Teaching by Example: An exemplar-based computerized program of instruction in positive reinforcement, negative reinforcement, positive punishment and negative punishment

by

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We accept this thesis as conforming to the required standard

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ABSTRACT

The objective of the present study was two-fold: first, to develop, using exemplars and student-centered methodology, a concise and effective computerized program of instruction focusing on the discrimination among positive reinforcement (PR), negative reinforcement (NR), positive punishment (PP) and negative punishment (NP); and second, to provide future researchers with information regarding some of the difficulties that are encountered during the development of an efficient, effective teaching tool. Fourteen subjects, all novices in the area of behavioural psychology, were individually run through the program, which consisted of five cumulative units, each containing a pretest, training session and posttest. Units dealt with the concepts of: (1) behaviour and stimulus, (2) contingency, (3) reinforcement and punishment, (4) stimulus addition and subtraction, and (5) discrimination among PR, NR, PP, and NP. The information was arranged in a hierarchy; that is, mastery of material in subsequent units required mastery of material provided in preceeding units. Subject feedback and computerized records of the responses from each subject in turn were analyzed and used to revise the program. A summary of these revisions is included. It was hoped that with continued revisions a goal of 90% correct on the five posttests would be obtained over a consecutive number of subjects. Results showed a mean of 95% correct on the posttests over the last five consecutive subjects, and an overall increase in performance levels across the 14 subjects.

These results suggest that student-centered methodology can be used to develop an effective exemplar-based computerized program of instruction. Considerations for future research in the development of computerized programs of instruction are discussed.

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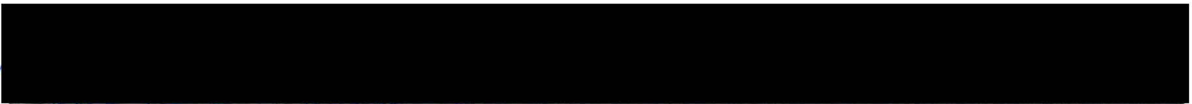
Dr. Bram C. Goldwater, Supervisor (Department of Psychology)



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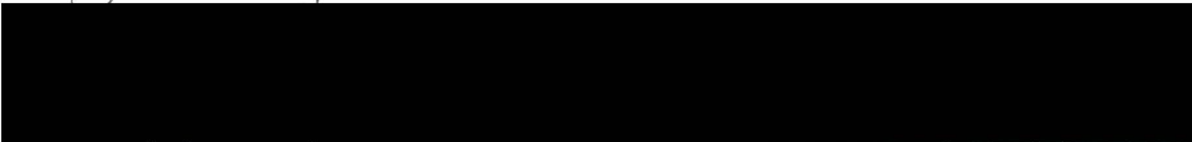

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Dedication

This is dedicated to my family, and especially Mel, for all of your love, support and encouragement throughout the writing of this thesis.

B.F. Skinner once stated that "students learn without teaching, but the teacher arranges conditions under which they learn more rapidly and effectively" (1965, p.6). This statement raises a question that has eluded researchers for decades: Under exactly what conditions do students learn more rapidly and effectively? In 1954, Skinner provided a viable answer to this question: an application of learning principles known as programmed instruction.

Programmed instruction emerged from the laboratories of learning psychologists to bridge the gap between experimentally based principles of learning, derived from animal and human studies, and the field of education, arguably the learning laboratory's most natural area of application. Since its introduction, programmed instruction has been the subject of many evaluative and comparative studies, some supporting the use of programmed instruction and the principles upon which it rests, and some not supporting its use as an effective teaching tool. This inconsistency need not reflect inadequacies in the principles of programmed instruction; rather, the discrepancies may be in the failure to properly apply effective principles in the design and testing of the programs under study (Gilbert, 1958; Vargas, 1986; Tudor and Bostow, 1991). From this point of view, what is needed is a renewed focus on the development of sound programs which (a) adequately utilize principles of learning, and (b) are subjected to careful validation and modification based on repeated testing with students. Such an endeavor might again demonstrate the power of programmed instruction, and foster its acceptance as an effective form of instruction.

One area that could benefit from programmed instruction is the teaching of behavioural principles and terminology and their application in the analysis of behaviour, which is often a challenge to students. For example, it has often been reported that the discrimination between negative reinforcement and punishment presents particular difficulty to students due to surplus meanings associated with the terms "negative" and "punishment" (McConnell, J.V., 1990; Tauber, R.T., 1990.) Students also appear to have difficulty with the analysis of behavioural episodes into antecedent, behavioural and consequent components. Although Holland and Skinner's (1961) programmed text "The Analysis of Behavior" is a prime example of the proper application of behavioural principles to the teaching of behavioural principles, new instructional techniques, based most particularly on the use of computers and exemplar training, have been developed since this text was published.

