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When Self-Pacing Goes Wrong: A Comparison of Two Methods for Reducing Computer-Based Racing

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Western Michigan University

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WHEN SELF-PACING GOES WRONG: A COMPARISON OF TWO METHODS FOR REDUCING COMPUTER-BASED RACING

by

Douglas A. Johnson

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Submitted to the
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Advisor: Alyce M. Dickinson, Ph.D.

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WHEN SELF-PACING GOES WRONG: A COMPARISON OF TWO METHODS FOR REDUCING COMPUTER-BASED RACING

Douglas A. Johnson, Ph.D.
Western Michigan University, 2009

Self-pacing, although often seen as one of the primary benefits of computer-based instruction (CBI), can also result in an important problem, namely, computer-based racing. Computer-based racing is when learners respond so quickly within CBI that mistakes are made, even on well-known material. This study compared traditional CBI with two forms of CBI designed to reduce computer-based racing: incentives/disincentives and postfeedback delays. All three formats were evaluated in terms of both performance and satisfaction using a between group repeated measures design with pretest and posttest. Dependent measures included posttest scores, satisfaction questionnaire ratings, percentage correct during learning, and total training time. Posttest scores favored the use of postfeedback delays to improve learning over incentives/disincentives and control conditions. Postfeedback delays negatively affected satisfaction in comparison to the control condition, although no satisfaction differences were found between incentives/disincentives and postfeedback delays.
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I'd like to thank my advisor, Alyce Dickinson, for continually helping me to craft better intellectual works. Thanks to Kevin Munson for lending me materials to help clarify my thinking during the early stages of this study. I'd also like to thank John Crosbie and Janet Emmendorfer of AME-Learning for their technical and financial assistance. This study could not have happened without the help of number of excellent research assistants: Dana Connor, Melissa Allen, Jacklyn Bove, Robert Long, Kimberly Rossman, Tobey Schipper, and Holly Vinson. Finally, thanks to my wife Sophie for her continued patience and support.

Douglas A. Johnson
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INTRODUCTION

Computer-based instruction (CBI) continues to grow as a training solution for business and industry, despite the fact that many other corporate training expenditures have remained fixed (Mullich, 2004; Oblinger & Rush, 2003). Multiple reasons can account for the popularity of CBI. CBI can improve learning over traditional instruction, reduce training time and costs, accommodate learners in geographically diverse locations, improve retention, and standardize content delivery (Allen, 2003; Kruse & Keil, 2000; Kulik, 1994; Schultz & Schultz, 2006).

CBI’s success in improving performance may in part be the result of its ability to enforce active responding. It has been repeatedly shown that frequently requiring learners to make an overt response during instruction can improve learning (Armel & Shrock, 1996; Bodemer, Ploetzner, Feuerlein, & Spada, 2004; Eckerman et al., 2002; Kritch & Bostow, 1998; Miller & Malott, 1997, 2006; Tudor, 1995). Many of the textbooks developed during the original programmed instruction movement of the 1960s tried to achieve active responding through frequent response requests (Brethower, 1963; Holland & Skinner, 1961). However, no matter how well designed a textbook is, it can never enforce a response request. There is always the possibility the learners will look at the correct answer without making a response (Markle, 1990). CBI differs in that active responding can be enforced, representing an advantage over textbooks and training manuals.

CBI also offers advantages over oral group instruction. In group instruction, interactive interchanges must be sacrificed so that large numbers can be taught simultaneously by individual instructors (Skinner, 1958). Thus, active responding is
typically lost with the lecture format. Some have tried to remedy this by utilizing unison responding, as seen with educational programs like Direct Instruction (Binder & Watkins, 1990; Maloney, 1998). However, the success of unison responding in programs such as Direct Instruction depends upon homogeneous skill levels among learners (Slocum, 2004). This may be a difficult criterion to meet, especially with adult learners whose skill levels may vary quite widely. Furthermore, unison responding involves overt responding in a group setting. Many adults, perhaps due to a history of being embarrassed publicly for speaking in a group setting, may be unwilling or hesitant to respond in a public setting. If responding is hesitant, this opens the possibility for learners to simply imitate the answers of other learners rather than providing their original answers. However, CBI can easily fix this concern by requiring constant interactions of every learner, even within a group format, that doesn’t require very public displays of overt responding.

Just because learners are actively responding with CBI, it does not necessarily mean that they are demonstrating understanding of the material (Markle, 1990). A CBI program should be more than an “electronic page-turner,” in which learners simply advance the content (Kruse & Keil, 2000). Fortunately, CBI can be designed to enforce demonstrative interactions, much like an effective tutor. Although one-on-one tutors are just as capable at producing such interactions, the associated time and costs of one-on-one instruction often make such a solution impractical. Enforced, demonstrative interactions that are practical on a large scale may be CBI’s most important and unique contribution. The possibility of standardizing delivery of pre-tested and validated content opens up the possibility for CBI to be more effective than individual tutors. The consistent use of carefully scripted and pre-tested instructional sequences has often been
found to produce superior learning outcomes over less scripted approaches (Binder & Watkins, 1990; Engelmann, 1992).

Another frequently cited benefit of CBI is the ease of implementing learner self-pacing (Henry, 1995; Kruse & Keil, 2000; Milheim & Martin, 1991). Learner pacing may represent a rare point of agreement among educational, cognitive, and behavioral theories. For example, the theories of constructivism and discovery learning are very popular within the educational community (Alberto & Troutman, 2003; Carnine, 1992; Hirsch, 1996). Constructivism postulates that learners actively construct their own knowledge and that only self-constructed knowledge will be fully understood. Similarly, discovery learning postulates that the best learning comes from independent inquiry. Within both theories, the more control the learners have, the more they will learn. Thus, allowing learners to have complete control over the pace of learning fits with the idea of “learner-centered” teaching and is advocated by both constructivism and discovery learning advocates. Going “at your own pace” also seems more natural and is therefore in line with developmental approaches also popular within educational communities (Engelmann, 1992; Hirsch). Self-pacing is also encouraged by theories related to the locus of control, in that self-pacing is theorized to foster an internal locus of control (Milheim & Martin). Self-pacing allows students more time to process information, with this new information being better integrated with already constructed schemas (Henry; Milheim & Martin).

From a more behavioral perspective, the notion of self-pacing during instruction has also been very popular, at least with early behaviorists. B. F. Skinner thought education and training should allow learners to progress at their own rate and
incorporated this principle into his teaching machines (Skinner, 1954, 1958). He continued to support this principle when he moved from teaching machines to programmed instruction textbooks (Holland & Skinner, 1961). The Personalized System of Instruction (PSI) movement was strongly influenced by Skinner's educational ideals, and thus also incorporated the idea of allowing total self-pacing (Keller & Sherman, 1974).

As desirable as self-pacing may sound in theory, in practice it often has detrimental effects, with both CBI and other types of instruction. Learners are often found to be poor managers of their own time (Steinberg, 1977). As other activities compete for a learner's time, procrastination frequently occurs with respect to the assigned instructional material (Michael, 2004). When self-paced courses such as PSI have been implemented, they have often resulted in lower rates of completion due to such procrastination (Fox, 2004).

At this point, it may be beneficial to distinguish between two types of CBI self-pacing: overall course pacing and within unit pacing. Overall course pacing relates to the deadlines in which learners are expected to complete various CBI tutorial units and other assignments. Within unit pacing involves how much time a learner spends studying the material within a given CBI unit. When procrastination occurs with self-imposed deadlines for overall course pacing, the addition of externally set and frequent deadlines has been recommended to correct this problem (Fox, 2004; Hirsch, 1996; Michael, 2004). In recent times, at least within a behavioral perspective, self-pacing has no longer been recommended for overall course pacing. However, self-pacing within instructional units has often still been considered beneficial (Heinich, Molenda, & Russell, 1993).
Unfortunately, within unit self-pacing can also be problematic for CBI. In contrast to the procrastination problems seen with overall course self-pacing, within unit self-pacing can produce responding that is too rapid. Learners begin making “let’s-get-it-over” sloppy responses and therefore learn less (Markle, 1990). For example, Brown (2001) studied the performance of technical employees during an online training course. Many employees moved too quickly through the training, and consequently, had the worst test scores. The author postulated that the fast pace was motivated by an attempt to return to their other work obligations. The phenomenon of fast paced responding that results in mistakes, even on well-known material, has been termed “racing” (Crosbie & Kelly, 1993, 1994; Kelly & Crosbie, 1997; Munson & Crosbie, 1998). It has been hypothesized that computer-based racing occurs so that learners can more quickly obtain the conditioned reinforcers of unit completion and “being done.” Faster responding produces the subsequent material faster and moves the individual closer to escaping the current learning situation. As such, the individual can then move on to more reinforcing situations. As discussed earlier, utilizing enforced and demonstrative interactions that are practical for large numbers of learners is one of CBI’s most unique contributions. When learners begin blindly guessing at answers in order to finish more quickly, they are no longer demonstrating their understanding of the material. As such, computer-based racing undermines one of the most unique and important contributions of CBI.

