 10-inch TV monitor was located 8.2 cm below the two left response keys. The TV monitor was connected to a VHS videocassette recorder (VCR). The VCR functions were operated by the same computer and software that controlled the stimulus lights and response keys. An overhead light provided diffuse illumination and a ventilation fan helped mask extraneous sound.

Procedure

Prior to each subject's first session, he was asked to rate a list of videos on a scale of 1 (*would not like to watch*) to 10 (*would love to watch*). The list of videos was separated into three categories: 13 biographies, 10 documentaries, and 25 feature-length films. Subject to availability, only videos rated high by a subject were shown. Videos ran only during reinforcer periods (see below), and were shown in their entirety, beginning in each session at the point at which they ended in the preceding session. If a video ended during a session, the next preselected video was presented immediately. This was accomplished by copying the end of one video and the beginning of the next onto a single videotape to be used during the session. Sessions always began with a 1-min video presentation before the first trial.

Subjects were given minimal instructions, which were posted beside the response keys and read aloud to the subject before the first session: "You can play the video by pressing the response keys when lit. Press only one key at a time. Please remain seated. You will be informed when the session is over."

The first 10 trials of each session were forced-choice trials, 5 of each type in pseudorandom order, which ensured equal exposure to each schedule. The remaining trials (either 20, 36, or 50 depending on the condition, see below) were choice trials, during which both alternatives were concurrently available. Trials of either type began with the red illumination of the center key. A single response on this key extinguished the center keylight and illuminated either one side key (forced-choice trials) or both side keys (choice trials). The colors of the side keys (green and yellow) were uniquely associated with a choice alternative (counterbalanced across subjects). Five consecutive presses on an illuminated key terminated all key lights and initiated the delay period. The reinforcer delays following a choice were arranged on the clock, that is, as FT and VT schedules, without regard to a response. When the programmed delay elapsed, video was presented on the monitor for 30 s, followed immediately by the next trial. The left–right assignments of the choice alternatives were determined randomly each trial.

The experiment was divided into two parts. In Part 1, the schedules were FT and VT schedules of the same average delay, which was varied parametrically across conditions: 15 s, 30 s, and 60 s. The VT distribution was bivalued, with the short delay always equal to 1 s. The longer delay in each VT distribution was adjusted across conditions such that the arithmetic mean equaled that of the FT value, yielding delay elements of (1 s, 29 s), (1 s, 59 s), and (1 s, 119 s) for FT values of 15 s, 30 s, and 60 s, respectively. To hold session length to approximately 45 min, the number of trials per session varied across conditions: 60 (FT 15 s), 46 (FT 30 s), and 30 (FT 60 s). Part 1 conditions also included a two-session probe to assess delay sensitivity. In this condition, the longer delay in the VT distribution was omitted, yielding a choice between a 1 s video delay and either a 30 s (S19 and S23) or 60 s (S18 and S24) video delay. In these conditions, postreinforcer delays were added to short-delay choice trials to hold trial length constant across alternatives.

In Part 2, the 3 subjects showing a systematic preference for the VT schedule were exposed to additional conditions with pairwise choices between different VT distribution types (bivalued, exponential, rectangular, and normal, as described earlier) with equivalent mean delays of 30 s. Given the number of sessions subjects had already completed in Part 1, it was not practical to examine every possible combination of distribution types. Therefore, we ranked the distributions in order of value based on Equation 1, and began comparisons with the distributions with the highest value, as shown in Appendix A (bivalued vs. exponential). Once choice proportions were stable across three sessions, the more preferred distribution during that condition was replaced with the distribution of the next lowest predicted value (e.g., if bivalued was preferred to exponential, then bivalued was replaced with rectangular). The final condition involved a comparison between the normal distribution—the VT distribution with the highest proportion of longer delays—and an FT 30 s. Each condition beyond the first thus involved a new distribution type pitted against a distribution from the immediately prior condition (the less favorable distribution). Because the less favorable distribution in Condition *n* was often the more favorable distribution in Condition $n + 1$, sensitivity to distribution type would be evident through repeated reversals of preference. To separate schedule-related changes in preference from color biases, the new (generally less favorable) distribution was assigned the color associated with the more favorable distribution from the preceding condition.

