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An Empirical Analysis of Interspersal Research Evidence, Implications, and Applications of the Discrete Task Completion Hypothesis

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Because assignment completion is often reinforced, researchers have posited that when students work on assignments with many discrete tasks (e.g., 20 mathematics problems), that each completed discrete task may be a conditioned reinforcer (e.g., Skinner et al., 1999). If the discrete task completion hypothesis is accurate, then relative task completion rates should influence choice behavior in the same manner as relative rates of reinforcement. In the current study, previous interspersal research was combined across experiments and regression analysis revealed a linear relationship between relative problem completion rates (RPCR) and choice in accordance with the matching law (Herrnstein, 1961, 1970). These results support the discrete task completion hypothesis and suggest that interspersing additional brief tasks enhances interval schedules of reinforcement. Theoretical and applied implications of the current study and the discrete problem completion hypothesis are discussed and directions for future research are provided.

Keywords: Discrete task completion hypothesis, Matching law, Conditioned reinforcement, Second-order schedules, Assignment choice.

INTRODUCTION

Theory development can contribute to the development, application, and evaluation of effective prevention and remediation procedures (Hughes, 2000). Recently, researchers have been collecting data on student choice behavior that supports a specific hypothesis that has applied educational and psychological implications. The purpose of this paper is to (a) briefly review research on choice behavior, (b) describe the *discrete task completion hypothesis*, (c) evaluate the discrete task completion hypothesis by applying

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meta-analytic procedures to studies of the interspersal procedure, (d) delineate theoretical and applied implications of the discrete task completion hypothesis and the interspersal procedure, and (e) provide direction for future researchers.

Student Choice Behavior

A large body of research has shown that increasing students' active academic responding promotes acquisition, maintenance, and generalization of skills and enhances fluency (Binder, 1996; Gettinger, 1995; Greenwood, Delquadri, & Hall, 1984; Skinner, Fletcher, & Henington, 1996). However, even when educational activities are structured to occasion high rates of responding, little learning is likely to occur unless students choose to engage in these activities (Skinner, Wallace, & Neddenriep, in press). As educators increase the probability of students choosing to engage in assigned activities, they also may reduce the probability of students engaging in disruptive behaviors that are incompatible with assigned behaviors or allow them to escape or avoid assigned activities (Dunlap, Kern-Dunlap, Clarke, & Robbins, 1991; Kern, Childs, Dunlap, Clarke, & Falk, 1994; Lentz, 1988). Thus, procedures designed to increase the probability of students *choosing* to engage in assigned academic behavior can enhance learning rates and decrease inappropriate classroom behavior.

Herrnstein's (1961, 1970) research on choice behavior allowed him to develop the matching law; a mathematical model that could precisely predict choice behavior based on relative rates of reinforcement. Myerson and Hale (1994) conceptualized student classroom behavior as a continuous choice between engaging in assigned behavior or engaging in inappropriate behaviors. In accordance with the matching law, the amount of time students allocate toward each class of behavior is a function of the relative rates of reinforcement for each behavior. For example, if inappropriate behavior is reinforced on a variable interval (VI) 60-s schedule and assigned behavior is reinforced on a VI 30-s schedule, a student would be expected to allocate twice as much time to the assigned behavior (i.e., 2:1 ratio).

Myerson and Hale's (1994) conceptual work was supported with studies in educational environments (e.g., Martens & Houk, 1989; Martens, Lochner, & Kelly, 1992). For example, Martens and Houk (1989) operationally defined and measured two competing incompatible behaviors, (on-task and off-task behavior) and manipulated interval schedules of reinforcement (i.e., teacher attention) for each class of behavior within educational environments. Researchers controlled attention by recording on-task and off-task behavior and using a "bug in the ear" device to instruct the teacher when to deliver attention. Results showed that relative rates of reinforcement could be used to predict and control students' on- and off-task behavior levels in accordance with the matching law.

Other researchers have investigated the matching law by providing students with a choice of two distinct academic tasks or assignments (Mace, McCurdy, & Quigley, 1990; Mace, Neef, Shade, & Mauro, 1996; Neef, Mace, & Shade, 1993; Neef, Mace, Shea, & Shade, 1992). For example, Mace et al. (1990) used single-subject designs to investigate the effects of reinforcement rates on time allocated to one of two types of assignments. Within sessions, students were given repeated opportunities to choose to work on either division or multiplication problems. When reinforcement was equivalent for work on both types of problems, students allocated approximately equal amounts of time to both types of problems. When the schedule of reinforcement was 2:1 across problem types, the time students allocated toward working on each type of problem approached this 2:1 ratio. Subsequent researchers confirmed these findings and also showed that relative effort required to complete each type of problem, relative immediacy of reinforcement, and relative quality of reinforcement affected student choice behavior (e.g., Horner & Day, 1991; Mace et al., 1996; Neef et al., 1993; Neef, Shade, & Miller, 1994).

In these application studies, educators or researchers were required to continuously monitor, evaluate, and deliver reinforcers contingent upon each student's behavior. Within classroom settings educators may find it difficult to engage in such behaviors. Recent research on the discrete task completion hypothesis and the interspersal procedure suggests that educators may be able to manipulate schedules of reinforcement without having to deliver tangible (e.g., nickels or tokens) or social (e.g., teacher attention) reinforcement contingent upon student choice behaviors (e.g., Skinner, Robinson, Johns, Logan, & Belfiore, 1996).

