The Effect of Number of Prior Operant Repetitions on Choice Behavior

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Abstract

Human participants in two experiments learned to perform behaviorally equivalent operants consisting of sequences of keystrokes on the computer keyboard. The independent variables were the number of times operants were practiced, both the ratios of those numbers as well as the absolute numbers. The dependent variable was the number of times each operant was then chosen in forced-choice tests.

The ratios of repetition frequency tested ranged from 25:50 to 300:750. The observed general preference for the high-repetition operants was shown to depend on both the ratio and the absolute number of repetitions of the low-repetition alternative, with the preference weaker when the number of repetitions of the lower-repetition alternative is above a certain threshold, suggesting a partial automatization explanation of the results. In addition, preference was systematically affected by the amount of familiarity participants had with the general procedure, regardless of the specific operants being tested.

An important issue in experimental psychology is how learning history variables interact with prevailing conditions in determining the properties of learned behavior. Of the many different history variables that can be experimentally manipulated, the one addressed in the present two experiments is the effect of the number of prior repetitions of operants (often called "practice") on subsequent preferences among those operants.

While the present studies could also have been conducted with other kinds of response sequences or units, including ones that do not meet the criteria for the definition of an operant, the advantage of using the operant as the unit is that a) it has been studied extensively, b) it is ubiquitous, and c) the results obtained will then be generalizable to other types of operant classes.

When conducting an experiment to compare the effects of different values of a history variable in an individual participant (rather than assigning each value to a different group of participants and then comparing averages), each participant must learn several distinct but behaviorally equivalent operant classes. In the present studies, each participant learned up to fifty-four operant classes presumed to be behaviorally equivalent. All of these consisted of a sequence of eight keystrokes whose beginning and end was behaviorally marked in a consistent way. Even though the operant as a whole is comprised of a series of keystrokes, the entire sequence (usually executed, after practice, in approximately two seconds or less) can be regarded as a single operant. The justification of this view is that all operants, regardless of type, consist of sequences of sub-operants, and any response sequence can function as an operant provided that its beginning and end is marked consistently by behavioral events, as explained in Mechner (1992) and Mechner, Hyten, Field, & Madden (1997).

The specific learning history variable addressed here is the number of times each of the operant classes was repeated by the participants during the training sessions. The

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research literature relating to the repetition variable can be divided into experiments examining the effects of repeated exposure to stimuli and experiments examining the effects of repeated performance of actions (or operants). This division mirrors the distinction in traditional memory research between the two types of memory often referred to as declarative and procedural (also often termed explicit and implicit memory; see Squire, 2004 for a review).

Neuroimaging research supports the distinction between these two memory systems, with declarative memory being correlated with activity in the medial temporal lobe (often with additional activation in the pre-frontal cortex), while procedural memory tends to be correlated with activity in the striatum or the cerebellum. The term "implicit memory" tends to be used as a catch-all category for all types of learning that take place without explicit awareness. In real-world situations, of course, most learning requires both explicit and implicit memory. The operant used in the current experiments involves both declarative and procedural memory, therefore corresponding more closely to real-world learning than many laboratory memory paradigms.

There is a large body of memory research on the relationship between frequency of exposure to a stimulus and later recall of that stimulus, with a significant number of experiments also dealing with the effect of the spacing of repeated exposures on recall. The general finding is that a greater number of repetitions of the item to be learned produces improved recall regardless of spacing. This effect is not due merely to the greater amount of time spent viewing the stimulus, since, for example, two four-second exposures produce significantly more correct responses than one eight-second exposure (Liu & Ma, 1970; Nelson, 1977). On the other hand, some experiments have shown no effect of repetition on recall (Craik & Watkins, 1973; Hall & Buckolz, 1982; Jacoby, 1973).

There are also many studies of the relationship between amount of training and the degree of control acquired by stimuli in discrimination/generalization tasks (Farthing & Hearst, 1968; Sewell & Nickel, 1979) and in reversal (Lovejoy, 1966; Mackintosh, 1965, 1969). In general, results from this body of research show that additional training beyond the minimum required for mastery of the task (sometimes also called overlearning, or overtraining) improves stimulus control and leads to faster reversal, although this effect is far from clear-cut and some of the findings are conflicting.

In addition, a number of experiments have examined the relationship between frequency of exposure to a stimulus and later ratings of liking for those stimuli. The resulting preference for the more frequently-seen stimuli is termed the mere-repeated-exposure phenomenon (Hamid, 1973; Maslow, 1937; Zajonc, 1968, 2001a, 2001b). This effect is quite robust; it even occurs when stimuli are presented subliminally and participants are unaware of having seen some of them more frequently than others, suggesting that the formation of a preference is not due to a mere increase in explicit familiarity with a given stimulus (Zajonc, 2001a). The number of exposures necessary to generate preference often depends on the type and complexity of the stimuli used (Hamid, 1973; Saegert & Jellison, 1970). However, nowhere in the literature does there appear to be any examination of the effect of repetition on preference for distinct actions, or operants (rather than stimuli). The current experiments thus explore whether the mere-repeated-exposure effect is also seen when the repeated entity is the performance of operants rather than stimulus exposures.

Regarding repetition of actions, there does exist a large motor learning literature relating to what is sometimes called the law of practice, which states that retention and/or fluency of performance of a motor skill increases with repetition in a negatively accelerated function (Annett, 1979; Newell & Rosenbloom, 1981). Often associated with this type of research is the term automaticity, which refers to the resulting behavior's speed, stereotypy, accuracy, and resistance to disruption (Shiffrin, 1988, pp. 740-767; Schmidt, 1988, p. 74). In general, memory for motor skills is retained over longer intervals than memory for verbal items (see Annett, 1979 for a comparison between the two literatures). In the motor learning literature, however, learning typically takes place to a criterion, which implies that the number of repetitions was not held constant across subjects.