Due to the large number of elements in the exponential and normal distributions, the five forced choice trials per session with these distribution types were constrained. To ensure adequate sampling from the various regions of these distributions, the elements were arranged in ascending order and then divided into five approximately equal sets. The five forced choices were then drawn randomly, one from each set, with the order of the sets also randomly determined. Conditions lasted for a minimum of three sessions (minimum of two sessions for sensitivity test conditions) and until choice proportions showed no systematic trends. Table 1 shows the sequence and number of sessions per condition for each subject.

At the conclusion of the experiment, each subject was presented with a postexperimental questionnaire, which prompted responses regarding the subject's experiences over the course of the experiment. Subjects were given a list of the video titles they had watched and were asked to indicate whether they had seen the video previously and to rate each video (on a scale of 0 to 10) with respect to how much they enjoyed it. The questionnaire also asked subjects to rate the extent to which they agreed with five statements addressing the environmental events controlling their choices. These statements took the form of "During sessions, I pressed the keys (A) so that the session would end faster, (B) so

Table 1
Sequence and Number of Sessions Per Condition for Each Subject

Part 1			
	Green key	Yellow key	Sessions
Subject 18			
	FT 30 s	VT 30 s (1s, 59s)	4
	FT 60 s	VT 60 s (1s, 119s)	3
	FT 30 s	FT 1 s	1
	FT 1 s	FT 30 s	1
	FT 15 s	VT 15 s (1s, 29s)	3
Subject 19			
	VT 30 s (1s, 59s)	FT 30 s	3
	VT 15 s (1s, 29s)	FT 15 s	3
	VT 60 s (1s, 119s)	FT 60 s	3
	FT 60 s	FT 1 s	1
	FT 1 s	FT 60 s	2
Subject 23			
	VT 30 s (1s, 59s)	FT 30 s	8
	VT 60 s (1s, 119s)	FT 60 s	3
	VT 15 s (1s, 29s)	FT 15 s	3
	FT 30 s	FT 1 s	1
	FT 1 s	FT 30 s	1
Subject 24			
	FT 1 s	FT 30 s	1
	FT 30 s	FT 1 s	1
	FT 30 s	VT 30 s (1s, 59s)	3
	FT 15 s	VT 15 s (1s, 29s)	3
	FT 60 s	VT 60 s (1s, 119s)	3

Part 2			
	Green key	Yellow key	Sessions
Subject 19			
	Exponential	Bivalued	5
	Exponential	Rectangular	11
	Normal	Rectangular	7
	Normal	FT 30 s	6
Subject 23			
	Exponential	Bivalued	4
	Exponential	Rectangular	10
	Normal	Rectangular	5
	Rectangular	Normal	2
	FT 30 s	Normal	2
	FT 30 s	FT 1 s	2
	Normal	FT 30 s	3
	FT 30 s	Normal	2
	FT 30 s	Rectangular	1
	FT 30 s	Bivalued	3
Subject 24			
	Bivalued	Exponential	7
	Rectangular	Exponential	8
	Normal	Exponential	7
	Normal	FT 30 s	8
	Normal	Rectangular	6

Note. FT = fixed time; VT = variable time.

that I could watch the video sooner, (C) to postpone watching the video, (D) so that the video would end faster, and (E) to get to the next video sooner." The questionnaire also included graphs of the various distribution types, with respect to which the subjects were asked to rank each delay distribution from least to most preferred in the context of the experiment (i.e., choosing a delay to a 30 s video presentation).