There are several possible methods for reducing the likelihood of computer-based racing. One possibility is through the partial reduction of learner control. The use of postfeedback delays is one method for partially reducing learner control that has been shown to improve learner performance (Crosbie & Kelly, 1993, 1994; Kelly & Crosbie,
Postfeedback delays involve an enforced delay by the computer following the provision of feedback. When using CBI with postfeedback delays, the learner proceeds through the material at his or her own pace until a request for a demonstrative interaction is encountered. The learner either selects or constructs an answer (depending on the question format) and submits his or her answer. The computer provides some form of feedback. Immediately after the feedback, the computer enforces a delay for a predetermined time, thus preventing the learner from immediately proceeding to subsequent material. When the time period elapses, control is returned to the learner, allowing him or her to proceed to subsequent material when ready. Although it may seem more intuitive to have postfeedback delays follow only incorrect responses, Crosbie and Kelly (1994) found evidence to the contrary while investigating the possibility that postfeedback delays function as punishers for mistakes. In this experiment, they compared no delay, 10-second postfeedback delay after all answers, and 10-second postfeedback delay after only incorrect answers. They found that only the 10-second postfeedback delay after all answers improved performance over no delay, suggesting that punishment was not the mechanism of action for the effectiveness of postfeedback delays.

Postfeedback delays appear to work in part by allowing further exposure and time to study instructional material. In a second experiment, Crosbie and Kelly (1994) demonstrated support for the inference by utilizing two 10-second postfeedback delay conditions and a no delay condition. In the first postfeedback delay condition, the question, the participant's response, and the correct response remained on the screen during the postfeedback delay. In the second postfeedback delay condition, the screen
became blank during the postfeedback delay. The third condition involved no postfeedback delays and was completely learner paced. The researchers found that there were no differences between the no delay condition and the postfeedback delay with a blank screen condition. However, the postfeedback delay condition in which the question, response, and feedback remained on the screen produced a greater percentage of correct responses than the other two conditions.

Postfeedback delays may also work by disrupting the reinforcement for rapid responding (Munson & Crosbie, 1998). Recall that the assumed reinforcer for computer-based racing is the production of subsequent material and moving one’s self to a closer state of completion with regards to the instructional task. As such, rapid responding is reinforced with the more rapid presentation of subsequent material. However, when utilizing postfeedback delays, rapid responding does not produce subsequent material faster, so reinforcement is reduced for this type of response pattern.

Another way of decreasing computer-based racing is by implementing contingent incentives and disincentives. Munson and Crosbie (1998) investigated this possibility by paying participants a 5 cent incentive for every correct answer while completing a CBI program. The disincentive was a 5 cent subtraction from their earnings for every incorrect answer. Incorrect answers represented a net loss of 10 cents because participants not only lost the 5 cents they could have earned, but also lost 5 cents that was earned previously. Munson and Crosbie found that implementing contingent incentives and disincentives improved performance in comparison to conditions in which payment was received independent of performance. Participants within this arrangement have complete control
over self-pacing. However, computer-based racing response patterns will be punished and appropriate pacing decisions will be reinforced.

While behavior analysts have often disapproved of the use of punishment in training and teaching, particularly the use of physical reprimands and strong social disapproval (Skinner, 1954), there is evidence to support its use. For example, a meta-analysis by Getsie, Langer, and Glass (1985) found that punishment improved discrimination learning over reward alone. As the disincentives used by Munson and Crosbie (1998) demonstrate, punishers can be mild yet effective. It is likely that punishment improves learning by slowing down responding (and thereby reducing racing) (Borresen, 1973; Donahue & Ratliff, 1976; Tindall & Ratliff, 1974). Furthermore, punishment can also cause organisms to attend to stimuli more carefully than they would otherwise (Balaban, Rhodes, & Neuringer, 1990; Muenzinger, 1934; Ratliff & Root, 1974).

While other possibilities exist for reducing computer-based racing, only postfeedback delays and contingent incentives/disincentives have been empirically studied for the purpose of reducing such racing. However, these two methods have yet to be directly compared to one another to assess their relative impact on performance. Both methods have a number of advantages and disadvantages. Postfeedback delays require very little monitoring of learner interactions to be effective, therefore reducing supervisory demands. However, by their very nature, programmed delays automatically increase training time. Furthermore, learners often dislike being artificially slowed in their progress. For example, Kelly and Crosbie (1997) utilized 10-second postfeedback delays and found that participants often complained about the delay. Furthermore, total
training time increased by 25% when compared to the no delay condition. This can be particularly problematic if learner satisfaction has an impact on program adoption. In the article, they suggested the investigation of 5-second postfeedback delays to see if improved performance could be retained while eliminating learner dissatisfaction.

Munson and Crosbie (1998) reported that unlike postfeedback delays, contingent incentives and disincentives did not negatively impact satisfaction. Although the contingent incentives and disincentives increased total training time by 15% relative to the control condition, this increase in training time was less than the increase found with postfeedback delays in the Kelly and Crosbie (1997) study. Complete learner control over within unit pacing can be retained, with all the benefits suggested by advocates of self-pacing, possibly without producing undesirable computer-based racing. However, there is an important disadvantage to using contingent incentives/disincentives: someone must evaluate the performance of learners. Thus, this solution involves the cost of increased supervision of CBI. Furthermore, the linguistic capabilities of computers are too limited to evaluate any complex learner responses, necessitating judgments by human evaluators (Chase, 1985; Pear & Martin, 2004), thus adding to the labor cost of this method. Finally, if monetary incentives are used, this can potentially add more to the financial costs associated with this method.

While the disadvantages associated with the aforementioned methods are problematic, each may be worth the costs if they improve learning within a CBI format. The question becomes which method is more effective, in terms of both performance and satisfaction. This study sought to address this question by comparing the effects of
postfeedback delays and contingent incentives/disincentives with each other and with normal CBI conditions.
METHOD

Participants and Setting

Seventy-two university students who had not taken or were not currently enrolled in PSY 3600 (Concepts and Principles of Behavior Analysis), PSY 3960 (Behavioral Training and Teaching Strategies), or PSY 5480 (E-Learning) were recruited via in-class announcements and on campus flyers. The script for the in-class announcements can be found in Appendix A and a copy of the campus flyers can be found in Appendix B. After completing 21 of the instructional units, participants took a posttest and those who scored 75% or better on the posttest received a $5.00 bonus at the conclusion of the study. Due to attrition, only 61 participants completed the posttest and were included in the analyses. Two additional participants quit the study before they finished the last six units that were used to assess satisfaction with the three experimental conditions. The remaining 59 participants were paid a $15 bonus for completing all instructional units. Participants were paid in a lump sum for completion of the instructional units at the end of the study, as well as all other payments (further details on payment can be found in the Experimental Procedures section below).

Sessions were conducted in a university laboratory (Wood Hall, 2532) containing four desktop computers, keyboards, mice, chairs, and tables (see Appendix C for a diagram of the layout of the laboratory). Each computer was partitioned from one another by cubicle walls so that adjacent participants could not view each others’ screens. Cubicle walls also prevented experimenters from observing the screens of participants while instructional units were being completed.
Experimental Apparatus

Instructional material. A computer program created in Macromedia Flash presented 27 units, which consisted of sets 1-16 and 18-28 of the material from Holland and Skinner's (1961) *The Analysis of Behavior*. Sets 17 and 29 are review sets, which were used as the basis for pre- and posttests. For 16 of the experimental units, paper-based supplementals entitled exhibits accompanied the CBI program (see Appendix D for a sample). These exhibits were based on the exhibits used in the Holland and Skinner textbook.

Brevity of CBI tutorials has been a criticism of prior experimental research (Tudor & Bostow, 1991). It was important that a large number of units were used (a) to address possible interpretations that the novelty of the instructional method could be responsible for any observed effects (Skinner, 1984), (b) to facilitate the acquisition of a sufficiently large repertoire to allow variation in performance outcomes, and (c) to ensure that a large number of pre- and posttest questions could be drawn from the reviews sets of the Holland and Skinner (1961) text.

There were several reasons for using this text as the instructional material. First, the material was designed to be used in a teaching machine (Holland & Skinner, 1961) and thus is well suited for adaptation to a CBI format. The textbook had been frequently tested and refined before publication in its current form. This is important because one should not expect instructional material, no matter how well crafted, to work well on its first draft (Engelmann, 1992; Rummler, 1965). Finally, CBI versions of this text were used for many of the previous studies on computer-based racing (Crosbie & Kelly, 1993,
1994; Kelly & Crosbie, 1997; Munson & Crosbie, 1998), and keeping the material consistent facilitated comparisons with this previous research.