Other studies in the operant learning literature have addressed the relationship between the number of times an operant was previously executed and its subsequent "strength." Most of these studies used operants defined by single switch closures (such as bar presses or key pecks) and examined resistance to extinction as a measure of operant strength (Dyal & Holland, 1963; Senkowski, 1978). Others examined responding in the presence of free food, often called contrafreeloading (Jensen, 1963; Lentz & Cohen, 1980). The results of these studies vary, and depend critically on how subsequent strength is defined and measured, and on the specific procedure and schedule used to control repetitions during training.

Finally, there are a few studies that attempt to measure the effect of repetition of actions on choice between alternatives. Individuals given practice in a particular problem-solving method, for example, are far more likely to choose that method later even when better alternatives are made available after additional training (Neves & Anderson, 1981). In a series of recent experiments in which subjects were asked to press a button indicating the choice of the best hypothetical train to a given city, they continued to select the practiced alternative (here referred to as a "routine") a majority of the time even after the contingencies had been explicitly changed so that the other option became optimal (Betsch, Haberstroh, Molter, & Glöckner, 2003). This effect was seen even when the routine had been practiced so few times that automatization, as it is normally defined, was not considered to have taken place.

One of the objectives of the present studies is to shed light on some of the possible reasons for the generally inconsistent and often-conflicting findings regarding the effect of number of repetitions, seen in the literatures referenced above. Some amount of repetition, however minimal, is usually necessary for learning to take place. When measuring learning in terms of preference among the different operants that were learned, the main questions addressed in the present experiments were:

a) What is the effect of different numbers of prior repetitions of operant behaviors on choice or preference?
b) Is there a minimum number of times a particular operant must be repeated in order to have a subsequent advantage in a choice situation?
c) What is the effect of the ratio of the number of times two operants were repeated on the advantage of one over the other?

These are basic questions, with practical implications ranging from educational theory and performance learning technology to addiction treatment.

The present studies address these questions by examining the relationship between number of prior repetitions of operants and their subsequent strength under simple two-alternative forced-choice conditions. The participants repeated up to fifty-four different but presumably equivalent operants different numbers of times during their experimentally imposed learning histories. The dependent variable was the relative number of times those same operants were chosen in subsequent tests in which stringent new requirements for accuracy and speed, including a punishment contingency, were imposed. These test conditions were designed to be stressful so as to sharpen the consequences of the choices and make the observed behavioral effects more sustained throughout the observation period and therefore presumably more stable.

EXPERIMENT 1

METHOD

Participants

Seven human participants of different ages, three male and four female, were recruited through flyers posted on a local university campus.

Apparatus

The experimental room contained four computer workstations separated by screens. Each of the computer keyboards was fitted with a particleboard “mask” that covered all the keys except those used in the experiment: 12 character keys (tyuighjkvbnm), the space bar, the enter key, the number keypad, and four function keys. The position of the mask was such that it prevented participants from touch-typing.

Procedure

All seven participants were subjected to the same procedure. The particular type of operant used in this experiment required the participants to type non-word sequences of keystrokes on the computer keyboard. Each sequence consisted of a press of the space bar, six character key presses (for example, "itkvhm") and a press of the enter key, in that order. The participants learned six of these operants at a time, each one distinct from the others, due to a different combination of letters, and typed each one a specified number of times before being tested for preference; they were then given a different set of six operants to learn and repeated each of them a certain number of times before being tested again, and so forth, for a total of nine sets of operants learned and nine tests during the experiment. This allowed nine different repetition ratios to be tested in Experiment 1.

In each set of six operants, three of them were repeated a lower number of times by the participants prior to testing (low-rep group) and the other three were repeated a higher number of times (high-rep group). Having three distinct (but presumably equivalent) operants per repetition level was an experimental design feature intended to help cancel any behavioral differences between operants. Throughout the preference tests, the participants were repeatedly offered a choice, always between two operants, and expressed their choice by typing one of them. The specific pairs of operants offered as choices varied throughout the test but one was always from the low-rep group and one from the high-rep group. Preference for the high-rep group could thus be measured by how often participants chose operants from that group during testing. The specific repetition levels for each set of operants are shown in the Appendix in Table 1, along with the order in which they were presented to the participants.

The participants completed one session every weekday for a total of 19 sessions, making the total length of the experiment almost four weeks. Each session took place at the same pre-scheduled time of day. The length of the sessions varied from participant to participant depending on how long it took them to type that session's fixed number of operants; the average session length was approximately 50 minutes. Participants were paid $5 in cash at the end of each session that they completed; in addition, they earned 28 cents for each correctly typed operant during the test periods. They signed consent forms agreeing to keep such factors as caffeine or substance consumption, meals and amount of sleep consistent from day to day during the course of the experiment. The money earned during testing throughout the study was totaled up for each participant and they received a check for that amount on the last day of the experiment. The total earned by the participants (including the guaranteed fee of $5 per session) varied from a low of $450 to a high of $590.

At the beginning of each session the participants logged on to a workstation by typing their initials, the date, and the session number. The procedure then was as follows: Each of the six operants in a given group was numbered with an arbitrary reference number from two to nine (the number one was never used as a reference, to avoid unconscious favoritism). A number appeared in the middle of the computer screen to cue the participants to type that particular operant. (At any time during the session they were able to press the corresponding key on the number keypad, causing the letters making up that operant to be displayed on the screen for three seconds.) Participants then typed the operant, beginning with the space bar, followed by the six letters, and ending with the enter key. The screen display was black until the space bar was pressed. Then it changed to blue for the duration of each operant, reverting back to black after the enter key was pressed. The letters typed by the participants did not appear on the screen.

If an operant was typed correctly, a bright green square approximately 4 by 6 inches in size flashed in the middle of the screen for 500 milliseconds immediately following completion of the operant. If the operant was typed incorrectly, the green square did not appear and the screen simply went back to black. Either way, the participant was then free to type the same operant again, at his or her own pace, until 25 correct repetitions had been completed (incorrectly typed operants were not counted toward the total). At that point, a different operant's identification number was displayed on the screen as a cue to begin typing that operant. This continued until the programmed number of required repetitions for each operant had been performed. The blocks of 25 operants were pre-programmed in an order designed to be unpredictable to the participants. Depending on the repetition ratio, completing the total required number of repetitions for all six operants in a given set took from one-half to three sessions.