Results

In the probe condition to assess delay sensitivity, all 4 subjects showed exclusive or near-exclusive preference for the shorter video delay (96% across subjects). When subjects were given a choice between the FT and VT schedules, there was strong and reliable preference for the VT schedule across all delay values for 3 of the 4 subjects (96% across the final three sessions per condition). Subject 18 was only slightly risk prone (50–60% preference for the variable across all experimental sessions) across the range of delay values. Preference for the FT schedule was not observed for any subject under any condition.

Figure 1 shows choice proportions for each of the pairwise choices for the 3 subjects in Part 2. Solid lines indicate the proportional value of the green alternative as determined by Equation 2,

$$P_A = \frac{V_A}{(V_A + V_B)}, \tag{2}$$

where P_A is the proportion of choices allocated to alternative A, and V is the value of the alternative A distribution (green) or B distribution (yellow), as calculated from Equation 1. Proportional values in Figure 1 are based on obtained delay distributions. Subject 19 showed clear and reliable preference for the bivalued distribution over the exponential distribution, the exponential over the rectangular, the rectangular over the normal, and the normal over the FT. Subject 24 also preferred the bivalued to the exponential distribution. Unlike Subject 19, however, this subject showed a slight preference for the rectangular over the exponential (63% over the final three sessions). For this subject, then, the exponential distribution remained in place, pitted against the normal distribution, which resulted in clear preference for the exponential distribution. In subsequent conditions, this subject preferred the normal distribution to the FT, and the rectangular to the normal, as predicted by Equation 2.

Subject 23 also preferred the bivalued to the exponential and the exponential to the rectangular distribution. For this subject, however, a color bias precluded clear assessment of several subsequent conditions, as the option associated with the green key was selected consistently without regard to schedule. We took several measures to counter this strong bias, but only when the green key was associated with the FT and the yellow key a 1-s delay or a bivalued VT distribution did choices favor the yellow key.

Given the large number of elements in some of the distributions, the relatively small number of trials (particularly for the less preferred option), and the random method of element selection, the obtained delays for a given option varied from session to session, sometimes substantially, from the pro-