Discrete Task Completion Hypothesis

The discrete task completion hypothesis posits that while working on assignments with many discrete tasks, a completed task is a conditioned reinforcer. This hypothesis is based on assumptions regarding a student's history of reinforcement for academic behavior. Many academic assignments contain discrete tasks that students complete at their own pace (e.g., independent seatwork with 20 mathematics problems). Consequences are often delivered contingent upon a student's response to assignments. Students may avoid aversive consequences that are delivered when they fail to complete their assignments (Skinner et al., 1999). For example, students who complete assignments may not be required to stay inside during recess. In this manner, completing assignments is negatively reinforced. Completing an assignment also may be positively reinforced (Logan & Skinner, 1998). For example, after completing an in-class assignment, a student may be allowed to engage in preferred behaviors such as working on a computer. These opportunities to engage in preferred behaviors may be reinforcers (Premack, 1965). Other positive reinforcers delivered contingent upon assignment completion include praise, grades, and tangible reinforcers.

If students have a learning history where completing an assignment is an event that is often followed by positive and/or negative reinforcement, then through the process of classical conditioning, a completed assignment (a stimulus) could become a reinforcing stimulus (Skinner et al., 1999). If a completed assignment is a reinforcing stimulus, then through the process of higher order conditioning (Pavlov, 1927), any event that consistently precedes assignment completion could become a reinforcing stimuli. When an assignment is composed of multiple discrete tasks, a completed assignment is consistently preceded by completed discrete tasks. Thus, each completed discrete task also could become a reinforcing stimulus (Skinner et al., 1999).

Figure 1 displays the outcome of this proposed conditioning process. In Figure 1, the primary antecedent stimulus (S_{D1}) is the teacher instructing students to complete a five-problem multiplication assignment. When they are finished with this assignment, they are positively reinforced (S^R) by being able to engage in a preferred behavior (e.g., read, work on a computer). Following the S_{D1}, students make five responses (r_1–r_5). The completed first problem is a discriminative stimulus (S_{d2}) that is followed by the student beginning to work on the second problems (i.e., initiating r_2). This process, which is similar to chaining, continues until the student performs their final response (r_5). The final completed problem serves as the terminal discriminative stimuli (S_{dt}). Following the S_{dt}, (i.e., the completed assignment) a student may have access to the reinforcing stimuli (S^R) such as being able to work on the computer. If one assumes that most students have a learning history where assignment completion is often followed by reinforcement, then through the process of classical conditioning, each completed problem (S_{d2}–S_{dt}) may become a conditioned reinforcer (S^{cr1}–S^{cr5}). Therefore, based on the discrete task completion hypothesis, as student progress through the assignment in Figure 1, they would be exposed to five conditioned reinforcing stimulus events (one for each problem completed). Additionally, the completed assignment (S_{dt}) may serve as an additional and distinct (e.g., qualitatively different and superior) conditioned reinforcer.

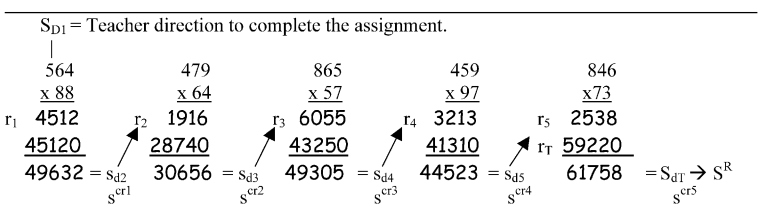

Figure 1. The discrete task completion hypothesis applied to a five-problem assignment.

This process has been supported by basic research on chained schedules of reinforcement (e.g., Catania, Yohalem, & Silverman, 1980; Fantino, 1969; Gollub, 1977; Kelleher, 1966). Although these studies suggest that a completed discrete task presented early in an assignment may be a low-quality reinforcing stimulus, basic research on second-order conditioning suggests that this may be sufficient to alter responding provided that completing an assignment is reinforced with high-quality reinforcers. Findley and Brady (1965) compared primate responding on two schedules. During the fixed ratio schedule, reinforcement (e.g., food) was delivered following every 4000 responses. During the second-order schedule, the FR 4000 was supplemented with a conditioned reinforcer (i.e., brief presentation of a bright light) delivered following every 400th response. Comparisons of responding across schedules showed that the second-order schedule resulted in higher rates of responding and briefer post-reinforcement (post-food) pauses. Thus, even if completed discrete tasks presented early in an assignment are low-quality reinforcers, because completing assignments is often followed by high-quality reinforcement (e.g., being able to engage in preferred behaviors) these stimuli (i.e., completed discrete tasks) may have a powerful effect on behavior (e.g., choice) that is caused by second-order schedules.

If each completed discrete task is a reinforcing stimulus, then increasing task completion rates should increase rates of conditioned reinforcement. This increase in discrete task completion rates and rates of reinforcement should affect student choice behavior as predicted by Herrnstein's (1961, 1970) matching law. Thus, when given the choice of two assignments, students should allocate their time (choice behavior) based on relative discrete task completion rates (Skinner, Robinson et al., 1996).