In addition to the Holland and Skinner (1961) text, an introductory computer module was used to familiarize learners with how the CBI program worked in an effort to minimize variability in experimenter instructions and so participants could acclimate to computer-based instruction prior to the contact with the Holland and Skinner material. During the instructional units, the experimenters did not clarify any of the material presented by the computer program. It was important to let the CBI program do as much of the teaching as possible otherwise it would have been difficult to discern whether the program or the experimenter did the teaching (Brethower, 1966).

Each unit began with a screen displaying a “Begin Unit” button (see Appendix E). The instructional program was set so that it took up the entirety of the screen, with screen resolution set at 800 x 600. After the “Begin Unit” button was clicked, the computer recorded the current time. Previous research has suggested that it is important that learners know their current progress within a unit (Chase, 1985), so every unit displayed the total number of questions and the current question participants were completing. Every instructional slide of the unit contained brief and incomplete statements requiring the learner to supply a response. Participants constructed responses for each question by typing the response on the keyboard (see Appendix F) and then clicking a “Submit Your Answer” button. Some questions contained multiple parts to answer (see Appendix G for an example). Answers to every part of the question needed to be correct in order for the question to be marked as correct. After clicking the “Submit Your Answer” button, participants could no longer alter their answer. Feedback consisted of the correct answer
being displayed immediately after clicking “Submit Your Answer” (see Appendix H).
Participants then scored the correctness of their response by typing either “C” or “I” and clicking a “Submit scoring” button to help ensure that they were attending to the feedback (see Appendix H). When participants completed all of the instructional slides, an “End Unit” button was displayed on the screen (see Appendix I). After participants clicked this button, the current time and all the participant’s responses, including supplied answers and self-scoring, were recorded by computer and sent to a password-protected and secure section of a website accessible only by the lead investigator. These data were identifiable by the participant number only.

*Pretest and posttest.* All participants completed a 51 question paper-based pretest in order to screen potential participants who already knew the material and to obtain a covariate measure (see Appendix J). Questions were drawn from review sets 17 and 29 of the Holland and Skinner (1961) text and covered material taught in non-review sets 1-16 and 18-22. The posttest was identical to the pretest.

*Experimental Design*

Although the alternating treatments design is often used within behavior analysis for making empirical comparisons between different interventions, this design was not employed in this study. Despite its popularity, the alternating treatment design is problematic due to sequence and contrast effects (Komaki & Goltz, 2001). Careful counterbalancing can often solve the problem of sequence effects, however, contrast effects remain an inherent problem. Furthermore, single subject designs are problematic when attempting to generalize results to a population that may be heterogeneous in its reactions to an intervention (Huitema, 2001).
Therefore, a between group repeated measures design with pretest and posttest was used to assess differences in learning. The participants were randomly assigned to one of three groups: postfeedback delay, incentives/disincentives, or control. These three conditions are described in more detail below. The postfeedback delay condition had 21 participants randomly assigned to it, whereas the incentives/disincentives and control conditions had 20 participants randomly assigned to each. To assess differences in terms of satisfaction, after the posttest, each participant was exposed to all three instructional methods before satisfaction data were collected.

Experimental Procedures

Introductory session. All introductory sessions were conducted by the lead investigator. The study did not begin until it had been approved by Western Michigan University’s Human Subjects Institutional Review Board (HSIRB) (see Appendix K). Only participants who signed a consent form approved by the HSIRB were included in this study. Participants had to answer “No” to all of the questions listed on the exclusionary criteria questionnaire (see Appendix L). After consent was obtained and participants met the inclusion criteria, they were randomly assigned to one of the three conditions. The first introductory script was read to participants at this point (see Appendix M) and following this script they were given a handout relevant to their experimental condition (see Appendices N-P). During this initial session, participants also completed a paper-based quiz to assess their understanding of the payment conditions (see Appendices Q-R). Participants had to score 100% on the quiz in order to participate and were given two attempts to do so. The quiz they completed varied depending on the experimental condition to which they were assigned. Individuals who
failed to pass the payment quiz would have been immediately dismissed (see Appendix S).

Following the payment quiz, qualifying individuals completed the pretest. Participants were informed that they could earn $5.00 if they score a 65% or better on the pretest, however, these participants would have been immediately excluded from further participation. Pretests were immediately scored by the lead investigator. Excluded individuals would have been debriefed and paid immediately (see Appendix S). Participants were not told in advance that scoring 65% or better would exclude them from the study. Due to screening criteria related to having taken certain psychology courses, it was not expected that any individuals would be excluded on the basis of the pretest.

Following the grading of the pretest, the second introductory script was read to qualifying participants (see Appendix T), who then completed a computer-based introductory tutorial to familiarize them with the navigation and format of the computer-based instructional units. This initial meeting concluded with qualifying participants being scheduled for experimental sessions. Qualifying participants were not paid for this initial meeting. No participants were excluded on the basis of the above criteria.

Experimental sessions. Each experimental session took less than an hour to complete. Previous research using a similar task has shown that fatigue often occurs when three or more units are completed (Crosbie & Kelly, 1994), therefore participants only completed two units per session. Each unit was estimated to take approximately 18 minutes to complete, with estimates ranging between 8 to 35 minutes per unit (thus, an average session time of 36 minutes). No more than two sessions were completed by a participant per day, with a minimum of a two-hour break between sessions.
Sessions began with an experimenter seating the participant in front of a computer already set to the appropriate unit. The experimenter then told the participant whether or not an exhibit accompanied the unit and asked the participant to click “Begin Unit” when he or she was ready. When the participant clicked “Begin Unit,” the experimenter left the view of the participant and recorded the start time. When the unit was complete, the computer informed the participant to let the experimenter know that he or she was finished. At this point the experimenter recorded the finished time. The computer automatically recorded the start and end time; the experimenter recorded times were used to ensure the accuracy of the computer recorded times.

*Postfeedback delay.* Participants were paid 5¢ for each question they completed, regardless of accuracy. Paying by question (rather than by time) helped to more directly tie effort to payment as well as increasing the similarity to the incentives/disincentives condition (see below). After participants clicked the “Submit scoring” button, there was a 5-second delay during which the material could not be advanced. The incomplete statement, feedback, and the participant’s response remained visible on the screen. In addition, a red bar that progressively decreased in size appeared on the screen during the delay (see Appendix U). When the red bar disappeared, a button appeared along with the text “Proceed to next question” (see Appendix V). Clicking the button allowed the participant to advance to the next question. Other than the imposed delay, the presentation of material was learner-paced.

*Incentives/disincentives.* Participants were paid 5¢ for each question they answered correctly and lost 5¢ for each question they answered incorrectly (net loss of 10 cents). Participants did not lose more money than they earned for each unit (i.e., they did
not owe the experimenter any money if performance was poor). Immediately after clicking the "Submit scoring" button, the "Proceed to next question" button appeared. Progression through each unit was entirely learner-paced.

Control. Participants were paid 5¢ for each question they completed, regardless of accuracy. Immediately after clicking the "Submit scoring" button, the "Proceed to next question" button appeared. Progression through each unit was entirely learner-paced. This was meant to be analogous to a typical workplace setting where employees are paid for the time they spend completing computer-based training. Although employees are typically paid by the hour, not by the question, it is necessary to pay in this fashion to keep this condition as similar as possible to the other two experimental conditions outside of the independent variable. Furthermore, the more questions a unit contained, the longer it took to complete. As such, there was a relation between the amount of time on the job and the amount of payment, just like with hourly pay in the workplace.

Posttest. Participants in all three groups completed a paper-based posttest during a separate session following the completion of unit 21 (set 22 of Holland & Skinner, 1961) and prior to taking unit 22 (set 23 of Holland & Skinner). As indicated earlier, participants were told that they could earn an additional $5.00 for scoring 75% or better on the posttest. Posttests were graded by the lead investigator and participants were informed of how they performed. Participants were also told that the experimental conditions of the final three sessions would differ for each unit (six units total). Participants were given a description of the experimental conditions to read (see Appendix W).
Comparison phase. After taking the posttest, participants were exposed to each of the three conditions using an alternating treatments design in order to obtain satisfaction measures. Satisfaction ratings often do not differ across experimental conditions unless participants are exposed to all conditions, thus enabling them to make meaningful comparisons with respect to their relative satisfaction with each condition (Bucklin & Dickinson, 2001; Dickinson & Gillette, 1993). As with prior sessions, participants completed two units per session. The final six units consisted of sets 23-28 from the Holland and Skinner (1961) text. Two units were presented under the postfeedback delay condition, two under the incentives/disincentives condition, and two under the control condition. The order in which participants were exposed to these conditions was randomly determined for each participant. Prior to pressing the “Begin Unit” button, the experimenter handed the participant a description of the possible experimental conditions (see Appendix W) and told him or her “You’ll be completing this unit under the [1st condition/2nd condition/3rd condition].” The participant then completed the instructional unit as normal.