As soon as the programmed number of repetitions for all six operants in a group had been completed, a message appeared on the screen instructing the participants to start the preference test for that group. During testing, two numbers appeared on the screen instead of just one; the participant chose whichever one of those two operants he or she preferred and typed it (always beginning with the space bar and ending with the enter key, as during practice). If the operant was typed correctly, a high-pitched beep sounded and a message appeared on the screen, stating "You just earned 28 cents. Ring it up." (The green square was never presented during testing.) Every time money was earned the participant was required to type the amount earned on the number keypad and press enter to add the money to his or her running total, which was displayed continuously in the top left-hand corner of the screen throughout the test period. If the operant was not typed correctly (i.e. did not match one of the two operants offered as a choice), a low-pitched tone sounded and a message appeared on the screen saying "You just lost 14 cents." 14 cents was then automatically subtracted from the participant's total. Then another pair of numbers appeared on the screen and the participant chose one of the corresponding operants to type, and so on for the duration of the testing period.

If at any time during testing participants paused for more than 3.5 seconds between keystrokes, they were also penalized 14 cents, in the same manner. If participants were unable to remember either of the two operants offered as a choice and needed to press one of the corresponding number keys on the number keypad in order to display the letters on the screen before typing the operant, they were also penalized 14 cents. During each test period participants were presented with 216 opportunities to choose and type an operant. Each of the six operants was offered as a choice the same number of times in a given test, half the time listed as the first of the two choices and half the time listed as the second. Each of the three operants in the low-rep group was also paired an equal number of times with all of the operants in the high-rep group and vice versa. The choices were always presented in an order designed to be unpredictable.

The sole purpose of the first session of the experiment was to familiarize the participants with the procedure and to eliminate the initial steepest portion of the inevitable learning curve regarding the procedure. The data gathered during this first session were not counted toward the final results of the experiment. During this practice session participants were individually instructed in the task; they were then given four (instead of six) operants, different from the ones to be used in the experiment proper, which they were required to type 40 times apiece. They were then given instructions as to the format of the test before completing an abbreviated test in which they had 48 chances to choose and type an operant and earn 28 cents. They were told that this was just a practice test to allow them to become familiar with the procedure and that the money earned would not count toward their total compensation for the rest of the experiment.

RESULTS

In each test period, the number of times operants from the low-rep and high-rep groups were chosen (i.e., typed) by the participants was recorded. Figure 1 shows the number of times participants typed high-rep vs. low-rep operants as a proportion of all choice opportunities for all 9 programmed repetition ratios, averaged across all participants. In other words, for each of the different repetition ratios that were tested, the average percentage of operants that were chosen from the high-rep group is the lighter (upper) part of that column, while the average percentage of operants chosen from the low-rep group is the darker (lower) part. Individual data are shown in the Appendix in Table 2, listed by participants' initials; the "Average" column of this table is what is shown in Figure 1.

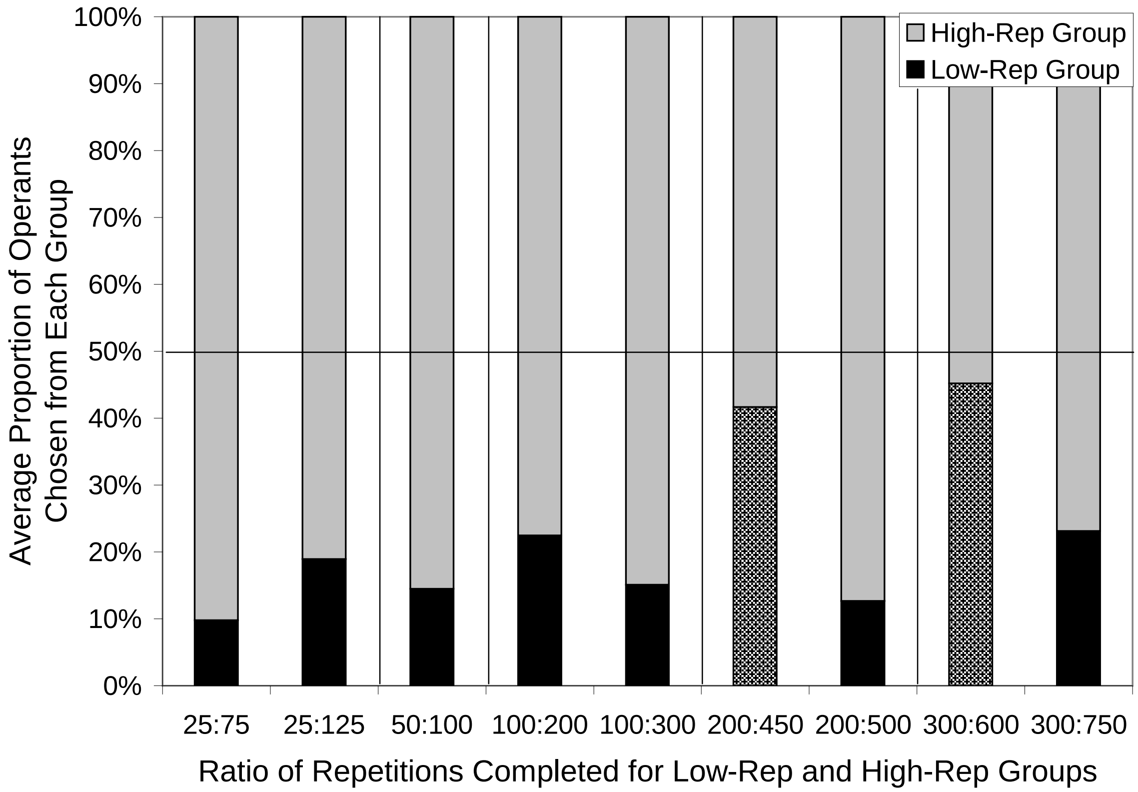

Fig. 1. Results from all nine tests in Experiment 1. The upper part of each column shows the average proportion of choices of operants from the high-rep group, and the lower part shows the average proportion of choices from the low-rep group. The columns are grouped according to the low-rep value for easier visual comparison, rather than in chronological order. The two columns in which the lower part is dotted rather than solid black are those tests in which the average preference for the high-rep group was not statistically significant.