Research on the Interspersal Procedure

Researchers studying the interspersal procedure have conducted numerous group design experiments investigating the relationship between choice behavior and relative problem completion rates that support the discrete task completion hypothesis (e.g., Cates & Skinner, 2000; Cates et al., 1999; Logan & Skinner, 1998; Skinner et al., 1999; Skinner, Robinson et al., 1996; Wildmon, Skinner, McCurdy, & Sims, 1999; Wildmon, Skinner, & McDade, 1998). These studies differed from previously described single-subject design academic choice studies of the matching law (e.g., Mace et al., 1990, 1996; Martens et al., 1992; Neef et al., 1992, 1994). In the single-subject design studies, multiple sessions were run where students were given many opportunities to choose individual problems from two assignments and the time each student allocated to each assignment served as the dependent variable. During the group design interspersal studies, students were given distinct assignments (e.g., interspersal or control assignment sheets) with multiple discrete problems or tasks and instructed to work on each assignment for the same amount of time before being asked to choose their next assignment. Thus, while groups of students (28–94 students) worked problems from both assignments, each student had only one opportunity to choose and the primary dependent variable was the proportion of students who chose each assignment (e.g., interspersal or control assignment).

From both an applied and theoretical perspective, the biggest difference across the single-subject design studies and group choice studies was the procedure for delivering reinforcement. During the single-subject design studies, researchers controlled schedules of reinforcement, and reinforcement (e.g., tokens, money, points, teacher attention) was delivered immediately and on precise interval schedules. In the group design studies, the reinforcement was assumed to be a completed discrete problem or task. Thus, experimenters, teachers, or computers did not deliver reinforcement based on a priori schedules. Rather, reinforcement rates were dependent upon and equivalent to each student's self-paced discrete task or problem completion rates. In order to alter problem or task completion rates, experimenters altered assignments by interspersing additional brief problems. For example, Skinner, Robinson et al. (1996) constructed control assignment sheets that contained 16, three-digit by two-digit target multiplication problems (e.g., 567×84=__). On the experimental assignment (interspersal assignment) researchers interspersed six additional one-digit by one-digit problems (4×6=__) following every third three-digit by two-digit target problem. Results showed that this procedure increased problem completion rates. Mean problem completion rates on the control assignment were 9.9 in 305 s compared to 13.5 in 305 s on the interspersal assignment. Additionally, significantly more students selected or chose an interspersal assignment for their next assignment.

Subsequent studies (e.g., Logan & Skinner, 1998; Wildmon et al., 1999; Wildmon et al., 1998) showed that interspersing briefer problems increased problem completion rates and the proportion of students choosing the interspersal assignment across students (e.g., college students, sixth-grade students) and tasks (computation problems, word problems). Other studies suggested that novelty effects (e.g., interspersing novel problems caused students to prefer or choose the interspersal assignments), and problem ease (the brief problems were easier than the target problems) did not cause students to prefer the interspersal assignments (Martin, Skinner, & Neddenriep, 2001; Skinner, Fletcher, Wildmon, & Belfiore, 1996; Skinner, Robinson et al., 1996).

In another study, Skinner et al. (1999) showed that relative problem completion rates (RPCR) operated like relative rates of reinforcement. In this study, experimenters altered RPCR across control and interspersal assignments by altering the target problems (e.g., 4×1, 4×2, 4×3, and 4×4 digit problems). As target problem length increased, RPCR (i.e., problem completion rates on interspersal assignment divided by problem completion rates on control assignments) and the proportion of students choosing the interspersal assignment increased.

Purpose of the Current Study

Enhancing rates of reinforcement for assigned academic behavior can increase the probability of students choosing to engage in assigned work, thereby reducing disruptive classroom behaviors and enhancing achievement. Researchers have posited that, while working on assignments composed of many discrete tasks, that each completed task is a reinforcing stimulus (e.g., Skinner et al., 1999). If the discrete task completion hypothesis is accurate, then educators can enhance rates of reinforcement for academic behaviors without having to deliver reinforcers. The current study was designed to further examine the discrete task completion hypothesis by combining RPCR data and choice data across interspersal experiments and using linear regression to determine if RPCR predicted choice behavior in accordance with the matching law.

METHOD

Experiments Included in the Analysis

In the current study, previous research on the interspersal procedure was combined and analyzed. Many researchers have attempted to manipulate student academic performance, choice, and academic behavior (e.g., on-task behavior) by altering the sequence of tasks (e.g., Cooke, Guzaukas, Pressley, & Kerr, 1993; Cooke & Reichard, 1996; Cuvo, Davis, & Gluck, 1991; Dickinson & Butt, 1989; Horner, Day, Sprague, O'Brien, & Heatherfield, 1991; Neef, Iwata, & Page, 1977; Neef, Iwata, & Page, 1980; Roberts & Shapiro, 1996; Roberts, Turco, & Shapiro, 1991). However, only studies that met the following criteria were included in this analysis:

(a) The experiments were published or accepted for publication in nationally refereed journals.
(b) The experiments employed group design and analysis procedures.
(c) A dependent variable was the percentage of students who chose one assignment over another.
(d) Students were required to work on assignments containing discrete tasks.
(e) Discrete problem completion rates were altered by adding and interspersing briefer tasks.
(f) Data on RPCR across assignments were collected and reported.