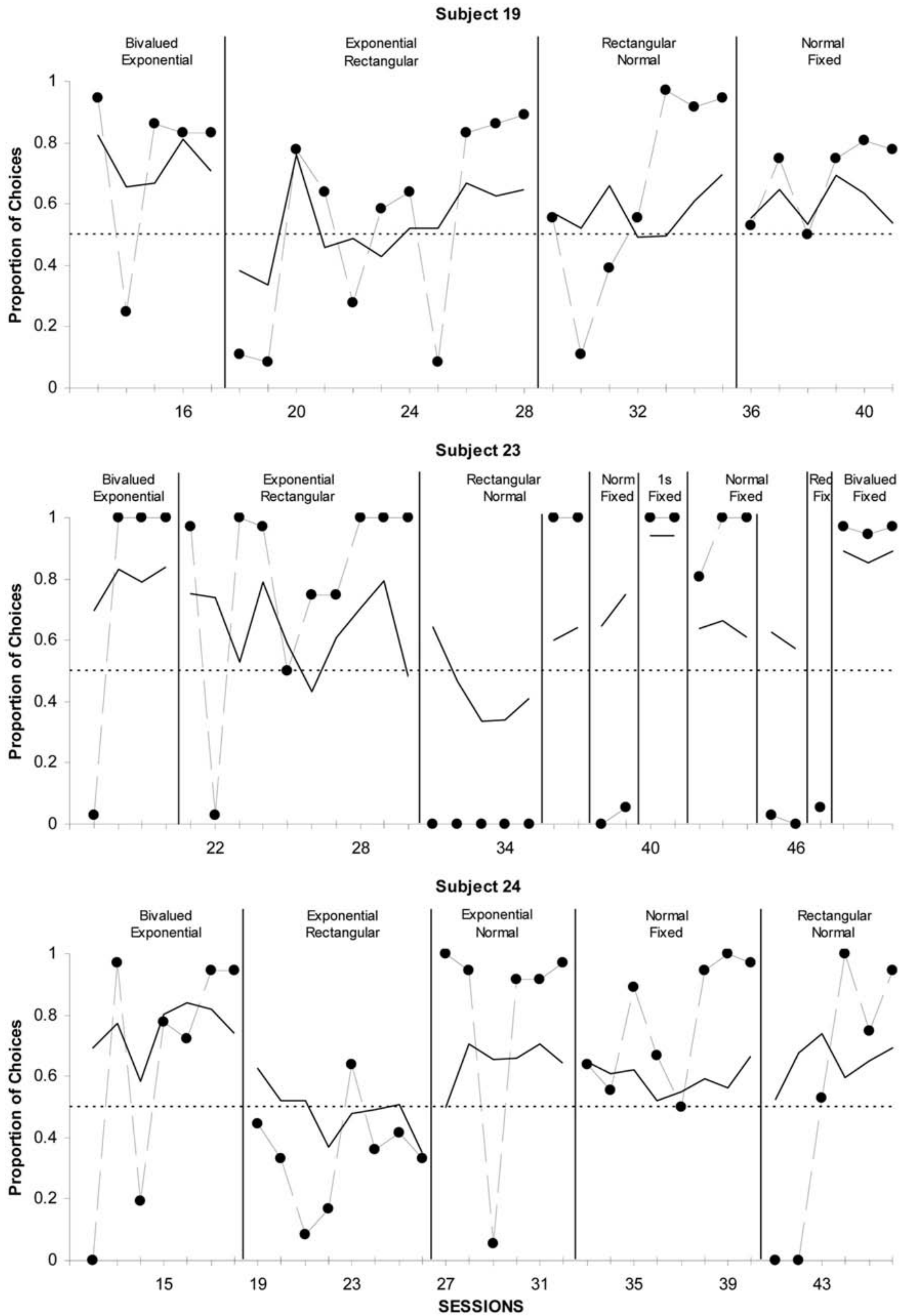

Figure 1. The proportion of choices for the higher valued alternative (based on Equation 1) for each subject in Part 2. The higher valued delay distribution is indicated above the lower valued distribution for each condition. Solid data paths indicate the proportional value of the higher valued alternative as calculated by Equation 2, using the obtained delay distributions for each session.

grammed value. Although in most cases the obtained distributions of delays did indeed approximate the programmed values, there were a few notable exceptions. For example, consider the exponential versus rectangular comparison for Subject 24. Although the programmed exponential distribution contained a higher proportion of short delays than the rectangular, the obtained delay distributions revealed very similar proportions (11.8% of exponential trials had a 1-s delay compared to 10.4% of rectangular trials; see Appendix A). Using Equation 1 to compare the obtained distributions for only the final three sessions of the rectangular versus exponential condition, the obtained exponential distribution had a lower value (.08) than the obtained rectangular distribution (.10). Thus, although this subject's preference for rectangular over exponential runs counter to the delay-based averaging of programmed delays, it is entirely consistent with the delays actually experienced by the subject. When evaluated against the obtained delay distributions, Equation 1 predicted obtained steady-state preferences in all 14 of 14 conditions with three or more sessions in Part 2, across all 3 subjects.

The rank order of each subject's preferences for the different delay distributions used are presented in Appendix B. Both the rank-order preferences derived from experimental sessions and the rank-order preferences reported by the subjects in the postexperimental questionnaire are shown for each subject along with the group mean. Because not every possible pairwise comparison was included in the study, this analysis assumes transitivity of preference. For example, if bimodal was preferred over rectangular and rectangular was preferred over normal, then the bimodal was assigned a higher rank than the normal even if that latter comparison was not directly tested. For none of the subjects were reported preferences in perfect accord with experimentally determined preferences and in only 13% (2 of 15) of cases were ordinal values from questionnaire results and experimental results in accord. Using Equation 1 as a reference point, 80% (12 of 15) of ordinal values from experimental results were consistent with Equation 1, whereas only 13% (2 of 15) of questionnaire results were consistent with the equation. A concordance comparison of rank order for each distribution relative to each of the others yielded a .73 gamma association between Equation 1 predictions and experimental results (a 1.0 indicating a perfect positive correlation) whereas questionnaire results are associated with Equation 1 with a −.27 gamma and experimental results with a gamma of −.40 (a −1.0 indicating a perfect negative correlation).