Debriefing. During a debriefing session conducted by the lead investigator, participants rated their satisfaction with the three instructional conditions on a 9-point rating scale (see Appendix X). The lead investigator then read the debriefing script (see Appendix Y) and participants were shown a receipt detailing their payment (see Appendix Z). Participants then received payment for their participation, and any questions they had were answered. It was estimated that participants would earn approximately $7 per hour in addition to completion and posttest bonuses. The hourly rate was based on the following: approximately 480 minutes to complete all 27
instructional units based on time estimates from Holland and Skinner (1961), 1145 questions total for all 27 units, and 5 cents for every question. Thus, the total payment for completing all questions (or completing all questions correctly for the incentives/disincentives group) is $57.25. Dividing that by the estimated total time results in an average payment per minute of 0.119 (57.25 / 480). Multiplying the payment per minute by 60 results in an hourly rate of approximately $7.14.

**Dependent Measures**

The following were used to assess the differences between CBI formats: number correct on the pretest, number correct on the posttest, percentage correct per instructional unit, minutes spent completing each unit, accuracy of self-scoring, and satisfaction survey ratings. Percentage correct rather than raw number was used for assessing performance within instructional units to establish a common scale on the instructional units that varied by the number of questions. The density of rewards was calculated using the approximate hourly rate for each participant, based on the total earnings divided by the total training time for each participant. All of these numbers were calculated by experimenters and were based on data recorded by the computer (see Appendix AA for an example). The computer recorded the participant number, experimental condition, date, start time, end time, typed answers, and self-scoring. These data were transmitted via the internet to a section of the lead investigator's website. This information was password protected and accessible only to the lead investigator.

Given the limitations of computers to evaluate complex answers, human evaluators were needed to score participant responses. For example, the correct answer to a question may be “response.” If a participant typed “behavior” or “response,” the
computer would score these as incorrect, even though such alternative terms or spellings may be considered acceptable by a human evaluator. Thus, the data collected by the computer were printed out and given to the experimenters so that participant answers could be scored for accuracy. Date, start time, and stop time were also manually recorded by experimenters (see Appendix BB for a data sheet example).

All printed data forms were kept in file folders identified only by the participant’s number. The participant’s name was not included anywhere in the file folders. During the study, the files were kept in a locked cabinet inside the experimental laboratory (2532 Wood Hall). The lead and undergraduate investigators had keys to permit them to access the files in order to conduct experimental sessions.

Interobserver Agreement

Interobserver agreement was collected on participant responses and the time spent completing each unit. Two experimenters independently scored the accuracy of participant responses made during learning, with every question being marked as correct or incorrect for 100% of the units. Time measures were scored by comparing the computer records with the experimenter records for start and completion times for 30% of the units. This was done to ensure the computer was recording time accurately. Any duration that differed by less than one minute was marked as an agreement. Interobserver agreement on both measures were calculated by dividing the number of agreements by the number of agreements plus disagreements (point by point agreement), and then multiplying by 100.
Data Analysis

A one-factor ANCOVA was used to determine whether the percentage of correct answers on the posttest differed. The percentage of correct answers on the pretest was used as the covariate. A one-factor ANOVA was used to determine differences in terms of satisfaction, the amount of time spent on units, and the percentage of correct responses within units. The ANOVAs based on time and the percentage correct were drawn from data from the first 21 instructional units, the units completed prior to the posttest and comparison phase. Correlations between participant self-scoring percentage correct on each unit and experimenter percentage correct scoring was also calculated for all participants overall, each condition, and each individual participant. If the correlation between self-scoring and experimenter scoring was low, this would suggest that participants were not attending to the feedback and the inclusion of their data would be problematic. A one-factor ANOVA was calculated to see if there were differences between groups related to self-scoring accuracy. A one-factor ANOVA was also used to determine whether groups differed with respect to the average hourly pay.
RESULTS

Table 1 displays the raw means for the percentage correct for both the pretest and posttest. Two participants in the postfeedback delay and one participant in the incentives/disincentives condition scored more than 75% on the posttest. No participants in the control condition scored above 75% on the posttest. Table 2 shows the adjusted means for the posttest data, based on the ANCOVA analysis. Table 3 displays the source table for the results of the ANCOVA. The obtained differences were statistically significant ($F = 5.90$, $p = 0.005$). Fisher’s protected LSD pairwise comparisons were calculated to discover the source of the differences. The differences between the incentives/disincentives and control conditions were not significant at the .05 level. The differences between postfeedback delays and the other two conditions were significant at the .05 level.

Table 1

<table>
<thead>
<tr>
<th>Condition</th>
<th>$n$</th>
<th>Pretest</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postfeedback Delay</td>
<td>21</td>
<td>6%</td>
<td>51%</td>
</tr>
<tr>
<td>Incentives/disincentives</td>
<td>20</td>
<td>4%</td>
<td>31%</td>
</tr>
<tr>
<td>Control</td>
<td>20</td>
<td>4%</td>
<td>32%</td>
</tr>
</tbody>
</table>
Table 2

Adjusted Means for Percentage Correct: Posttest

<table>
<thead>
<tr>
<th>Condition</th>
<th>n</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postfeedback Delay</td>
<td>21</td>
<td>49.2%</td>
</tr>
<tr>
<td>Incentives/disincentives</td>
<td>20</td>
<td>32.6%</td>
</tr>
<tr>
<td>Control</td>
<td>20</td>
<td>34.5%</td>
</tr>
</tbody>
</table>

Table 3

Source Table for Analysis of Covariance: Posttest

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.T.</td>
<td>3305</td>
<td>2</td>
<td>1652.5</td>
<td>5.90</td>
<td>0.005</td>
</tr>
<tr>
<td>ResW</td>
<td>15956.5</td>
<td>57</td>
<td>279.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ResT</td>
<td>19261.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4 displays the raw means for the satisfaction rating. Due to attrition following the completion of the posttest, two participants did not provide satisfaction data because they were not sufficiently exposed to all three experimental conditions. Table 5 shows the source table for the one-factor ANOVA. The obtained differences were statistically significant ($F = 69.46, p < 0.001$). Tukey pairwise comparisons revealed that the differences between the control condition and the other two conditions were statistically significant at the .05 level. No other statistically significant differences were discovered.
Table 4

Satisfaction Ratings

<table>
<thead>
<tr>
<th>Condition</th>
<th>n</th>
<th>Satisfaction Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postfeedback Delay</td>
<td>59</td>
<td>5.4</td>
</tr>
<tr>
<td>Incentives/disincentives</td>
<td>59</td>
<td>5.1</td>
</tr>
<tr>
<td>Control</td>
<td>59</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Table 5

Source Table for Analysis of Variance: Satisfaction

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>360.757</td>
<td>2</td>
<td>180.379</td>
<td>69.46</td>
<td>0.000</td>
</tr>
<tr>
<td>T x Pp</td>
<td>301.243</td>
<td>116</td>
<td>2.597</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>662.000</td>
<td>118</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6 displays the approximate hourly rate for participants (based on total earnings and total time for first 21 units). Table 7 shows the source table for the one-factor ANOVA based on hourly earnings. The obtained differences were statistically significant ($F = 66.41, p < 0.001$). Tukey pairwise comparisons revealed that the statistically significant differences between all conditions at the .05 level.
Table 6
Mean Hourly Earnings

<table>
<thead>
<tr>
<th>Condition</th>
<th>n</th>
<th>Hourly Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postfeedback Delay</td>
<td>21</td>
<td>$5.29</td>
</tr>
<tr>
<td>Incentives/disincentives</td>
<td>20</td>
<td>$1.88</td>
</tr>
<tr>
<td>Control</td>
<td>20</td>
<td>$6.33</td>
</tr>
</tbody>
</table>

Table 7
Source Table for Analysis of Variance: Hourly Earnings

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>217.73</td>
<td>2</td>
<td>108.87</td>
<td>66.41</td>
<td>0.000</td>
</tr>
<tr>
<td>Within</td>
<td>95.07</td>
<td>58</td>
<td>1.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>312.81</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8 shows the means for the total time durations of the first 21 units. It should be noted that one hour and 14 minutes of the time duration for the postfeedback delay condition can be accounted for by the 5-second postfeedback delays. Table 9 displays the source table for the one-factor ANOVA for the time duration, including the time resulting from the postfeedback delays themselves. The obtained differences were statistically significant ($F = 5.23, p = 0.008$). Tukey pairwise comparisons revealed that the differences between the postfeedback delay condition and the other two conditions were statistically significant at the .05 level. No other statistically significant differences were seen. Table 10 shows the source table for the one-factor ANOVA for time duration,
excluding the time resulting from the postfeedback delays. The obtained differences were not statistically significant ($F = 0.05, p = 0.956$).