The two columns in which the lower portion is dotted are for the tests in which preference for the high-rep group was <u>not</u> statistically significant. In all other tests, preference for the high-rep operants, while never universal, was statistically significant at the .01 level using paired-values t-tests. Thus, preference for the high-rep group was weakest when the number of repetitions for the low-rep group was highest – either 200 or 300 – unless the ratio was also high (at least 2:5).

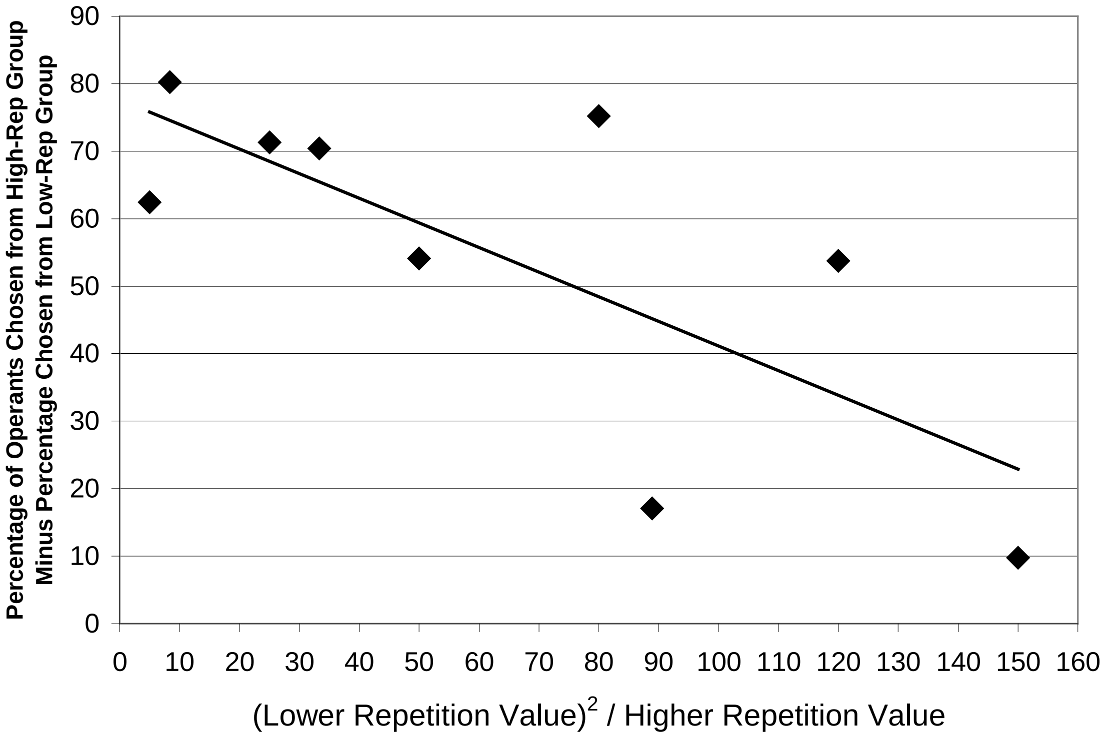

Fig. 2. Results from all nine tests in Experiment 1. Relationship between the ratio and absolute number of repetitions for the high-rep and low-rep operants and the magnitude of the preference for high-rep group. The X axis is the lower number of repetitions in each comparison squared and divided by the higher one. The Y axis is the average percentage of operants chosen from the low-rep group minus the average percentage chosen from the high-rep group.

Figure 2 presents the same average data shown in Figure 1, in a different format so as to convey visually the relationship between the ratio of repetitions and the size of the resulting effect. In this figure the value on the X axis is an index formed by dividing the lower number of repetitions in each comparison by the higher one and then multiplying the resulting fraction by the lower number. This index thus encompasses both the ratio of the lower number to the higher, and the absolute values. The Y axis value is the average difference between the proportion of total operants typed during testing from the high-rep group and the proportion from the low-rep group. The trendline shows the linear relationship between the two. A more complete multiple regression analysis of this data, combined with data from Experiment 2, is presented in the results section for Experiment 2 below.

EXPERIMENT 2

In Experiment 1, a statistically significant average preference for the high-rep group was observed for all except the 200:450 and 300:600 ratios of repetitions. These two ratios have in common the fact that the lower values (200 and 300) are the two highest lower values used. Ratios that used a smaller number of repetitions for the low-rep group (25, 50 or 100) all resulted in a statistically significant preference for the high-rep group regardless of what number of repetitions was programmed for the high-rep group (in other words, ratios of 25:75 and 25:125 were indistinguishable in terms of the size of the high-rep preference produced). Therefore a decision was made to run another experiment focusing on smaller low-rep repetition values, varying the high-rep repetition values paired with them to determine how much of a ratio reduction is needed to reduce preference for the high-rep group below significance.

METHOD

Eight more participants were recruited in the same manner as previously, four men and four women of varying ages. The apparatus and procedure was identical to that for Experiment 1, with two major changes. First, seven different repetition ratios were programmed, for a total of seven sets of six operants learned and tested. The specific repetition levels are shown in Table 3. Note that three of the repetition ratios (25:75, 50:100 and 100:200) are exactly the same as three of the ones in Experiment 1, while all of the others are lower than in Experiment 1. Due to the smaller total number of repetitions required in this experiment, Experiment 2 was completed in a total of 10 sessions over two weeks.

Second, although five of the participants in Experiment 2 were tested using the same format as in Experiment 1, the other three participants were given a different test format. The forced-choice test of Experiment 1, by its very nature, constrained the participants' preferences for individual operants to some degree: since there was always an option available from both the low-rep and high-rep groups, the most efficient way to take the test (by typing the fewest number of unique operants possible) was to limit oneself to either the three low-rep operants or the three high-rep operants. In order to avoid this constraint, these three participants in Experiment 2 were allowed to type any of the six operants they liked during the test period, provided they adhered to a minimum variability requirement: each operant typed could not be one of the two most recently chosen. This was done to ensure that the results of Experiment 1 were not merely an artifact of the testing procedure, as they logically could have been.