Discussion

Three of 4 subjects showed a clear preference for variable over fixed reinforcer delays (Part 1). These results are inconsistent with previous research with humans in this area (Kohn et al., 1992; Weiner, 1966), but are consistent with a large body of research on the topic with nonhuman subjects. Procedural differences, particularly in the nature of the reinforcer, represent the most obvious explanation for differences between the present and prior human data. Unlike previous experiments with humans in this domain, the present experiment used a consumable-type reinforcer: access to brief video clips. This procedural change enhanced delay sensitivity, producing results more akin to those seen with other animals. Similar results have been reported with humans on choice procedures with video clips (Hackenberg & Pietras, 2000) and other consumable-type reinforcers such as juice (Forzano & Logue, 1994) and escape from noise (Stockhorst, 1994).

Three of 4 subjects not only preferred variable delays over fixed reinforcer delays of the same mean value (Part 1), but also preferred variable distributions with higher proportions of shorter delays (Part 2). Both of these outcomes follow from the nonlinear averaging of reinforcer delays, an important feature of contemporary models of reinforcer value (Mazur, 2006). In general, there was systematic preference for the distribution with the greater proportion of short delays, suggesting a sensitivity to reinforcer immediacy like that seen in other animals (Killeen, 1968; Mazur, 1984, 1986). Similar averaging principles have been proposed by Bateson and Kacelnik (1995) and Gibbon, Church, and Fairhurst (1988). Although differing in detail, all such averaging rules assign differential weight to shorter delays in a distribution. As such, distributions with a higher probability of short delays (e.g., positively skewed distributions) should be preferred to distributions with a higher probability of long delays (e.g., negatively skewed distributions) with the same arithmetic mean. The data from Part 2 show that preferences were not only sensitive to variance in the delay distributions, but were ordered with respect to reinforcer immediacy (as calculated by Equation 2). These human data are therefore not only in qualitative but also in rough quantitative agreement with the nonhuman data.

That 1 of the 4 subjects in Part 1 conditions did not show the same strong preference for the variable delay seen in the other subjects may raise questions about the potency of video access as a reinforcer. To be sure, this type of reinforcer differs from unconditioned reinforcers such as food and water in a number of ways. For one thing, unlike more standard consumable reinforcers, video access depends on a specific conditioning history outside of and prior to the experiment. Given the varied histories people have with TV and videos, individual differences in the reinforcing efficacy of video access are perhaps to be expected.

Another distinctive feature of video access relative to more standard reinforcers is that its reinforcing efficacy depends at least in part on the continuity of the signal over time. This, in turn, depends on a variety of factors, including the duration of the clip, the rate or temporal pattern of the clips, and the behavior required to produce clips, to name just a few. These are all variables in need of further exploration and analysis. Apart from the present emphasis on species comparisons, a better understanding of the variables contributing to the reinforcing efficacy of video access would enhance its use as a methodological tool for use in long-term human behavioral research more generally.

Choice patterns were not related in any obvious way to verbally reported preferences. This lack of correspondence may reflect differences in the way the two samples of behavior were collected. The choice data were collected over hundreds of trials spanning several weeks whereas the verbal reports were collected in a single setting. Also, unlike the choice data, meaningful consequences were not differentially contingent on the verbal reports. Subjects may also have lacked the background to understand and respond effectively to the preference queries, even with the visual aids as supplement. Even so, the extent of the noncorrespondence is striking. Responses to postexperimental questionnaires were often in direct opposition to choices made during the experiment. This underscores the need for further work examining the relationship between verbally reported and actual preferences. There is considerable evidence that such verbally guided behavior may have properties unlike that of behavior governed by direct experience with the contingencies (e.g., Hackenberg & Joker, 1994). This should not be taken to imply that studies with verbally arranged choices do not yield meaningful data on human decision making, for certainly they do. What humans do (including what they say they will do) in these situations is an important question in its own right, as it maps well onto many real-life situations. It would be premature, however, to conclude from studies with verbal/hypothetical outcomes that choices in language-proficient humans occurs for the same reasons—as a result of similar mechanisms—as it does for other animals. A similarity in outcome may be the result of quite different mechanisms.