Table 8
Mean Total Time Durations

<table>
<thead>
<tr>
<th>Condition</th>
<th>$n$</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postfeedback Delay (including delay)</td>
<td>21</td>
<td>8 hours, 28 minutes</td>
</tr>
<tr>
<td>Postfeedback Delay (excluding delay)</td>
<td>21</td>
<td>7 hours, 14 minutes</td>
</tr>
<tr>
<td>Incentives/disincentives</td>
<td>20</td>
<td>7 hours, 7 minutes</td>
</tr>
<tr>
<td>Control</td>
<td>20</td>
<td>7 hours, 5 minutes</td>
</tr>
</tbody>
</table>

Table 9
Source Table for Analysis of Variance: Time Including Delay

<table>
<thead>
<tr>
<th>Source</th>
<th>$SS$</th>
<th>$df$</th>
<th>$MS$</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>93622</td>
<td>2</td>
<td>46811</td>
<td>5.23</td>
<td>0.008</td>
</tr>
<tr>
<td>Within</td>
<td>519584</td>
<td>58</td>
<td>8958</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>613206</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 10
Source Table for Analysis of Variance: Time Excluding Delay

<table>
<thead>
<tr>
<th>Source</th>
<th>$SS$</th>
<th>$df$</th>
<th>$MS$</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>809</td>
<td>2</td>
<td>405</td>
<td>0.05</td>
<td>0.956</td>
</tr>
<tr>
<td>Within</td>
<td>519584</td>
<td>58</td>
<td>8958</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>520393</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 11 displays the Pearson correlations between the total amount of time spent learning during units 1-21 and the scores on the posttest. These correlations were calculated both including and excluding the time from the 5-second postfeedback delays. None of the correlations were statistically significant.

Table 11

<table>
<thead>
<tr>
<th>Total Time Duration Correlated with Posttest Score</th>
<th>$r$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excluding 5-second postfeedback delay</td>
<td>-0.055</td>
<td>0.673</td>
</tr>
<tr>
<td>Including 5-second postfeedback delay</td>
<td>0.107</td>
<td>0.411</td>
</tr>
</tbody>
</table>

Table 12 shows the mean percentage correct within unit. Table 13 displays the source table for the one-factor ANOVA for the proportion of correct responses within units. The obtained differences were not statistically significant ($F=1.66$, $p=0.198$).

Table 12

<table>
<thead>
<tr>
<th>Condition</th>
<th>$n$</th>
<th>Percent Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postfeedback Delay</td>
<td>21</td>
<td>67.9%</td>
</tr>
<tr>
<td>Incentives/disincentives</td>
<td>20</td>
<td>62.1%</td>
</tr>
<tr>
<td>Control</td>
<td>20</td>
<td>60.1%</td>
</tr>
</tbody>
</table>
Table 13

Source Table for Analysis of Variance: Proportion Correct Within Units

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>0.0672</td>
<td>2</td>
<td>0.0336</td>
<td>1.66</td>
<td>0.198</td>
</tr>
<tr>
<td>Within</td>
<td>1.1699</td>
<td>58</td>
<td>0.0202</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1.2370</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 14 shows the Pearson correlations between participant self-scoring percentage correct and experimenter scoring percentage correct for each condition. One of the participants from the incentives/disincentives condition was excluded from the correlation calculations because he or she self-scored every answer as correct, regardless of accuracy. All correlations were statistically significant ($p < .001$). Table 15 displays the source table for the one-factor ANOVA for scoring correlations. Obtained differences were not statistically significant ($F = 1.61, p = 0.208$).

Table 14

Pearson Correlations between Participant and Experimenter Scoring

<table>
<thead>
<tr>
<th>Experimenter Scoring Correlated with Participant Self-Scoring in:</th>
<th>$r$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postfeedback Delay</td>
<td>0.966</td>
<td>0.000</td>
</tr>
<tr>
<td>Incentives/disincentives</td>
<td>0.927</td>
<td>0.000</td>
</tr>
<tr>
<td>Control</td>
<td>0.943</td>
<td>0.000</td>
</tr>
<tr>
<td>Overall</td>
<td>0.942</td>
<td>0.000</td>
</tr>
</tbody>
</table>
Table 15

Source Table for Analysis of Variance: Scoring Correlations

<table>
<thead>
<tr>
<th>Source</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>0.02071</td>
<td>2</td>
<td>0.01035</td>
<td>1.61</td>
<td>0.208</td>
</tr>
<tr>
<td>Within</td>
<td>0.36561</td>
<td>57</td>
<td>0.00641</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.38632</td>
<td>59</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Interobserver agreement on participant responses averaged 97.2% and never fell below 86.7% for experimental sessions. There was 100% agreement between computer recorded time durations and experimenter recorded time durations for sampled units.
DISCUSSION

As indicated by Tables 1-3, the postfeedback delay condition was most effective in improving performance on posttest measures. However, as indicated by satisfaction ratings (Tables 4 and 5), participants disliked being artificially slowed by such delays as compared with the control condition. Satisfaction with postfeedback delays did not differ from the incentives/disincentives condition. Overall, the control condition was the most preferred condition. This is not surprising, given that this condition allowed participants to earn money unhindered by delays in their progress and without regard to accuracy. Furthermore, as Table 6-7 indicate, the control condition resulted in the highest rate of earnings at a statistically significant level.

Although the control condition was the most favored condition, the performance data argue against its use in instructional situations where learning outcomes are of primary importance. In fact, it may be the case that one should not expect that the most effective learning solution will be the most popular solution. As others have pointed out, even though the outcomes of learning (i.e., fluent performance) might be enjoyable, the learning process itself is often stressful, especially when one must learn a large amount of material in a short time (Lindsley, 1992; Michael, 2004).

Similar to previous studies using 10-second postfeedback delays (Crosbie & Kelly, 1993, 1994; Kelly & Crosbie, 1997), the current study found 5-second postfeedback delays to be effective at improving the retention of instructional material. However, the current study conflicts with the previous study on the use of contingent incentives and disincentives to reduce computer-based racing (Munson & Crosbie, 1998). Munson and Crosbie found that contingent incentives and disincentives improved
performance over noncontingent incentives without negatively impacting satisfaction. The current study found roughly the opposite, with contingent incentives and disincentives failing to improve performance and also significantly reducing satisfaction. Given that the same instructional material and monetary arrangements were used in both studies, it is worthwhile to note possible explanations for this discrepancy.

One possible explanation relates to differences in research design. Munson and Crosbie (1998) used an alternating treatments design in which participants were exposed to 10-15 sessions of each condition (incentives/disincentives and control), with the order of presentation randomly determined for each participant. In the present study, participants were only exposed to one experimental condition prior to collection of performance measures. It is possible that contrast effects were present in Munson and Crosbie, with participants responding to the rapidly alternating conditions differently than they would have if the conditions were presented in isolation (Komaki & Goltz, 2001). Given that it is improbable that instructional arrangements would be rapidly alternated in an applied setting, the current study may be more representative of applied performance than the study conducted by Munson and Crosbie.

Although contrast effects may possibly explain differences in posttest outcomes, they are unlikely to explain differences in satisfaction data. In both Munson and Crosbie (1998) and the current study, participants were exposed to multiple experimental conditions in an alternating fashion prior to the collection of satisfaction measures. One possible explanation for the satisfaction differences may relate to sampling error. In Munson and Crosbie, only three research participants were utilized. To illustrate why this is problematic, it may be useful to look at the satisfaction ratings in the current study.
Although the majority of participants rated incentives/disincentives as less satisfactory than the control condition, there were still six individuals who rated these conditions as equal. Furthermore, seven participants assigned only a 1 point difference between these conditions. If one theorizes that this study’s sample is representative of the population as a whole, one could then assume that 22% (13 out of 59 surveyed participants) of the population would rate virtually no difference between incentives/disincentives and control conditions. The notion that a sample of three people (as in Munson and Crosbie) is highly likely to be subject to sampling error and that all three participants came from the unrepresentative 22% minority is quite plausible. Sampling error might not only explain the satisfaction discrepancies, it could potentially account for the performance discrepancies as well. Ultimately, when dealing with an intervention that is likely to generate large variability in responding across participants, it is important to use adequate sample sizes and use caution when interpreting studies utilizing small samples.

As Tables 8-10 illustrate, programmed delays did significantly increase training time, although they did not appear to disrupt pacing. When the computer wasn’t enforcing a delay, none of the three conditions differentially affected the rate at which participants responded to the material. As such, the current study presents no evidence that postfeedback delays work by disrupting the reinforcement for rapid responding. Other variables are needed to explain the differences in posttest performance.

As Table 11 shows, there is no significant correlation between the amount of time one spends in contact with instructional material and posttest scores. In other words, people who took extra time with the instructional material did no better or worse than those who took less time. Thus, simple duration of exposure is insufficient to explain
outcome differences. As Tables 12-13 demonstrate, there were no significant differences between conditions with regards to accuracy of supplied answers during the learning process itself. As Tables 14-15 demonstrate, there were also no significant differences between conditions with regards to self-scoring accuracy.