(g) Target problems across control and experimental (interspersal) assignments were equated.
(h) Students were allowed to choose between one of two assignments—a control assignment or an interspersal assignment with additional interspersed discrete tasks.

Finally, data from one study (i.e., Cates et al., 1999) that met these requirements were excluded because sequence effects may have contaminated results. In this study, some students chose between non-equivalent assignments prior to choosing between equivalent assignments.

Experiments that met the criteria for inclusion in this research are described in Table 1. Participants for these experiments included college, high school, and sixth grade students. Target tasks included mathematics word problems and computation problems. Interspersed tasks included

Table 1
Description of experiments analyzed in the current study

Study	Students	Target tasks	Interspersed tasks	Target/brief problems	Time (s)
Skinner, Robinson et al., 1996 Experiment 1	51 college students	16, three-digit by two-digit problems	6, one-digit by one-digit problems	3/1	305
Wildmon et al., 1998	61 college student	8, two-digit× two-digit+two-digit× two-digit word problems	3, four-digit× one-digit word problems	3/1	555
Logan & Skinner, 1998	28 sixth-grade students	25, four-digit× one-digit problems	9, one-digit+ one-digit problems	3/1	480
Wildmon et al., 1999	76, ninth-, tenth-, eleventh-, and twelfth-grades	8, two-digit× two-digit+two-digit× two-digit word problems	3, four-digit× one-digit word problems	3/1	640
Skinner et al., 1999 Comparison A	94 college students	18, four-digit× one-digit problems	6, one-digit× one-digit problems	3/1	255
Skinner et al., 1999 Comparison B	94 college students	18, four-digit× two-digit problems	6, one-digit× one-digit problems	3/1	255
Skinner et al., 1999 Comparison C	94 college students	18, four-digit× three-digit problems	6, one-digit× one-digit problems	3/1	255
Skinner et al., 1999 Comparison D	94 college students	18, four-digit× four-digit problems	6, one-digit× one-digit problems	3/1	255

briefer addition and multiplication computation and/or word problems. Time allotted to working on each assignment ranged from 240 to 915 s.

Common methodology across studies. In each of the experiments included in the current analysis, students were exposed to both control and experimental (i.e., interspersal) assignments. The target problems on the interspersal and control assignments were matched (e.g., 15 three-digit by two-digit problems on each assignment). Interspersal assignments were then constructed by adding briefer problems (e.g., one-digit by one-digit problems). In all studies, these additional briefer problems were interspersed following every third target problem.

Across experiments, procedures were used to allow researchers to collect data on problem completion rates across the entire class. Specifically, students were given equal time to work on each assignment, but typically not enough time to complete either assignment. In each experiment, if a student finished one or both assignments before being told to stop or failed to follow directions (e.g., skipped problems), that student's data were eliminated from analysis procedures. After working on both assignments, students answered some question with respect to each assignment (e.g., which assignment requires the most effort to finish). Students then were told that they would have to complete an additional assignment, but they would be allowed to choose which type of new assignment they would like to complete (i.e., interspersal or control). Students were informed that their new assignment would contain the same number and types of problems to which they had just been exposed. The proportion of students choosing the interspersal assignment served as the primary dependent variable. Statistical procedures were used to test for differences in problem completion rates across control and interspersal assignments (e.g., *t*-tests) and to determine if the proportion of students choosing the interspersal assignments (e.g., chi-square) was significant.

Data Analysis Procedures

The current study was designed to determine if a linear relationship exists between RPCR and the proportion of students who chose interspersal assignments. Linear regression was calculated for the formula $y = ax + c$; where y equals the proportion of students who chose the interspersal assignments and x equals RPCR. Regressions and $x-y$ correlations were calculated for the percentage and base 10 log data. All correlations were considered significant at the $p < .05$ level.

Table 2 contains the raw data, percentage data, and base 10 log data for both y (i.e., students choosing interspersal assignments) and x (i.e., RPCR) across studies. The percentage data for the proportion of students choosing the interspersal assignment (i.e., y) was calculated by dividing the number