What is needed to address questions of mechanism are procedures more analogous to those used with other animals—procedures that rely more on direct experience with actual outcomes and less on verbally stated outcomes. This was a central objective of the present study. When the procedures used to study choice in humans and other animals were made more similar, performances also converged. That human choice patterns can be brought into alignment with well-established findings with other animals suggests that prior human–animal differences may have more to do with procedural disparities than with genuine species differences.

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Appendix A

Programmed and Obtained Delay Distributions

Programmed Delay Distributions (all values in seconds, all *M*s = 30)

Bivalued: 1, 59

Exponential: 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 5, 5, 5, 5, 5, 5, 5, 5, 10, 10, 10, 10, 10, 10, 10, 10, 15, 15, 15, 15, 15, 15, 15, 20, 20, 20, 20, 20, 20, 25, 25, 25, 25, 25, 30, 30, 30, 30, 30, 35, 35, 35, 35, 40, 40, 40, 40, 45, 45, 45, 50, 50, 50, 55, 55, 55, 60, 60, 65, 65, 70, 70, 75, 75, 80, 85, 90, 95, 100

Rectangular: 1, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 59

Normal: 1, 1, 5, 5, 5, 10, 10, 10, 10, 15, 15, 15, 15, 15, 15, 20, 20, 20, 20, 20, 20, 20, 20, 25, 25, 25, 25, 25, 25, 25, 25, 25, 30, 30, 30, 30, 30, 30, 30, 30, 30, 30, 35, 35, 35, 35, 35, 35, 35, 35, 35, 40, 40, 40, 40, 40, 40, 40, 40, 45, 45, 45, 45, 45, 45, 50, 50, 50, 50, 55, 55, 55, 59, 59

Obtained Delay Distributions (arithmetic mean, value based on Equation 1)

Subject 19: Bivalued (33.1 s, 0.23), Exponential (32.4, 0.10), Rectangular (28.6, 0.08), Normal (30.0, 0.05)

Subject 23: Bivalued (28.9 s, 0.27), Exponential (28.0, 0.12), Rectangular (32.3, 0.07), Normal (29.5, 0.06)

Subject 24: Bivalued (30.7 s, 0.25), Exponential (29.6, 0.11), Rectangular (28.6, 0.10), Normal (30.7, 0.05)

(*Appendixes continue*)

Appendix B

The Rank Order of Preference for Each Distribution for Each Subject Based on Experimental and Questionnaire Results

	Experimental rank	Self-report rank
Subject 19		
	1 Bivalued	1 Rectangular
	2 Exponential	2 Bivalued
	3 Rectangular	3 Exponential
	4 Normal	4 Normal
	5 Fixed	5 Fixed
Subject 23		
	1 Bivalued	1 Normal
	2 Exponential	2 Rectangular
	3 Rectangular	3 Exponential
	3 Normal	4 Fixed
	3 Fixed	5 Bivalued
Subject 24		
	1 Bivalued	1 Fixed
	2 Exponential	2 Bivalued
	3 Rectangular	3 Normal
	4 Normal	4 Rectangular
	5 Fixed	5 Exponential
Average		
	1 Bivalued	2.3 Rectangular
	2.3 Exponential	2.7 Normal
	2.7 Rectangular	3 Bivalued
	3.7 Normal	3.3 Fixed
	4.3 Fixed	3.7 Exponential

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