Tables 12 and 14 may suggest some possible mechanisms of action for postfeedback delays. Participants in the postfeedback delay condition tended to be the most accurate on within unit answers and self-scoring. It is possible that the extended time exposure to supplied answers and feedback fosters continued remediation, which translates to increased accuracy, better self-assessment, and improved retention. Again, as Table 11 illustrates, this is more than just simple extended time periods. However, since statistical significance was not reached with either within unit accuracy or self-scoring measures, caution is warranted with this interpretation.

Based on the present study and previous studies (Crosbie & Kelly, 1993, 1994; Kelly & Crosbie, 1997), there is evidence that postfeedback delays of 5-second and 10-second durations can improve performance in a computer-based instructional format. However, these differing durations have yet to be directly compared to see which are most effective at improving performance. A delay that is too short is unlikely to foster remediation, whereas a delay that is too long is going to unnecessarily frustrate learners and increase training time. What is unknown is what duration is optimal for learning and satisfaction. Future research should address this question by directly comparing postfeedback delays of different durations.

Although the present study did not support the use of this particular arrangement of monetary incentives for improving performance, this does not mean monetary
incentives in general are ineffective. There are a number of studies demonstrating the effectiveness of monetary incentives for improving performance (Bucklin & Dickinson, 2001). One could argue that the incentives were too small for each response or that learners didn’t realize the cumulative amount of incentives they were earning (or failing to earn), but previous research has shown that even small incentives delivered in the absence of feedback can be effective (Johnson, Dickinson, & Huitema, 2008). It is also possible that the punishment contingencies involved with the monetary disincentives disrupted learning, but the fact that accuracy during learning was the same in the incentives/disincentives condition as the other two conditions argues against this interpretation. The reasons for the ineffectiveness of this particular arrangement for incentives/disincentives are unclear. Future research should investigate under what arrangements incentives and disincentives are effective with computer-based instruction (both monetary and non-monetary incentives). For example, future research could investigate arrangements where participants gain 5 cents for only correct answers (contingent incentives without disincentives), or earn 3 cents for every answer regardless of accuracy but also gain an additional 2 cents for correct answers (base pay plus contingent bonus for accuracy).

Future research should also examine other methods for reducing computer-based racing. Two potential examples include branching formats and the incorporation of mastery learning. In branching formats, supplemental material is automatically added to instruction following mistakes on the part of the learner. This is contrasted with linear formats, where all learners are exposed to the same amount of material regardless of accuracy during learning. For example, Green, Eppler, Ironsmith, and Wuensch (2007)
compared performance under a branching format with a linear format and found superior results with the branching format.

With mastery learning, learners must achieve some predetermined performance criteria during an instructional section before being allowed to proceed to subsequent instructional material. For example, Montazemi and Wang (1995) developed two versions of a CBI system, one with mastery criteria and one without. In the version with mastery criteria, incorrect responses caused the program to reset to an earlier instructional frame. Performance was found to be superior under the program utilizing mastery learning.

If computer-based racing is maintained by the conditioned reinforcer of unit completion and “being done,” then branching and mastery learning may work in part due to postponing the reinforcer contingent upon mistakes. In both formats, mistakes automatically add in either supplemental material or review of previously viewed material, therefore delaying the time until unit completion. Unfortunately, the studies mentioned above did not include sufficient time measures to determine if learners’ self-pacing was altered under either branching or mastery learning formats.

Besides examining different postfeedback delay durations, alternative incentive arrangements, branching formats, and mastery learning in isolation, future researchers should consider studying different combinations of the strategies. For example, postfeedback delays with incentives may be more effective than either one alone.

Ultimately, the main contribution of this study shows that postfeedback delays even as brief as 5 seconds can improve learning in a computerized instructional format, even if not for reasons of self-pacing. There is much to be done to investigate self-pacing
and other factors that influence the effectiveness of computer-based instruction.

Computer-based instruction, like other forms of training and teaching, needs to be more than just cutting edge hardware and software. It requires a careful analysis of both behavior and instructional content in order to produce effective and efficient learning.
REFERENCES


Appendix A

In-class Recruitment Script
Recruitment Script

Hello, my name is Doug Johnson and I am a doctoral student in psychology at Western Michigan University. I am looking for individuals to participate in a study designed to test computer-based instruction under various conditions. The computer tutorials will teach about the experimental analysis of behavior, and therefore is likely to be beneficial to you in your future classes if you are a psychology major or minor.

If you are currently enrolled in or have completed PSY 3600 (Concepts and Principles of Behavior Analysis), PSY 3960 (Behavioral Training and Teaching Strategies), or PSY 5480 (E-Learning) you are not eligible to participate in this study because you would be too familiar with the material to be taught.

Sessions will be less than one hour, with an average session duration of 36 minutes. You will be asked to attend 17 sessions over an 8-week period. The amount of money you will earn will depend upon the conditions in the study, but it is likely that you will earn approximately $7.00 / hour. Additionally, there will be payment bonuses available dependent on performance.

Your participation is completely voluntary and you may withdraw at any time. If you do withdraw, you will be paid the money you have earned up to that point. Your willingness to participate in the study or your withdrawal from the study at a later time will not affect your grade in this or any other class.

If you would like to learn more about this study, please email me at djohnson@operant-tech.com. You may also call me at (269) 599-3668 if you prefer. [write email and phone number on board].

Thank you!
Appendix B

Recruitment Flyer
Research Participants Needed

I am looking for individuals to participate in a study designed to test computer-based instruction under various conditions. The computer tutorials will teach about the experimental analysis of behavior, and therefore is likely to be beneficial to you in your future classes if you are a psychology major or minor.

If you are currently enrolled in or have completed PSY 3600 (Concepts and Principles of Behavior Analysis), PSY 3960 (Behavioral Training and Teaching Strategies), or PSY 5480 (E-Learning) you are not eligible to participate in this study because you would already be familiar with the material to be taught.

Time commitment: 17 sessions (over the course of 8 weeks)

Session length: Less than an hour (average time: 36 minutes)

Payment: Varies, but will be roughly equivalent to $7.00 per hour plus bonuses

If you are interested in learning more about this study, please contact Doug Johnson. Be sure to provide your name, e-mail and/or telephone number, and the times you can be reached.

All information is confidential.

Thank you!

E-mail: djohnson@operant-tech.com
or
Phone: (269) 599-3668
Appendix C

Diagram of Laboratory Layout
Appendix D
Sample of Unit Exhibit
Exhibit for Unit 27

*Read exhibit now and refer to it as needed.*

A mouse was kept in a standard experimental box continuously for several days. After every 25th response (pressing a bar), a mechanism delivered a small pellet of food. (Water was continuously available.) The experiment was repeated with five different kinds of mice, as follows: (Letters refer to their cumulative records.)

(A) A mouse poisoned by goldthioglucose which damages part of the brain called the hypothalamus causing overeating and obesity.

(B) A mouse with surgical damage to the hypothalamus, with the same effects as mouse A.

(C) A normal mouse from a normal strain.

(D) An obese mouse from a strain some members of which suffer from hereditary obesity.

(E) A normal mouse from the same strain (mice E and D were litter mates).
Appendix E

Begin Unit Screenshot
When you're ready to begin, click the button below:

Begin Unit
Appendix F

Submit Your Answer Screenshot
Q 3: In (D), "neutral stimulus" means a tone which *** effect on salivation before conditioning.

Type your answer(s) in the space(s) below.

Submit Your Answer
Appendix G

Multi-part Response Request Screenshot
Q 22: In Figure 10, the rate was highest between (1) and , zero between (2) and , and intermediate between (3) and .
Appendix H

Feedback Screenshot
Q 1: Phase 1. The pigeon is on a(n) (1) ***(TT) schedule with an average interval of 1 minute. A response maintained on this schedule will be extinguished rather (2) _____ when reinforcement is discontinued.

Your answers
(1) variable interval
(2) quickly

Correct answer(s)
variable-interval
slowly

Was your answer correct? Score with c or i Submit scoring
Appendix I

End Unit Screenshot
Unit almost complete
Click the button below to finish this unit.

End Unit
Appendix J

Pretest/Posttest
Test

- The number of words needed to complete an item is indicated by the number of blanks. Thus “_____” indicates a one-word response, whereas “______” indicates a two-word response. When asterisks (*) are used in place of blanks, fill in as many words as you think necessary to respond to the item.

- The abbreviation TT calls for a technical term. When it is used, a nontechnical word is incorrect.

Q1: On a cumulative record, the slope of the line indicates (1) ***, and the hatch marks or pips usually indicate (2) **.

Q2: (1) _____ behavior is strongly influenced by the consequences of previous similar responses, whereas (2) _____ behavior depends upon a preceding stimulus.

Q3: In a conditioned reflex, when a conditioned stimulus is repeatedly presented alone, the magnitude of the conditioned response (1) _____ and the latency of the conditioned reflex (2) _____, until (3) _____ is complete.