Table 2
Proportion, logarithmic, and percentage data analyzed and residuals

Study	Relative problems completion rates	Assignment choice data	Residuals: All studies	Residuals: Outlier removed
Skinner, Robinson, et al., 1996 Experiment 1	13.53 interspersal/ 10.19 control=1.33 57.04%, log=0.12	36 interspersal/ 15 control=2.40 70.59%, log=0.38	−1.67%, log=0.04	1.40%, log=0.04
Wildmon et al., 1998	6.39 interspersal/ 4.98 control=1.28 56.20%, log=0.11	40 interspersal/ 21 control=1.90 65.57%, log=0.28;	−3.91%, log=0.09	0.10%, log=0.00
Logan & Skinner, 1998	17.00 interspersal/ 13.73 control=1.24 55.32%, log=0.09	22 interspersal/ 6 control=3.67 78.57%, log=0.56	12.02%, log=0.29	outlier
Wildmon et al., 1999	6.46 interspersal/ 5.10 control=1.27 55.88%, log=0.10	47 interspersal/ 29 control=1.62 61.84%, log=0.21	−6.57%, log=0.11	−2.22%, log=0.00
Skinner et al., 1999 Comparison A	18.49 interspersal/ 13.85 control=1.34 57.17%, log=0.13	66 interspersal/ 28 control=2.36 70.21%, log=0.37	−2.48%, log=0.10	0.45%, log=−0.03
Skinner et al., 1999 Comparison B	7.82 interspersal/ 5.44 control=1.44 58.97%, log=0.16	75 interspersal/ 19 control=3.95 79.79%, log=0.60	1.12%, log=0.02	2.07%, log=0.00
Skinner et al., 1999 Comparison C	4.85 interspersal/ 3.11 control=1.56 60.93%, log=0.19	79 interspersal/ 15 control=5.27 84.04%, log=0.72	−1.13%, log=0.04	−2.35%, log=−0.07
Skinner et al., 1999 Comparison D	3.16 interspersal/ 1.96 control=1.61 61.72%, log=0.21	85 interspersal/ 9 control=9.44 90.43%, log=0.97	2.63%, log=0.11	0.55%, log=0.05

of students choosing the interspersal by the number choosing the interspersal and control assignment and multiplied by 100. Thus, for the Skinner, Robinson et al. (1996) study, y=36/51 (100)=57.04%. RPCR (i.e., x) was calculated by dividing the mean number of problems completed on interspersal assignments by the mean number of problems completed on interspersal and control assignments. This proportion was converted to percentage data by multiplying by 100. Thus, for the Skinner, Robinson et al. (1996) study, x=13.53/23.72 (100)=70.59%. In the current analysis, it was unnecessary to include the number of seconds (i.e., time—see Table 1, column 6) in the rate calculations as time spent working on experimental and interspersal assignments was held constant in each experiment.

A second regression was run so that current results could be compared to the matching law. The generalized matching law is represented by the following formula: $\log (B1/B2)=(a) \log (R1/R2)+\log c$; where $B1$ equals behavior allocated to option 1, $B2$ equals behavior allocated to option 2, $R1$ equals reinforcement rates for $B1$, and $R2$ equals reinforcement rates for $B2$. In the current study, for each experiment; $B1$ equaled the number of students who chose an interspersal assignment; $B2$ equaled the number of students who chose a control assignment; $R1$ equaled the mean number of problems completed on the interspersal assignment; and, *R*2 equaled the number of problems completed on the control assignment. These ratios were then transformed to base 10 logarithmic data. Based on the matching law, *a* should equal 1 and log *c* should equal 0, if no bias is present (Myers & Myers, 1977).

RESULTS

Figure 2 displays the linear regression for percent data. Results of the linear regression for the percentage data yielded the following formula: $y=3.32x-117.04$. The $x-y$ correlation was $r=.82$ ($r^2=.66$). This correlation was statistically significant. Residuals ranged from −6.57 for the Wildmon et al. (1999) study to 12.02 for the Logan and Skinner (1998) study (see

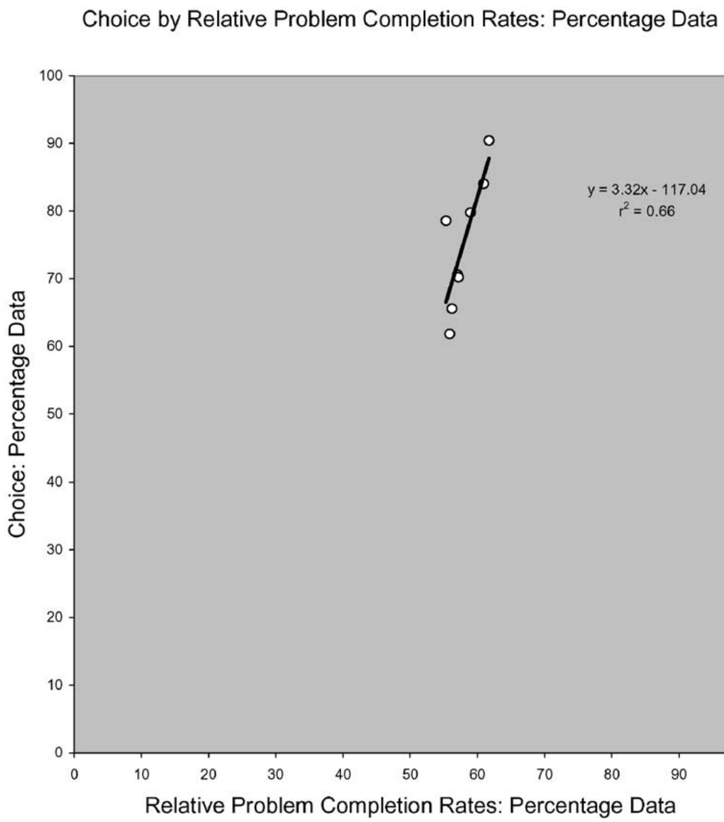

Figure 2. Linear regression for the proportion of students who chose the experimental or interspersal assignment by relative problem completion rates (percentage data).