RESULTS

Once again, the number of times operants from the low-rep and high-rep groups were chosen by the participants during testing was recorded.

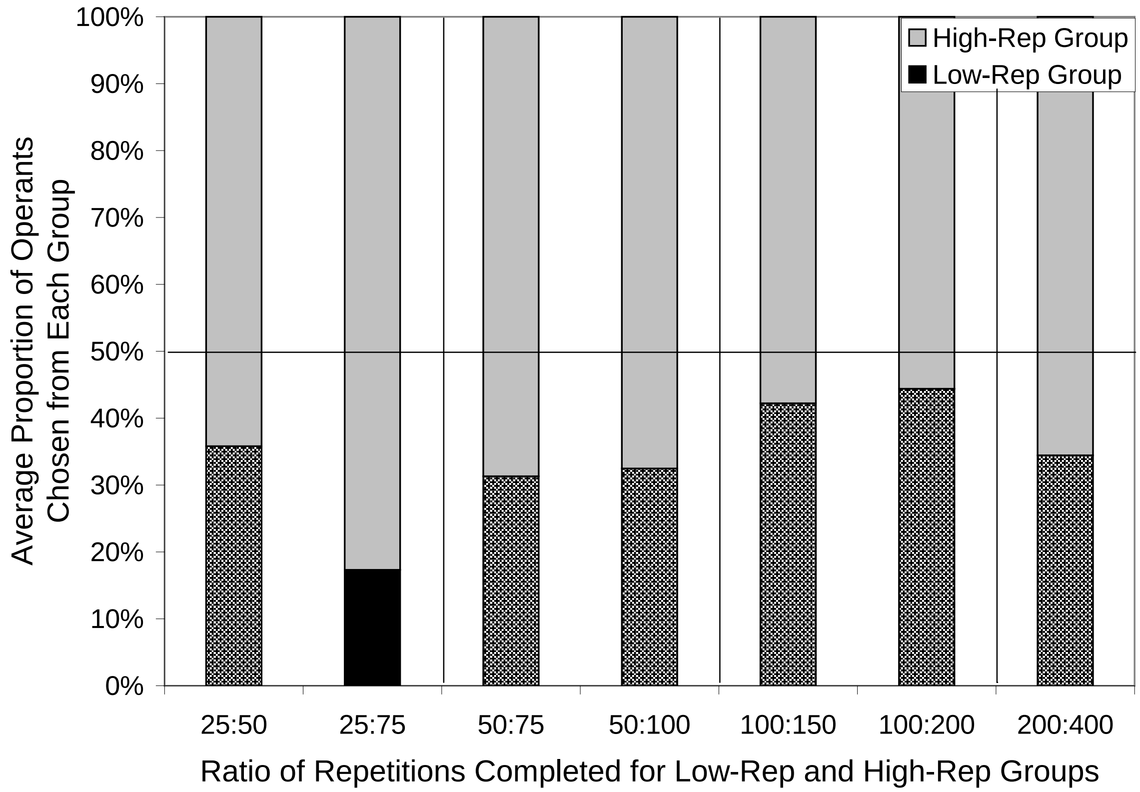

Fig. 3. Results from all seven tests in Experiment 2. The upper part of each column shows the average proportion of choices of operants from the high-rep group, and the lower part shows the average proportion of choices from the low-rep group. The columns are grouped according to the low-rep value for easier visual comparison, rather than in chronological order. The six columns in which the lower part is dotted rather than solid black are those tests in which the average preference for the high-rep group was not statistically significant.

Figure 3 shows the number of times participants typed high-rep vs. low-rep operants as a proportion of total choices in the test period for the 7 programmed repetition ratios, averaged across all participants. Individual data is shown in the Appendix in Table 4: data from the three participants who had the alternative test format are shown on the right side of the table just before the “Average” column. While they show less tendency to extremism than the other participants (being less likely to choose all of their operants from only one of the two groups), their data are not significantly different from that of the others, and thus are averaged with those of the other five participants and shown in Figure 3. As can be seen from the number of dotted columns, none of the tests produced a statistically significant preference for the high-rep group except for the 25:75 (1:3) ratio, the steepest ratio programmed in Experiment 2.