Q4: When a pigeon is reinforced for pecking a key, the reinforcing stimulus occurs (1) _____ a peck, and the (2) _____ at which this response is (3) _____ (TT) increases.

Q5: Turning off a television commercial is reinforced by termination of a(n) (1) _____ reinforcer; turning on a very funny program is reinforced by the presentation of a(n) (2) _____ reinforcer.

Q6: Name the response systems involved in the following: walking to the table, putting food in the mouth and chewing it, (1) *** muscle; moistening food with saliva, (2) **; passing food into stomach, (3) **; and providing stomach with digestive juices, (4) **

Q7: Many so-called traits ascribed to individuals (aggressiveness, persistence, friendliness, etc.) are simply alternate ways of indicating an individual's _____ of emitting certain types of behavior.

Q8: In differential reinforcement, one form or magnitude of behavior is (1) *** and other, possibly rather similar forms or magnitudes, are (2) **.
Q9: The experimenter deliberately arranges reinforcement for key pecking, but superstitious behavior is conditioned by _____ reinforcement.
Q10: In a reflex, the (1) _____ of a stimulus is the intensity which is barely sufficient to (2) _____ a(n) (3) _____.
Q11: An important aspect of respondent conditioning is the _____ relation between presentations of the initially neutral stimulus and of the unconditioned stimulus.
Q12: After a chimpanzee has exchanged tokens for food, water, a mate, etc., the tokens * * * effective as reinforcers if the chimpanzee is well-fed but deprived of water.
Q13: Conditioned operants are eliminated in two contrasting ways: the response is emitted without reinforcement in the process called (1) _____, but is not emitted in the process called (2) _____.
Q14: In conditioning a reflex, as the number of pairings of the conditioned and unconditioned stimuli increases, the latency of the conditioned reflex (1) _____ and the magnitude of the conditioned response (2) _____, until both reach a limit.
Q15: A psychologist fed a baby when he emitted "coos," but not when he cried. We would expect that crying when hungry would be (1) _____ (TT) because of the withholding of (2) _____ (TT).
Q16: Certain groups of responses, such as those elicited by a sudden loud noise, are characteristic of a state of _____.
Q17: When we differentially reinforce successive approximations to a final form of behavior, we are _____ behavior.
Q18: Persistent head scratching, pencil chewing, table tapping, etc., while studying are frequently conditioned (1) _____ operants resulting from (2) _____ contingencies of reinforcement.
Q19: Two ways of effectively preventing unwanted conditioned behavior are: (a) to (1) _____ it by withholding reinforcement, or (b) to condition some (2) _____ behavior.
Q20: A stimulus which elicits a response without previous conditioning is called a(n) (1) ___; a stimulus which elicits a response only after conditioning is called a(n) (2) ___.

Q21: If an airplane spotter never sees the kind of plane he is to spot, his frequency of scanning the sky (1) ___. In other words, his “looking” behavior is (2) **. (TT)

Q22: You will not continue to work if your pay checks “bounce” because the (1) ___ generalized reinforcing effect of such a check disappears in (2) ___.

Q23: A simple operant can be conditioned very rapidly if the organism is (1) ___ to the situation and if a reinforcer follows the response (2) ___.

Q24: In shaping any given behavior, we gradually change the criterion for reinforced responses. The desired behavior is approached by **.*

Q25: To condition a reflex, a neutral stimulus is (1) ___ with a(n) (2) ___.

Q26: In the usual experiment, when a peck operates the food magazine the (1) ___ reinforcement is immediate, whereas the (2) ___ reinforcement is slightly delayed.

Q27: In a reflex, the more intense the stimulus, the greater the (1) ___ of the response and the shorter the (2) ___ of the reflex.

Q28: When a response is elicited by a stimulus without previous conditioning, the sequence is called a(n) ___.

Q29: The pairing of two stimuli is necessary for conditioning (1) ___ behavior; reinforcement is necessary for conditioning (2) ___ behavior.

Q30: Reaching for a glass of water or saying "Water, please" are examples of (1) ___ behavior; any specific instance of such behavior, however, is called a(n) (2) ___.

Q31: Lying generates stimuli which have acquired the power to elicit the conditioned responses which occur in ___.
Q32: A particularly slow learner may require many reinforcements before developing a high rate of responding. He is _____ likely to develop superstitious behavior than a faster learner.

Q33: Operant behavior has direct consequences on the environment. A consequence which results in an increase in the subsequent rate of the operant response is called a(n) ____. (TT)

Q34: If in teaching the shot-put, a coach is “satisfied” with every throw, no matter how bad, he (1) ** * using successive approximation and he (2) ** * using differential reinforcement.

Q35: Smooth muscles change the (1) ____ of various (2) ____ organs.

Q36: A conditioned reinforcer can become a(n) * * * by being paired with several unconditioned reinforcers appropriate to various deprivations.

Q37: The reinforcers used by animal trainers are (1) ____ arranged, but a pigeon foraging for food among leaves in a park is working under (2) _____ contingencies.

Q38: When behavior decreases in frequency and when, so far as we know, no previous conditioning of the behavior has taken place, we call the process not extinction but _____.

Q39: Learning to say “ball” makes it easier for the child to learn to say “fall” because the two responses have * ***.

Q40: The professional winetaster can make very fine (1) ____. He shows little (2) ____ among various wines.

Q41: Availability of reinforcement depends on the passage of time in (1) ____ schedules, and on the number of responses in (2) ____ schedules.

Q42: If a bright white light is often present when a response is reinforced, a light of medium intensity should produce a rate of responding (1) ____ than that of the bright light and (2) ____ than that of a very faint light.
Q43: A response occurring immediately after a reinforcement is never reinforced on a(n) (1) ______-interval schedule. A response immediately after reinforcement is sometimes reinforced on a(n) (2) ______-interval schedule.

Q44: Responses reinforced by the generalized reinforcers of affection, approval, etc., are often extinguished very (1) _____ because reinforcement has occurred (2) _____ due to the subtlety of the stimuli.

Q45: Response magnitude varies closely with stimulus intensity in the case of (1) _____ behavior, but much less so in the case of (2) _____ behavior.

Q46: An organism may emit the same response to two fairly similar stimuli when only one of them has been present during reinforcement. The term for this phenomenon is * * *.

Q47: When a response is under the control of a single property of a stimulus (which cannot exist alone), we call it a(n) * * *.

Q48: Intermittently reinforcing temper tantrums makes them very _____ to extinction.

Q49:

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
</table>

(1) _____ fixed-interval  
(2) _____ variable-interval  
(3) _____ fixed-ratio  
(4) _____ variable-ratio

Q50: In operant discrimination we speak of a *three-term* contingency. Events are arranged in this order: (a) present the (1) _____, (b) wait for the (2) _____, and (c) (3) _____.

Q51: In establishing a discrimination, a response is (1) * * * in the presence of one stimulus and (2) * * * in the presence of another stimulus.

THE END
Appendix K

HSIRB Research Approval Letter
Date: September 17, 2008

To: Alyce Dickinson, Principal Investigator
    Douglas Johnson, Student Investigator for dissertation

From: Amy Naugle, Ph.D., Chair

Re: HSIRB Project Number: 08-09-10

This letter will serve as confirmation that your research project entitled “Reduction of Racing in Computer-Based Instruction” has been approved under the expedited category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you may only conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: September 17, 2009
Appendix L

Exclusionary Criteria Questionnaire
Please complete the following questions. All information you provide will remain confidential.

Have you taken, or are currently taking, any of the following classes?

PSY 3600, Concepts and Principles of Behavior Analysis  ___ Yes  ___ No
PSY 3960, Behavioral Training and Teaching Strategies  ___ Yes  ___ No
PSY 5480, E-Learning  ___ Yes  ___ No

Experimenter use only: Participant number _______
Appendix M

First Introductory Instructional Script
During this study, you will complete 27 computer-based instructional units to teach you basic concepts in the analysis of behavior. You will also be paid for your participation. Details on the payment methods will be described in a handout I will give you shortly. You cannot keep a copy of this handout. You will have to complete a brief quiz to ensure your understanding of the payment methods. You must get 100% on this quiz and you will have two attempts to do so. Failure to pass this quiz will exclude you from being able to participate further in this research.