The purpose of the present study is two-fold: first, to develop a concise and effective computerized program of instruction, incorporating exemplar training, and focusing on the discrimination among positive reinforcement, negative reinforcement, positive punishment and negative punishment; and second to provide future researchers with information regarding some of the difficulties that are encountered during the development of an efficient, effective teaching tool. It is my hope that these efforts will provide an illustration, if not a model, of procedures which can be used to establish sound, empirically based forms of programmed instruction.

In the remainder of this section I will review the principles of learning which underlie programmed instruction; summarize the body of literature concerning evaluative and comparative studies, including sources of discrepancies within these studies; discuss the advantages of computerized programmed instruction over non-computerized programmed instruction; and propose an explanation for the kinds of discrepancies found in the studies mentioned above. I will discuss the use of exemplar training (Miller, 1980) in programmed instruction, and how this technology can be applied to the teaching of positive reinforcement, negative reinforcement, positive punishment, and negative punishment.

Programmed Instruction: Principles of Learning

As mentioned earlier, programmed instruction is based on a set of principles, derived from animal and human studies in the learning laboratory, which have been applied to the field of education, or more specifically, the area of teaching technology. The principles of learning that are used in programmed instruction are generally agreed upon and are summarized in James G. Holland's paper entitled, "Teaching Machines: An Application of Principles from the Laboratory" (1960). He identified the following principles of programmed instruction:

**immediate feedback*

**active responding*

**gradual progression*

**fading of prompts*

*contingent responding

*discrimination training

*student-centered methodology

Each of these principles is said to contribute in an important way to the effectiveness of programmed instruction as a teaching tool. It is for this reason that an elaboration of these principles and a review of studies evaluating their importance is warranted. This will be followed by a discussion of research comparing the overall effectiveness of programmed instruction with that of "traditional" (teacher-centered) instruction.

The reader will note that many of the experiments cited in the present study are from the 1960's. The decision to focus on these studies was made for two reasons. First, in keeping with the objective of the present study, namely, a return to the principles of learning first proposed by Skinner, it was necessary to refamiliarize myself and the reader with the objectives and methodology of those people first studying programmed instruction. Secondly, as discussed below, in the current literature there is a lack of carefully-validated programs and latitude in what researchers refer to as programmed instruction, which makes the analysis of the results obtained in these studies difficult and tenuous.

Immediate Feedback

Feedback signals the student as to whether the student's response is correct or

incorrect, immediately after the response is emitted. Under the assumption that confirmatory feedback is a positive reinforcer, this contingency should increase or maintain the student's answering behaviour, which is clearly a critically important property of effective instruction. The effectiveness of a reinforcer depends, in part, on how quickly it is presented following the response (Skinner, 1954; Miller, 1980). As Skinner (1954) pointed out, "...the lapse of only a few seconds between the response and reinforcement destroys most of the effect" (p.6).

The research evaluating the importance of immediate feedback in programmed instruction has not been conclusive. Lublin (1965) found that students completing a portion of a programmed instruction text without immediate feedback did better on a criterion test than those students that had received immediate feedback following every frame. Similar results have been obtained in other studies (e.g. Moore and Smith, 1964; O'Day, Kulhavy, Anderson and Malaynzski, 1971). However, these results were not supported by Anderson, Kulhavy and Andre (1971), who used a computer-controlled program which required students to enter their responses before any feedback was given. They found that students receiving feedback learned significantly more than those not receiving feedback. Similar results have been obtained in other studies (Meyer, 1960; Kaes and Zeaman, 1960). One reason for this discrepancy, suggested by Anderson et. al (1971), is that in the case of the studies not supporting the use of immediate feedback, the students in the feedback condition had the opportunity to "peek" at the answers prior to constructing a response - thus violating another

important principle of effective programmed instruction: active responding. This was confirmed in their experiment, where students who were permitted to "peek" at the answers prior to responding learned less than groups receiving either 100% corrective feedback or no feedback, but who were required to construct a response first. Other research (Holland, 1965) suggested that programs which are more difficult in content may benefit most from immediate feedback, likely because, in the case of easier material, the student can often provide his/her own feedback and so may not require external feedback in order to progress through the program.

The importance of immediate feedback in programmed instruction has thus received only partial support. Nonetheless, the present study will include immediate feedback as originally proposed by Skinner, as the evidence questioning its importance is equivocal, and there are strong theoretical arguments against excluding it as an important variable in programmed instruction. Moreover, by utilizing computerized programmed instruction, the present study will avoid any possibility of "peeking," as the student will be required to emit a response prior to receiving feedback.