Table 2 for residuals). Analysis of studentized residuals (stdr) showed that the data from Logan and Skinner (1998) was an outlier (stdr=7.70). No other data points yielded a stdr larger than ± 1.4 (Belsley, Kuh, & Welsch, 1980). Exploratory analysis was conducted with the outlier (Logan & Skinner, 1998) removed. Results of the linear regression for percentage data with the outlier removed yielded the following formula: $y=4.42x-182.99$ and residuals ranged from -2.35 to 2.07. With the outliers removed, the $x-y$ correlation was significant ($r=.99$ and $r^2=.97$) and regression analysis showed that RPCR data could be used to predict the percentage of students choosing the experimental assignment within 3%.

Results of the linear regression for the base 10 log data yielded the following formula: $y=4.89x-.17$. Based on the generalized matching law, the slope should equal 1 and the intercept should equal 0. The intercept (i.e., .17) approached 0, but slope (i.e., 4.89) showed that more students chose the interspersal assignment than would be predicted by the matching law. The $x-y$ correlation was $r=.84$ ($r^2=.71$). This correlation was significant. Again the data point for the Logan and Skinner (1998) study was an outlier, stdr=2.35. With this outlier removed, $y=6.40x-.43$, $r=.99$, and $r^2=.98$. The $x-y$ correlation was significant.

DISCUSSION

Researchers investigating the interspersal procedure have found that interspersing additional briefer problems could increase problem completion rates and the probability of students choosing the assignment with the additional brief tasks. This procedure may alter choice behavior because under these conditions, a completed task may be a conditioned reinforcer. If the discrete task completion hypothesis is accurate, then RPCR should be related to choice behavior in accordance with the matching law. The current analysis revealed a clear linear relationship between RPCR and student choice behavior in the direction that corresponds to the matching law. Thus, the current study provides support for the hypothesis that, while working on assignments composed of multiple discrete tasks, each completed task is a reinforcing stimulus.

In the current study, reinforcement schedules could be conceptualized as ratio schedules where each problem completed results in conditioned reinforcement or as VI schedules because the time required to complete problems varies. When ratio schedules are used, organisms should exclusively choose the behavior that results in greater reinforcement. With concurrent VI schedules of reinforcement, students should allocate time to the two behaviors (i.e., choose) in direct proportion to those schedules of reinforcement. The current results show a linear relationship that would be expect when responding to concurrent VI schedules. With concurrent

VI schedules, the slope of the regression line (i.e., *a*) should approximate 1 (Herrnstein, 1961, 1970). However, in the current study, the base 10 log transformation data revealed a slope of 4.89, which suggests overmatching (i.e., more students chose the interspersal assignment than would be predicted by the matching law).

The overmatching found in the current study hinders our ability to draw strong conclusions regarding the hypothesis that a completed discrete task or problem is a reinforcing stimulus. However, when considering this limitation it is important to note that previous researchers have found that even after *repeated exposure* to concurrent stimuli and schedules of reinforcement, student choice behavior did not precisely match relative rates of reinforcement (e.g., Mace et al., 1990; Martens et al., 1992). The studies included in the current analysis were conducted across students and tasks, and students had only a brief exposure to the two assignments. Future researchers should determine if providing repeated exposure to assignments and multiple choice opportunities would cause student choice behavior and relative task completion rates to more precisely fit the matching law.

Despite conditions that may have reduced the probability of precise matching, results showed a strong linear relationship between RPCR and student choice behavior. When the outlier was removed, RPCR accounted for over 97% of the variance and allowed for the prediction of the percent of students choosing the interspersal assignment within a range of ±3%. This strong correlation supports the discrete task completion hypothesis.

Evaluation and Implications of the Discrete Task Completion Hypothesis

Empirical data can support or disconfirm hypotheses. The current analysis supports the discrete task completion hypothesis. However, if hypotheses are to enhance the process of developing and delivering effective prevention and intervention procedures, these hypotheses must be evaluated on other criteria (Hughes, 2000).

Applied value. Theories or hypotheses should have applied value (Hergenhahn, 1982). When assigned preferred educational activities, students are more likely to choose to engage in those activities and less likely to choose to engage in inappropriate or disruptive behaviors (Dunlap & Kern, 1996). One way to enhance student preference for assignments and the probability of them choosing to engage in assigned work is to reduce the time and effort required to complete the assignments (Beautrais & Davison, 1977; Davison & Ferguson, 1978; Horner & Day, 1991). This could be done by reducing assignment length (e.g., Kern et al., 1994) or replacing difficult, time-consuming tasks with briefer tasks that require less effort to complete (e.g., Cooke et al., 1993). However, these procedures may be unacceptable to teachers as they essentially involve reducing academic demands (i.e., watering down the curriculum), and therefore may reduce learning rates (Albers & Greer, 1991; Cates & Skinner, 2000; Logan & Skinner, 1998). The studies analyzed in the current paper have applied valued because they show how educators can increase the probability of students choosing to engage in assigned activities by increasing (i.e., adding brief tasks to assignments), rather than reducing assignment demands.