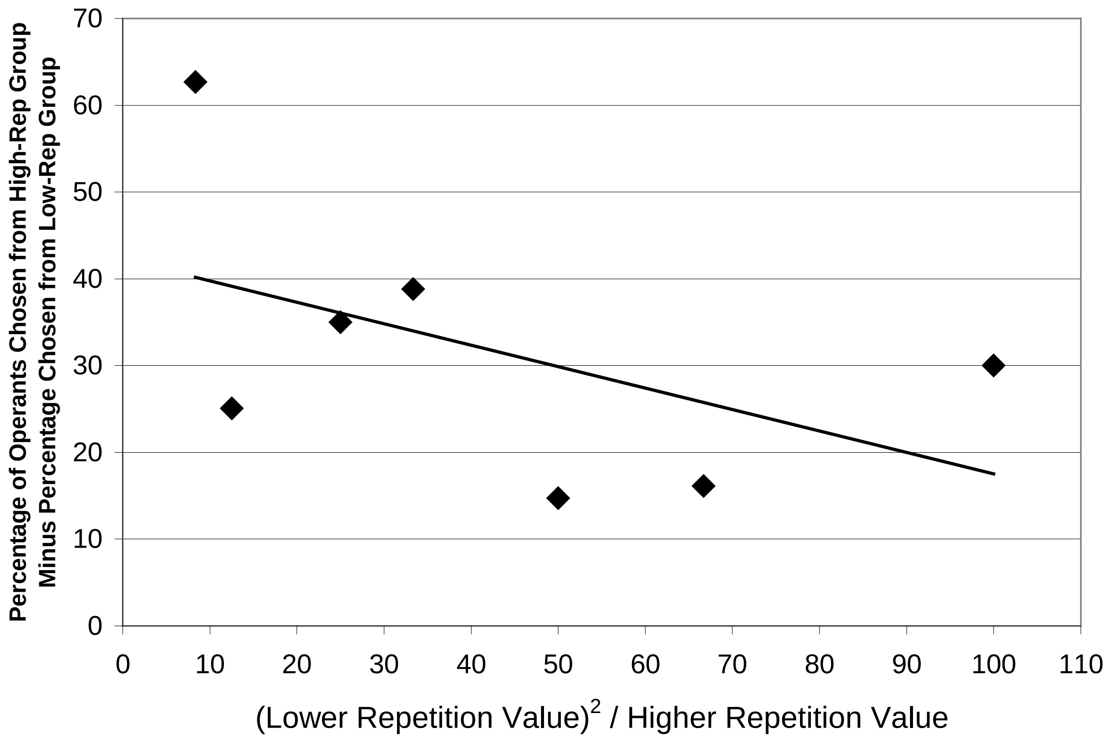

Fig. 4. Results from all seven tests in Experiment 2. Relationship between the ratio and absolute number of repetitions for the high-rep and low-rep operants and the magnitude of the preference for high-rep group. The X axis is the lower number of repetitions in each comparison squared and divided by the higher one. The Y axis is the average percentage of operants chosen from the low-rep group minus the average percentage chosen from the high-rep group.

As was done earlier, the same average data presented in Figure 3 is re-presented in Figure 4 in the same format to show visually the relationship between the ratio/range of repetitions and the resulting effect.

In order to express and quantify the relationship between the ratio of relative numbers of repetitions and the magnitude of the resulting preference for high-rep vs. low-rep ones, a number of multiple linear regression analyses were performed on the data from Experiments 1 and 2, both separately and together. These analyses also reconciled the differences in the results of the two experiments. In all regression analyses, the Y values are the average percentage of the test period operants from the high-rep group minus the average percentage that were from the low-rep group. It is important to stress that the Y values are averaged across participants.

The X_1 values were simply the lower number of repetitions in each ratio, and the X_2 values were the higher number of repetitions in each ratio. The use of only these values to calculate a multiple linear regression for the data from Experiment 1 results in an R^2 of .65. However, adding the order in which the sets of operants were learned and tested as an additional variable, X_3, causes the R^2 value of this regression equation to jump to .88.

Performing the latter multiple linear regression (with the same three X values) on the data from Experiment 2 results in an R^2 of only .45; the equation generated is also considerably different from the corresponding equation found in the multiple regression analysis of the Experiment 1 data. The same three-X regression analysis on the combined data from both experiments results in an equation with an R^2 of .75. This would suggest that the results from the second experiment are incompatible with those from the first, until one takes into account an important procedural difference between them: due to the lower repetition ratios being tested in Experiment 2, the participants in that experiment typed far fewer operants overall over a much shorter time period than did those in Experiment 1. Thus, one can add an X_4 to account for the variable defined as the total number of repetitions of the typing task itself (regardless of operant) previously completed by participants at the time they are being tested on a given repetition ratio. Now, the regression analysis performed on the data from Experiment 2 using these four X values results in an R^2 of .89. Finally, the same four-X regression analysis performed on the combined data from the two experiments results in an R^2 of .83. The data used in this final regression analysis, as well as the overall equation generated, are shown in Table 5 (values from Experiment 1 are in the top portion of the table and those from Experiment 2 in the lower portion).

DISCUSSION

The results of both experiments indicate that what may seem like small differences in relative numbers of repetitions (for example, 50:100) can result in quite a strong preference for the more highly practiced operants in at least most if not all participants. And what appear to be relatively large differences (for example 200:450) can show much weaker effects. This suggests that if the lower number of repetitions is high enough on an absolute scale, the high-rep alternative may lose much of its advantage. This finding is supportive of an automatization explanation for at least part of the observed effect, as both operants in the latter case are repeated often enough to undergo automatization. The idea that automatization is taking place in the more highly-practiced operants in both studies is given further support by the fact that those operants repeated 200 times or more are performed an average of .64 seconds faster during their last block of practice than during their first block. For operants practiced less than 200 times, this average speed-up is only .40 seconds. This may not seem like a large difference, but it is significant at the .0001 level.

Automatization, mentioned earlier, is an effect seen in both cognitive/perceptual skills and motor skills. Through repetition, elements of a behavioral sequence become fused into a single longer routine, with decreasing utilization of cues and feedback

(Glencross, 1973; Keele, 1982). As this fusing process proceeds, the routine become less and less chain-like and comes to function increasingly as a unit. This is the well-known "chunking" phenomenon. There is a large body of work on automatization looking at the effects of repeated practice on fluency and speed of the response. The speed-up effect appears to be very stable, following a log-log power law function (Newell & Rosenbloom, 1981). In addition, there is some evidence that the effect of practice on accuracy follows a similar function, but there has been much less experimental work done in that area (Newell & Rosenbloom, 1981). The current experiments show that the repetition frequency of operants affects preference for them as well, suggesting that above a certain threshold of repetitions, operants become automatized and gain a later advantage in choice situations. If the lower number of repetitions is high enough for automatization to take place, the advantage of the higher repetition operants diminishes, and the higher number of repetitions must be increased further for those operants' advantage to be maintained. The two tests in which the lower number of repetitions was the highest (300 repetitions) had the most subjects who split their test choices more or less evenly between the two repetition frequency categories (rather than skewing strongly to either one or the other).

For the tests of smaller absolute numbers of repetitions (25:50, for example), it is possible that the mere-repeated-exposure phenomenon (rather than automatization) is the reason for the preference for the more often-repeated alternative. As mentioned earlier, the operant behavior studied here combines both explicit memory for verbal stimuli and (implicit) motor learning. It would thus appear that the mere-repeated-exposure effect and the process of automatization are functioning in parallel, with one or the other becoming dominant at different absolute repetition levels.