Active Responding

Active responding requires that the student emit overt responses to questions within a program. An overt response, by definition, must be observable by others, as is the case when a response is vocalized, written or typed on a computer

keyboard.

In the classroom, particularly at the college/university level, a written response is normally required from the student on written examinations. Therefore, if the goal of the programmer is to maximize the possibility of generalization to examinations, the most logical response mode for training would also be written. More importantly, the physical record produced by written responses provides the programmer with important information regarding the student's strengths and weaknesses with respect to the programmed material, and the effectiveness of the program in general. Research has generally explored two dimensions of active responding: constructed-answer versus multiple-choice answer; and overt versus covert versus no-response modes. Coulson and Silberman (1960) and Fry (1960) demonstrated that constructed-answer responding better prepared students for writing both essay-style exams and multiple-choice exams, when compared with multiple-choice responding. The benefits of constructed-answer responding are of particular note, since the mode of response in training versus testing (typically multiple-choice) are arguably quite divergent in the constructed-answer mode.

As was the case for the literature on immediate feedback, studies of active responding have yielded negative as well as positive results (e.g. Williams, 1963; Cummings and Goldstein, 1964; Anderson, 1967; Tobias, 1973; Silverman, 1978). Anderson (1967,) found no difference in student performance across the three response modes of no-response, covert response and overt response. Holland and Kemp (1965), however, in their review of this literature, concluded

that studies which carefully controlled for the content of the question frames (e.g. excess verbiage, copying frames) yielded superior results for active responding over covert and no-response modes; studies failing to control for these variables found no significant differences among response modes. Holland and Kemp suggest that frames have to be carefully constructed before the effects of active responding can be meaningfully evaluated. Another moderating variable in the relation between programmed instruction performance and mode of response is the difficulty of the subject matter involved; that is, the more difficult the material is, the clearer the benefits of overt responding are (Williams, 1963; Kulhavy and Parsons, 1972).

Overall, the contribution of active responding to programmed instruction has not been conclusively established. Nonetheless, the present program will utilize active responding, not only because the literature provides some evidence for its importance, but also due to its usefulness in providing a record of student errors, which can provide information useful for correcting misleading or otherwise inadequate aspects of the program.

Gradual Progression

Gradual progression refers to a program which specifies a target behaviour, then presents the pertinent information sequentially in small, manageable units until the target behaviour is attained. This principle becomes particularly important when the use of complex terminology and concepts is the specified

target behaviour. In the present study, there are a number of behaviours (e.g. the discrimination between behaviour and stimulus) which need to be developed first, in order for the student to progress to a level of skill where they can identify and analyze complex examples.

"The principle of gradual progression serves not simply to make the student correct as often as possible, but it is also the fastest way to develop a complex repertoire" (Holland, 1960). Holland's first point alludes to what has been called "errorless" learning. It is useful to discuss the importance of errorless learning in programmed instruction in terms of the principles of both reinforcement and stimulus control. First, gradual progression consists of carefully sequenced steps which allow the student to emit a large number of correct responses, and consequently receive frequent reinforcement. This frequent reinforcement is beneficial both as a "motivational" factor (students will continue to make the required responses as long as their behaviour is reinforced) and as a tool to establish stimulus control over correct responses; that is, students receive substantial practice emitting the correct responses to the appropriate stimuli. As Deterline (1962) put it, "a student learns to respond to stimuli; and stimuli that are present when a response is made become related to that response." It follows that if an incorrect response is made in the presence of certain stimuli, those stimuli may acquire stimulus control not only over that specific response, but over similar responses emitted to subsequent exemplars. This would prove detrimental to the learner. The objective of gradual progression, then, is to create

many opportunities for the student to emit a correct response and to minimize the probability of incorrect responses, as well as to ensure that relevant stimuli acquire control over the correct responses.

The student's verbal behaviour is gradually shaped until it attains the terminal, or target behaviour, and this is where we encounter the element implicit in Holland's second point: sequencing. The verbal behaviours required to reach the target behaviour are arranged in a hierarchy from most basic to most complex. The result is that when students encounter complex concepts later in the program they will have already acquired the more basic verbal repertoire required to respond correctly at these later stages. The concepts build on one another until the target behaviour is attained.