Following the successful completion of this quiz, you will take a pre-test over the instructional material. Please attempt to do your best on this pre-test. As an incentive, you will receive a $5.00 bonus if you get 65% or better on this pre-test. After I grade the pretest and tell you your score, I will talk to you about the next steps. It is expected that today’s session will last approximately one hour. Do you have any questions?
Appendix N

Payment Handout: Postfeedback Delay Condition
You will earn 5 cents for every question you answer during the computer-based instructional units. The number of questions varies during each unit, so the amount of money you can earn will also vary. You will be paid following the completion of all 27 instructional units. To earn the $5 bonus for the pretest, you need to score 65% or better. To earn the $5.00 bonus on the posttest, you will need to score 75% or better. If you complete the entire study, you will also earn a $15 bonus. As indicated in the informed consent document, if you withdraw before the end of the study you will be paid the money you earned up to that point. While completing the instructional units, a red bar will appear as the computer processes your answers. This is normal and should not cause you any concern.
Appendix O

Payment Handout: Incentives/Disincentives Condition
You will earn 5 cents for every question you correctly answer during the computer-based instructional units. You will also lose 5 cents for every question you incorrectly answer during computer-based instructional units. Although the computer will ask you to grade your answers, your answers will also be independently graded by two experimenters. Their judgment will be used to determine whether or not your answer is correct. The number of questions varies during each unit, so the amount of money you can earn will also vary. You will be paid following the completion of all 27 instructional units. To earn the $5 bonus for the pretest, you need to score 65% or better. To earn the $5.00 bonus on the posttest, you will need to score 75% or better. If you complete the entire study, you will also earn a $15 bonus. As indicated in the informed consent document, if you withdraw before the end of the study you will be paid the money you earned up to that point.
Appendix P

Payment Handout: Control Condition
You will earn 5 cents for every question you answer during the computer-based instructional units. The number of questions varies during each unit, so the amount of money you can earn will also vary. You will be paid following the completion of all 27 instructional units. To earn the $5 bonus for the pretest, you need to score 65% or better. To earn the $5.00 bonus on the posttest, you will need to score 75% or better. If you complete the entire study, you will also earn a $15 bonus. As indicated in the informed consent document, if you withdraw before the end of the study you will be paid the money you earned up to that point.
Appendix Q

Incentives/Disincentives Pay System Quiz
Please answer the following:

1) How much money will you earn for every question you correctly answer during the computer instruction? _____

2) How much money will you lose for every question you incorrectly answer during the computer instruction? _____

3) Your answers will be considered correct (select one):
   A. As long as you click the submit button
   B. If you score your answer as correct
   C. If the experimenters decide the answer is correct
   D. If the computer decides the answer is correct

4) When will you be paid for the units you’ve completed? __________________________

5) What percentage correct on the pretest do you need to earn the $5.00 bonus? _____

6) How much of a bonus will you earn if you complete the entire study? _____

7) What percentage correct on the posttest do you need to earn the $5.00 bonus? _____
Appendix R

Postfeedback Delay and Control Pay System Quiz
Please answer the following:

1) How much money will you earn for every question you answer during the computer instruction? ______

2) When will you be paid for the units you’ve completed? _______________________

3) What percentage correct on the pretest do you need to earn the $5.00 bonus? ______

4) How much of a bonus will you earn if you complete the entire study? ______

5) What percentage correct on the posttest do you need to earn the $5.00 bonus? ______

Experimenter use only: Participant number ______
Appendix S

Debriefing Scripts for Excluded Individuals
If excluded for failure to pass payment quiz:

I would like to thank you for your interest in participating in this study. Unfortunately, we will not be able to include you as a participant due to the limited number of attempts allowed for the payment quiz, as it is critical that you demonstrate understanding of the payment procedures. Please do not discuss details of this study with other individuals. Do you have any questions?

If excluded for scoring 65% or better on pretest:

I would like to thank you for your interest in participating in this study. Unfortunately, we will not be able to include you as a participant. Due to your high performance on the pretest you are too knowledgeable about the subject matter to be taught. You will be paid immediately for taking the pretest and I would like to thank you for your time. Please do not discuss details of this study with other individuals. Do you have any questions?
Appendix T

Second Introductory Instructional Script
Unfortunately, you did not score high enough on the pretest to earn the bonus. However, now that you have completed the pretest, you will complete a computer tutorial on how to navigate the computer-based instruction. Our final step for the day will involve scheduling you for sessions so you can begin completing the instructional units. Do you have any questions?
Appendix U

Screenshot of Postfeedback Delay
Q 2: Reinforcement continues to be important after behavior has been acquired. Certain schedules of reinforcement continue to have an effect in ______ behavior in strength.

<table>
<thead>
<tr>
<th>Your answers</th>
<th>Correct answer(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>maintaining</td>
<td>maintaining</td>
</tr>
</tbody>
</table>

Was your answer correct? Score with c or in: c
Appendix V

Proceed to Next Question Screenshot
Q 3: Bending down to the food magazine makes the food visible. The *sight of food* (a conditioned reinforcer) **precedes** bending down to the magazine.

<table>
<thead>
<tr>
<th>Your answers</th>
<th>Correct answer(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>precedes</td>
<td>reinforces</td>
</tr>
</tbody>
</table>

Was your answer correct? Score with c or i: 1

Proceed to next question
Appendix W

Description of Conditions for Final Six Units
During these final three sessions, the payment conditions and other variables will be different for each unit. The unit you are about to begin will be under one of the following three conditions. The experimenter will tell you which of these three is in effect. Please do not discuss these conditions with any other participants.

1st Condition

You will earn 5 cents for every question you answer during the computer-based instructional units. While completing the instructional units, a red bar will appear as the computer processes your answers. This is normal and should not cause you any concern.

2nd Condition

You will earn 5 cents for every question you correctly answer during the computer-based instructional units. You will also lose 5 cents for every question you incorrectly answer during computer-based instructional units. Although the computer will ask you to grade your answers, your answers will also be independently graded by two experimenters. Their judgment will be used to determine whether or not your answer is correct.

3rd Condition

You will earn 5 cents for every question you answer during the computer-based instructional units.
Appendix X

Satisfaction Questionnaire
Please select a single number to represent your satisfaction with the three computer tutorial conditions:

How satisfied were you with the conditions in which there was a delay after your received feedback (the red bar appeared for five seconds)? (1st condition)

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not at all satisfied</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Extremely satisfied</td>
</tr>
</tbody>
</table>

How satisfied were you with the condition in which you earned money for correct answers and lost money for incorrect answers? (2nd condition)

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<tr>
<th>1</th>
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<th>3</th>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Extremely satisfied</td>
</tr>
</tbody>
</table>

How satisfied were you with the condition in which there was no delay and you received money for all your answers, regardless of accuracy? (3rd condition)

<table>
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<tr>
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<tr>
<td>Not at all satisfied</td>
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<td></td>
<td></td>
<td></td>
<td>Extremely satisfied</td>
</tr>
</tbody>
</table>

Experimenter use only: Participant number _______
Appendix Y

Debriefing Script
1. Thank you for participating in this study.

2. I would like to explain the purpose of the study to you.
   The purpose of this study was to compare how well individuals perform under various instructional conditions when using computer-based instruction, namely the three conditions you experienced during your final six units. Besides performance, we also wanted to investigate individuals’ preferences for those three conditions.

3. (Give participant data sheet indicating the amount of money earning for each instructional unit, posttest, completion bonus, and total). This form indicates the amount of money you earned for each session. As you can see, your total payment was _____.

4. Do you have any questions about this study or your participation?

5. Please do not discuss this study with anyone else because we have not yet completed it.
Appendix Z

Participant Form for Money Earned
### Amount of Money Earned Per Unit

**Participant Number:** ________________

<table>
<thead>
<tr>
<th>Unit Number</th>
<th>Amount Earned</th>
<th>Total Questions</th>
<th># Correct</th>
</tr>
</thead>
<tbody>
<tr>
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<td>_____________</td>
<td>54</td>
<td>__________</td>
</tr>
<tr>
<td>2</td>
<td>_____________</td>
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<td>__________</td>
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<td>3</td>
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<td>29</td>
<td>__________</td>
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<tr>
<td>4</td>
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**Units Total:** __________

**Posttest Bonus:** __________

**Completion Bonus:** __________

**TOTAL PAY:** __________
Appendix AA

Data As Recorded by Computer
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Condition|delay
Began unit at|16:37-5/15/2008
Finished unit at|17:02-5/15/2008
Participant's answers
3-1|decrease
Scored as|i
3-2|magnitude
Scored as|c
3-3|will not have an
Scored as|c
3-4|neutral stimulus
Scored as|c
3-5|was not
Scored as|c
3-6|conditioning
Scored as|c
3-7|two|stimulus|response
Scored as|c
3-8|unconditioned reflex
Scored as|c
3-9|simultaneously
Scored as|c
3-10|conditioning
Scored as|c
3-11|neutral|unconditioned
Scored as|c
3-12|short
Scored as|c
3-13|latency
Scored as|i
3-14|will not be
Scored as|c
3-15|eliciting
Scored as|c
3-16|conditioning
Scored as|c
3-17|conditioning
Scored as|c
3-18|neutral|conditioned
Scored as|c
3-19|conditioned
Scored as|c
3-20|conditioned - reflex
Scored as|c
3-21|without pairing it
Scored as|c
3-22|paired
Scored as|c
3-23|conditioned stimulus
Scored as|c
3-24|conditioning|extinction
Scored as|c
3-25|salivation
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END
Appendix BB

Data Sheet
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