If given the choice between two homework assignments, one containing 15 problems and the other containing either 18 or 21 similar problems, research on response effort, contingent skipping, and positive practice overcorrection suggests that students would choose the briefer assignment (e.g., Doyle, Jenson, Clark, & Gates, 1999; Foxx & Jones, 1978; Horner & Day, 1991; Lovitt & Hansen, 1976). Researchers investigating the interspersal procedure found that students chose assignments with 20% and even 40% more longer target problems when additional brief problems were added and interspersed (Cates & Skinner, 2000; Cates et al., 1999; Meadows, 2001). These studies have applied value as causing students to choose to do more schoolwork (e.g., 20–40% more target problems or tasks) by giving them even more work (i.e., the interspersed problems) can enhance acquisition, fluency, and maintenance of accurate responding (Ebbinghaus, 1885; Ivarie, 1986; Skinner & Shapiro, 1989). Because one way to get students to choose to engage in tasks that require more effort and time is to enhance reinforcement for that task, (e.g., Mace et al., 1996; Neef et al., 1993), these studies also provide empirical support for the hypothesis that task completion is a reinforcing event.

Previous researchers have manipulated rates of teacher-delivered reinforcement by interspersing easier or known tasks and delivering immediate reinforcement based on accurate responding. Such procedures increased rates of externally delivered reinforcement and increased on-task behavior and decreased incompatible disruptive behaviors (e.g., Horner et al., 1991). McCurdy, Skinner, Grantham, Watson, and Hindman (2001) interspersed additional brief problems during independent mathematics seatwork and found that this procedure alone (i.e., no additional reinforcement, such as tokens or attention following the completion of each problem) increased on-task levels in a second-grade student. Similar procedures were used with five students with behavior disorders and similar results were obtained (Skinner, Hurst, Teeple, & Meadows, in press). These studies demonstrate the applied value of the interspersal procedure, as educators were not required to continuously monitor and evaluate each student's academic responding and deliver immediate reinforcement to each student contingent upon their academic performance. Instead, educators may have enhanced rates of reinforcement for engaging in assigned academic work across all students by merely including more work (i.e., additional interspersed brief tasks).

Fit with existing data across phenomenon. Following a scientist–practitioner model, it is important that hypotheses fit with existing scientific studies. The discrete task completion hypothesis is supported by basic research on classical conditioning, operant conditioning, and the matching law. Each of these theories has a strong scientific research base (Baum, 1974; Catania, 1992; Fuqua, 1984; Malone, 1990; Mawhinney & Gowen, 1990; McDowell, 1988). Also, hypotheses should allow one to predict and control behavior across organisms, behaviors, and context (i.e., generality). Previous researchers found that *rapid pacing* (e.g., Carnine, 1976; Darch & Gersten, 1985), *explicit timing* (e.g., Rhymer, Dittmer, Skinner, & Jackson, 2000; Rhymer, Henington, Skinner, & Looby, 1999), *abrupt reduction in allotted time* (e.g., Van Houten & Little, 1982) and *breaking large assignments into smaller discrete tasks* (e.g., Malott, 2000) could increase the probability of students choosing to engage in assigned tasks (e.g., increased students' on-task behavior). Because each of these procedures also increases discrete task completion rates, the discrete task completion hypothesis may account for these findings. Thus, the discrete task completion hypothesis is supported by scientific studies designed to investigate different phenomena across participants, behaviors, settings, and context.

Specificity: the link between theory and practice. In addition to identifying conditions when they should apply (generality), hypotheses should also be delimiting and identify conditions when they *should not apply* (Malone, 1990). Specificity provides a clear example of the reciprocal relationship between theory development and effective practice. Replications across students, settings, contexts, or tasks can provide useful information with respect to situations when specific procedures are more likely to be effective, ineffective, or cause side effects. However, understanding causal mechanisms responsible for behavior change may be a more efficient and effective strategy for determining conditions when interventions are most likely to be effective. Based on the current hypothesis, interspersing additional brief work should not affect choice when assignments are continuous (i.e., not composed of discrete tasks). Support for this comes from a reading study. Martin et al. (2001) interspersed additional brief and easy paragraphs (second-grade level) to passages written at the seventh-grade level. Results showed that this procedure did not enhance choice behavior and students rated the passages with these additional paragraphs as more time-consuming. This finding is consistent with the current hypothesis and research on response effort. In the Martin et al. (2001) study, discrete task completion rates were not enhanced. Instead, researchers merely lengthened one continuous task, the reading of the passage. Thus, researchers increased the amount of time and effort required to complete one task, without increasing discrete task completion rates and rates of reinforcement.

Limitations, Assumptions, and Directions for Future Research

A serious limitation of the current study is that one researcher, his students, and his colleagues conducted all studies included in the current analysis.[1] A related limitation is the small number of data points available for this linear regression. Additional data from studies conducted by other researchers are needed to enhance the confidence of the current meta-analytic findings.