Studies evaluating the importance of gradual progression in programmed instruction (e.g. Gavurin and Donahue, 1961) have compared student performance following study with a portion of a programmed instruction text versus the same items "scrambled" (i.e. no longer sequenced). They concluded that there was no significant difference between the group studying the programmed text versus the group studying the "scrambled" text. Other studies have reported comparable findings (e.g. Levin and Baker, 1963). However, subsequent studies (e.g. Levin and Baker, 1963; Payne and Krathwohl, 1967; Vargas, 1984) demonstrated that the effects of sequence depend on the hierarchical nature of the concepts to be taught (i.e. the extent to which the mastery of later material depends on the mastery of earlier material).

The present study therefore utilizes the principle of gradual progression, as its subject matter is based upon a hierarchy of concepts, each subsequent concept requiring mastery of the concepts preceding it.

Fading of Prompts

A prompt can be defined "...as a stimulus that already controls or partially controls a response" (Anderson et. al, 1968). Its function is to increase the probability that the student will make a correct response based on the pairing of the prompt with the other stimulus material. When the prompts are being faded, the control over the student's response is being slowly transferred to the other stimuli in the frame, which must ultimately acquire stimulus control over the correct response. The objective of the fading procedure, then, is to ensure that when the fading procedure is complete, the student is able to emit the correct response when presented with only the pertinent stimuli. This technique is used in close cooperation with gradual progression whereby the information is presented in small increments with the gradual removal of prompts in order to shape complex verbal behaviour.

Studies concerning the importance of the fading of prompts in programmed instruction have focused less on whether or not prompting is an important part of programmed instruction, and more on what degree of prompting is the most effective (e.g. Lumsdaine, 1959; Taber and Glaser, 1962; Terrace, 1963; Anderson and Faust, 1967). For example, Anderson and Faust (1967) demonstrated that

when prompts are "over-used" or improperly faded, students do not learn the material as effectively. One reason for this, suggested in another study by Faust and Anderson (1967), is that students' responses do not come under control of the new stimuli because control is never adequately transferred to them: thus, when the prompts are eventually removed, the remaining stimuli do not evoke the correct responses.

Overall, researchers generally agree that the fading of prompts is an important aspect of programmed instruction. The results caution against over-prompting, however, as it does not lead to a successful transfer of stimulus control. Based on these findings, the present study will utilize the fading of prompts, keeping in mind the pitfalls of over-prompting.

Contingent Responding

Contingent responding occurs when the response required from the student is under the specific control of critical components of the current frame. In order to correctly answer the question, the student should be required to attend to the appropriate stimuli within the frame.

Studies investigating the importance of contingent responding are of particular concern to research on programmed instruction as this area affects all of the other principles discussed thus far. Most studies have documented the importance of contingent responding in effective programmed instruction (e.g. Holland, 1965; Doran and Holland, 1971; Schilmoeller and Etzel, 1978; Foster, 1983; Vargas,

1986). As an example of the interaction of contingent responding with other parameters of programmed instruction, Holland (1965) found that in studies demonstrating the superior effect of overt over covert responding, there was a larger number of contingent responses required than in those studies reporting no significant effect.

The present study utilizes contingent responding, taking care to analyze each frame carefully to determine which stimuli will come to control the student's behaviour.

Discrimination Training

Discrimination training is technically defined by Miller (1980) as "...reinforcing a behaviour in the presence of a particular stimulus and extinguishing that same behaviour in the presence of another stimulus." For example, if a researcher was interested in teaching a child to discriminate between an apple and an orange, she would reinforce the child for saying "apple" in the presence of an apple but would not reinforce the child for saying "apple" in the presence of an orange. Similarly, she would be reinforce the child for saying "orange" in the presence of an orange, but would not reinforce the child for saying "orange" in the presence of an apple. Discrimination training is often used in the teaching of "concepts." Concept learning is said to have occurred when the student is able to correctly identify a stimulus as belonging to a particular stimulus class and correctly identify a slightly different stimulus as belonging to a different stimulus class. Discrimination

training teaches the student to make fine distinctions between stimuli that share some properties in common, but differ, often subtly, along other dimensions. This, coupled with stimulus generalization within stimulus classes, makes up what is known as concept formation (Miller, 1980).

Studies on the importance of discrimination training in programmed instruction have demonstrated that in order for correct discrimination to occur, the student must be presented with many examples from each concept or stimulus class, representing stimuli containing similar properties and stimuli containing different properties (e.g. Hovland, 1952; Hovland, 1953; Holland and Skinner, 1961; Roderick and Anderson, 1968; Miller and Weaver, 1980). Through repeated exposure to stimuli, combined with overt responding, prompting and feedback, the student learns to respond differentially to these stimuli, as a function of their membership in different classes, based on their specific stimulus properties.