The preference effects seen in both studies also show a clear <u>interaction</u> between 1) the overall learning history for the task as a whole (as opposed to the performance of specific operants) and 2) the relative numbers of repetitions for the specific operants being tested at a given time. The fact that the R^2 for the Experiment 1 multiple regression equation rose from .65 to .88 when the order in which the repetition ratios were tested was added as an X variable indicates that learning (and testing) order accounts for a considerable amount of the variability in the data. In spite of the throw-away practice session scheduled at the beginning of each experiment, there appears to be a continuing effect of repeatedly learning and practicing these types of operants and being tested on them using the same test format. This effect progressively favors the high-rep groups regardless of the specific numbers involved. Note, for instance, that the two ratios in Experiment 1 which did not result in a significant preference for the high-rep group (200:450 and 300:600) both occurred early in the experiment. It is possible that increasing familiarity with the format of the test leads to increasing efficiency in test-taking strategies. This may well represent an interaction of explicit declarative memory (for test strategies) with the types of implicit memory inherent in the task.

Furthermore, adding the total number of repetitions completed as a fourth X variable to the regression analysis for the combined Experiment 1 and 2 data also raised the R^2 from .75 to .83. So, in addition to the effect of the actual relative number of repetitions being tested and the progressive effect of having been repeatedly tested on a certain type of task, there is an additional progressive learning effect of total repetitions of the overall task. Thus when repetition ratios of 50:100 and 100:200 were tested in Experiment 1, they produced a statistically significant preference for the high-rep operants, while when the identical ratios were tested in Experiment 2 (in which participants completed far fewer total repetitions) the effect, while present, was not statistically significant. This makes sense, as certain meta-elements, such as the mask on the keyboard, the use of the space bar and enter key, etc., were the same throughout both experiments. General familiarity with a procedure and apparatus increases with repeated exposure, even if individual behaviors within the procedure continue to show differential effects. Here we may be seeing automatization at work on a more cognitive level: automatization of the task as a whole. The speed and fluency of the performance as a whole certainly increased dramatically for all subjects during the course of both experiments. In any case, this effect is another type of history variable that would be present and active in any type of behavioral experiment involving repeated exposure to a particular procedure and apparatus– an effect that is often ignored when the results of procedures are analyzed and reported.

Finally, there are significant individual differences among participants. Even the repetition ratios that produced the strongest preference for the high-rep operants did not produce uniform results. Even those ratios that produced the weakest preference for the high-rep operants still caused some participants to choose the high-rep group a large majority of the time. One likely reason for this individual variability is the interaction between the participants' lifetime learning histories and the short-term learning history specifically programmed by these studies. Typing groups of letters on the computer keyboard, even ones intended to be nonsense patterns that do not form words, is still something with which most people in our society have considerable experience. Almost all of the participants, when debriefed at the end of the experiment, gave idiosyncratic reasons for liking certain operants more than others. When measured against individual preferences formed by idiosyncratic life histories, it seems plausible that the effects of short-term manipulations such as those used in these studies would often be small by comparison, and are therefore best measured by averaging indices that cancel out these individual differences. However, the results of these experiments nevertheless do provide a reliable equation for predicting the effects of number of repetitions on subsequent choice.

The broader significance of the present series of experiments is the demonstration that under performance conditions, the <u>choice</u> of behaviors, as well as the speed and accuracy of those behaviors once chosen, can be a function of the frequency of their repetition during learning, and of history variables in general.

REFERENCES

Annett, J. (1979). Memory for skill. In M. M. Gruneberg (Ed.), *Applied Problems in Memory.* New York: Academic Press.

Betsch, T., Haberstroh, S., Molter, B., & Glöckner, A. (2003). Oops, I did it again – relapse errors in routinized decision making. *Organizational Behavior & Human Decision Processes,* 93, 62-74.

Craik, F. I. M., & Watkins, M. J. (1973). The role of rehearsal in short-term memory. *Journal of Verbal Learning & Verbal Behavior,* 12, 599-607.

Dyal, J. S., & Holland, T. A. (1963). Resistance to extinction as a function of the number of reinforcements. *American Journal of Psychology*, 76, 332-333.

Farthing, G. W., & Hearst, E. (1968). Generalization gradients of inhibition after different amounts of training. *Journal of the Experimental Analysis of Behavior,* 11, 743-752.

Glencross, D. J. (1973). Temporal organization in a repetitive speed skill. *Ergonomics,* 16, 765-776.

Hall, C. R., & Buckolz, E. (1982). Repetition and lag effects in movement recognition. *Journal of Motor Behavior*, 14, 91-94.

Hamid, P. N. (1973). Exposure frequency and stimulus preference. *British Journal of Psychology*, 64, 569-577.

Jacoby, L. L. (1973). Encoding processes, rehearsal, and recall requirements. *Journal of Verbal Learning & Verbal Behavior,* 12, 302-310.

Jensen, G. D. (1963). Preference for bar pressing over "freeloading" as a function of number of rewarded presses. *Journal of Experimental Psychology,* 65, 451-454.

Keele, S. W. (1982). Learning and control of coordinated motor patterns: The programming perspective. In J. A. S. Kelso (Ed.) *Human Motor Behavior: An Introduction* (pp. 161-186). Hillsdale, NJ: Lawrence Erlbaum, Associates.

Lentz, B. E., & Cohen, S. L. (1980). The effect of prior training on the contrafreeloading phenomenon. *Bulletin of the Psychonomic Society,* 15, 48-50.

Liu, I. M., & Ma, H. H. (1970). On the nature of a training trial in verbal learning. *Journal of Experimental Psychology*, 86, 126-127.

Lovejoy, E. (1966). Analysis of the overlearning reversal effect. *Psychological Review,* 73, 87-103.

Mackintosh, N. J. (1965). Overtraining, reversal, and extinction in rats and chicks. *Journal of Comparative & Physiological Psychology*, 59, 31-36.

Mackintosh, N. J. (1969). Further analysis of the overtraining reversal effect. *Journal of Comparative & Physiological Psychology*, 67, 1-18.

Maslow, A. H. (1937). The influence of familiarization on preference. *Journal of Experimental Psychology,* 68, 662-665.

Mechner, F. (1992). The revealed operant: A way to study the characteristics of individual occurrences of operant responses. S. Glenn (Ed.) *Monograph Series*. Cambridge, MA: The Cambridge Center for Behavioral Studies.