Another limitation of the current study is the failure to more directly demonstrate that when given an assignment with multiple discrete tasks, each completed discrete task is a reinforcing event. Although the current data and previous research support this hypothesis, it is possible that discrete problem completion is not a reinforcing event, but rather a stimulus that under these conditions affects choice behavior like reinforcement. Future researchers should also evaluate alternative rival hypotheses. Some rival hypotheses are based on cognitive mediators. For example, students may prefer the assignments with the interspersed problems, because those problems are easier than target problems and completing these easier problems cause students to *feel*[2] better. A similar explanation is based on students self-regulating their behavior (e.g., self-evaluating their responses to easier problems and reinforcing themselves contingent upon positive self-evaluations). Although several studies of the interspersal procedure have failed to support these cognitive-behavior hypotheses,[3] (see Martin et al., 2001; Skinner, Fletcher, Henington, 1996), additional studies are needed to directly assess the discrete task completion hypothesis and rule out rival hypotheses.

[1] My students, colleagues, and I have been presenting this line of research at professional conferences and disseminating our results via publications in refereed journals in an attempt to encourage other applied and basic researchers to investigate this phenomenon. We recognized the need for other researchers to evaluate the discrete task completion hypothesis in order to enhance our ability to apply these findings and to confirm, correct, or refine our theories and concepts. I hope that this manuscript will serve to encourage such future scientific efforts.

[2] The posited hypothesis does not deny that in many instances people "feel good" when they complete a task or assignment. However, the feeling is not what causes the choice behaviors (Skinner, 1950). Instead, the discrete task completion hypothesis is based on the assumption that both the feeling and the choice behavior are caused by an organism's previous history of reinforcement for assignment completion and a consistent contingent and temporal relationship among completing discrete tasks, assignment completion, and reinforcement.

[3] Some have suggested that behavioral theory development has atrophied or "fossilized" because a sect of behaviorists refuses to adopt mentalisms (Evans, 1999; Hughes, 2000). I am compelled to indicate that the current posited hypothesis and related line of research support the opposite conclusion. If my students, colleagues, and I accepted mentalistic (e.g., some cognitive–behavioral theories), causal explanations for our results (e.g., self-reinforcement or feeling better), we would have eliminated the need to develop the current hypothesis that attempts to provide a comprehensive explanation of causal mechanisms by completing a causal sequence. Thus, the current study may actually support Skinner's (1974) contention that the ease with which researchers are able to create mentalistic causes of behavior could hinder theory development by allaying curiosity and bringing scientific inquiry to a stop.

The hypothesis posited, investigated, and evaluated in the current paper is not void of assumptions. Specifically, the proposed causal sequence rests on three assumptions or leaps of inference. One assumption is that most people, including students, have a learning history where assignment completion has been reinforced. This assumption is based on personal observations and experiences and, therefore, requires future research. The second assumption is that a completed assignment and a completed discrete task are stimuli. It is important to note that the behavior, working on tasks or assignments, is not assumed to be a reinforcing stimulus. Instead, the discrete task completion hypothesis rests on the assumption that when the discrete task is completed, this is a stimulus event. Applied research on chaining (e.g., Thvedt, Zane, & Walls, 1984) and basic theoretical research (e.g., Hull, 1931) both support this assumption. The third assumption is that classical conditioning causes discrete task completion to be a reinforcing event. Some research suggests that the proposed model of conditioned reinforcement (e.g., classical conditioning based on contiguity and consistency) may not be sufficient. However, alternative models of classical conditioning that are based on common contingencies and schedules of stimuli presentation also support the hypothesis that a completed discrete task should become a conditioned reinforcer (e.g., Fantino, 1969; Neuringer & Chung, 1967; Zimmerman, Hanford, & Brown, 1967). Future researchers should conduct studies designed to evaluate these three assumptions. Specifically, researchers should consider exposing participants to learning histories where assignment completion is punished, reinforced, or followed by no consequences an then evaluate the effects of increasing discrete task completion rates.

The current results showed a stable pattern of overmatching (i.e., more students choosing the interspersal assignments than would be predicted by the matching law). From an applied perspective, this finding is encouraging because it suggests that the interspersing procedure is more effective than would be predicted by previous research. However, this finding also suggests that another variable or other variables consistently affected choice behavior. Future researchers should conduct studies designed to identify this source of overmatching. Specifically, research may want to determine if negative reinforcement (temporarily avoiding longer problems), behavioral momentum (Belfiore, Lee, Vargas, & Skinner, 1997; Hutchinson & Belfiore, 1998), or second-order multiple schedule effects (e.g., assignment completion could be viewed as a FR1 schedule of reinforcement, and completion of each discrete task may represent a second-order interval schedule) may have caused this consistent overmatching (Findley & Brady, 1965).

In addition to conducting basic research designed to validate assumptions and identify the cause of the stable overmatching, future researchers should conduct applied studies. In the interspersal studies included in the current study, mathematics assignments were targeted. Future researchers should determine if this procedure would be effective across assignments composed of discrete tasks and activities, including vocational tasks (e.g., assembly line), other academic tasks (e.g., history, grammar, science), or recreational activities (e.g., exercise classes). During all experiments incorporated in the current study, RPCR were manipulated via only one procedure, interspersing additional brief items. Future researchers should extend this research by using other procedures that have been shown to be effective in altering discrete task completion rates (e.g., explicit timing procedures, reducing allotted time for assignment completion, and instructor pacing). Researchers should also conduct studies where they alter long, continuous tasks into multiple brief discrete tasks to determine if this hypothesis could be applied across assignments or activities (Martin et al., 2001).

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