Mechner, F., Hyten, C., Field, D. P., & Madden, G. (1997). Using revealed operants to study the structure and properties of human operant behavior. *Psychological Record,* 47, 45-68.

Nelson, T. O. (1977). Repetition and depth of processing. *Journal of Verbal Learning & Verbal Behavior,* 16, 151-171.

Neves, D. M., & Anderson, J. R. (1981) Knowledge compilation: Mechanisms for the automatization of cognitive skills. In J. R. Anderson (Ed.), *Cognitive Skills and Their Acquisition*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Newell, A., & Rosenbloom, P. S. (1981). Mechanisms of skill acquisition and the law of practice. In J. R. Anderson (Ed.), *Cognitive Skills and Their Acquisition*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Saegert, S. C., & Jellison, J. M. (1970). Effects of initial level of response competition and frequency of exposure on liking and exploratory behavior. *Journal of Personality & Social Psychology,* 16, 553-558.

Schmidt, R.A. (1988). *Motor Control and Learning: A Behavioral Emphasis*. Champaign, IL: Human Kinetics Publishers.

Senkowski, P. C. (1978). Variables affecting the overtraining extinction effect in discrete-trial lever pressing. *Journal of Experimental Psychology: Animal Behavior Processes,* 4, 131-143.

Sewell, W. R., & Nickel, R. (1979). Effect of length of training on stimulus control using a low density reinforcement schedule. *The Psychological Record,* 29, 401-408.

Shiffrin, R. M. (1988). Attention. In R. C. Atkinson, R. J. Herrnstein, G. Lindzey, & R. D. Luce (Eds.), *Stevens' Handbook of Experimental Psychology, Second Edition, Volume 2: Learning and Cognition* (pp. 739-812). New York: John Wiley & Sons.

Squire, L. R. (2004). Memory systems of the brain: A brief history and current perspective. *Neurobiology of Learning & Memory,* 82, 171-177.

Zajonc, R. B. (1968). Attitudinal effects of mere exposure. *Journal of Personality & Social Psychology Monograph Supplement,* 9, 1-27.

Zajonc, R. B. (2001a). Mere exposure: A gateway to the subliminal. *Current Directions in Psychological Science,* 10, 224-228

Zajonc, R. B. (2001b). Exposure effects: An unmediated phenomenon. In A. S. R. Manstead, N. Frijda, & A. Fischer (Eds.), *Feelings and Emotions: The Amsterdam Symposium.* Cambridge, United Kingdom: Cambridge University Press.

APPENDIX – TABLES

Table 1

Order in Which Sets Were Learned	Lower Number of Repetitions	Higher Number of Repetitions	Ratio
1	200	450	4:9
2	25	125	1:5
3	100	300	1:3
4	300	600	1:2
5	200	500	2:5
6	100	200	1:2
7	25	75	1:3
8	300	750	2:5
9	50	100	1:2

Table 2

Test #	# Reps	BO	JAR	LMA	MDJ	NIS	OMC	RMF	Average
1	200	174	47	3	60	38	92	140	79.14
	450	8	144	164	143	151	117	48	110.71
2	25	3	64	0	91	4	99	0	37.29
	125	191	129	190	103	197	108	198	159.43
3	100	1	31	0	0	0	103	80	30.71
	300	197	167	204	199	204	107	129	172.43
4	300	185	90	69	6	57	103	115	89.29
	600	9	93	120	186	148	108	94	108.29
5	200	2	0	0	0	1	107	72	26.00
	500	198	203	204	202	207	106	133	179.00
6	100	114	34	15	0	0	102	45	44.29
	200	66	167	167	195	212	101	160	152.57
7	25	8	26	0	0	0	99	2	19.29
	75	159	169	202	198	209	99	205	177.29
8	300	0	21	0	2	97	104	110	47.71
	750	211	185	213	194	101	108	99	158.71
9	50	63	15	3	0	0	89	32	28.86
	100	129	183	202	194	192	117	175	170.29

Table 3

Order in Which Sets Were Learned	Lower Number of Repetitions	Higher Number of Repetitions	Ratio
1	25	75	1:3
2	50	100	1:2
3	25	50	1:2
4	100	200	1:2
5	50	75	2:3
6	100	150	2:3
7	200	400	1:2

Table 4

Test #	# Reps	AEG	KL	MT	RJP	SW	LEC	LEM	PRV	Average
1	25	0	86	1	0	0	96	35	30	31.00
	75	150	73	214	191	198	75	115	166	147.75
2	50	0	38	1	133	0	65	61	198	62.00
	100	184	140	211	64	212	116	97	8	129.00
3	25	50	38	108	65	0	128	92	29	63.75
	50	99	136	70	127	207	60	45	171	114.38
4	100	14	79	211	60	167	67	84	1	85.38
	200	131	105	2	127	46	126	108	210	106.88
5	50	0	16	205	132	49	56	24	5	60.88
	75	184	187	4	66	149	128	141	210	133.63
6	100	64	73	159	68	125	0	74	122	85.63
	150	113	129	53	138	83	208	122	91	117.13
7	200	39	129	0	70	0	62	85	166	68.88
	400	150	69	209	130	214	145	93	38	131.00

Table 5

Ys (Difference in Usage)	$\mathbf{X_1}$s (Lower # of Repetitions)	$\mathbf{X_2}$s (Higher # of Repetitions)	$\mathbf{X_3}$s (Order of Tests)	$\mathbf{X_4}$s (Total # Reps Completed)
17.10	200	450	1	2158
62.45	25	125	2	2824
70.43	100	300	3	4240
9.77	300	600	4	7156
75.19	200	500	5	9472
54.09	100	200	6	10588
80.26	25	75	7	11104
53.74	300	750	8	14470
80.90	50	100	9	15136
62.67	25	75	1	541
35.01	50	100	2	1207
25.08	25	50	3	1648
14.73	100	200	4	2764
38.83	50	75	5	3355
16.14	100	150	6	4321
30.03	200	400	7	6337
$Y = -.72*X_1 + .27*X_2 - 1.85*X_3 + .004*X_4 + 45.39$				