The findings on the effectiveness of discrimination training versus lecture or expository style, have, in general, been fairly consistent in their support of discrimination training as an important component of programmed instruction (e.g. Miller and Weaver, 1976). The present study also utilizes discrimination training as a teaching tool, as many fine-grained discriminations may be necessary in order to discriminate among exemplars of the various terms involved.

Student-Centered Methodology, Comparative Studies and a Return to Basics

The essence of student-centered methodology is best summed up by Holland (1960). He describes student-centered methodology as follows:

> "When the student has trouble with part of a program, the programmer must correct this. The student's answers reveal ambiguities in items; they reveal gaps in the program and erroneous assumptions as to the student's background. The answers will show when the program is progressing too rapidly; when additional prompts are necessary; or when the programmer should try new techniques. When unexpected errors are made, they indicate deficiencies not in the student but in the program"(p. 44).

This is perhaps the most critical feature in the development of programmed instruction. It means allowing student feedback to shape the programmer's behaviour, which is not a common approach in the development of any teaching tool. The importance of this methodology has been stressed in many research papers over the decades (Holland, 1965; Johnson and Ruskin, 1977; Vargas, 1986; Fernhald, 1991). Suggestions for improving the usefulness of student feedback include intense analysis of student response records (Holland, 1965) and verbally interacting with the students as they progress through the program (Vargas, 1986). Regardless of how it is implemented, this principle is widely agreed upon as being critically important to the success of programmed instruction.

This being the case, it is difficult to understand why, in study after study, a lack of carefully tested and student-validated programs is cited as the reason why there are discrepancies in evaluative studies, difficulty in the interpretation of comparative studies and a lack of advancement with programmed instruction as a teaching tool.

It has been pointed out that problems with methodology in a variety of the studies concerning programmed instruction have made it very difficult to determine how important basic learning principles are for the effectiveness of programmed instruction, due to the inconsistent application of the principles of learning to the programs under study, and inadequate validation of the programs. It follows that attempts to then compare the relative effectiveness of programmed instruction with the myriad of approaches subsumed under the common title traditional instruction (i.e. lecture or expository, non-interactive style) must rest on even more uncertain ground. Even though there have been a number of studies favouring the use of programmed instruction over "traditional" instruction (Roderick and Anderson, 1967; Daniel and Murdoch, 1968; Fernhald, 1991) these studies must be approached carefully, as there appears to be a fair degree of latitude in what individual researchers refer to as programmed instruction (Holland, 1965; Foster, 1983; Vargas, 1986). Research efforts might more constructively return to the development of sound, student-validated programs, focusing on the principles of learning first described by B.F. Skinner.

The present research, therefore, is dedicated to the fundamental goal of

establishing a sound, effective, student-validated program for teaching some basic behavioural terms, a program which will utilize all of the principles of learning as summarized in Holland's (1960) paper. It will be left to future research to assess the relative contribution of each of the principles of learning to the effectiveness of programmed instruction in this, and other programs.

Computerized Programmed Instruction

The use of computerized programmed instruction has enabled researchers to control certain variables that could not previously be controlled with the use of a programmed instruction text.

One such variable is sequencing. Computers allow the programmer to control the order of presentation of material to the student, which was not possible with a textbook, as students could "skip" forward to subsequent sections without having fully mastered the concepts necessary to successfully complete subsequent units. By controlling the sequence of material and by allowing for performance-contingent progression, the computer can make it more likely that the student has mastered the basic concepts before proceeding to more difficult concepts, thus making it more likely that stimulus control over student responses is adequately acquired to permit student success at all levels of the program.

Another variable that can be controlled with the use of the computer is feedback. Anderson et. al (1971) demonstrated that when students are able to "peek" at the answers prior to responding, the effectiveness of programmed

instruction as a teaching tool is severely undermined. With the use of a computer, the researcher can control this variable so that students do not receive any feedback until they have emitted a task-relevant response. Control of this variable (i.e. "peeking") effectively reduces opportunities for cheating.

Computers also make it easier for the researcher to create a database into which all of the student's responses are recorded. This is especially advantageous as students' responses can then be analyzed by the researcher to determine areas of difficulty, or to determine the overall effectiveness of the program he/she has created.

Overall, the use of computers with programmed instruction has the potential to be an efficient and effective approach to the area of teaching technology, maintaining all of the original advantages offered by programmed instruction (i.e. self-pacing, immediate feedback, shaping, fading, mastery of concepts) and providing even greater control over variables which previously proved troublesome to researchers using programmed texts or other forms of programmed instruction.

What is exemplar training?

Before the research on exemplar training conducted by Miller and Weaver is discussed, an elaboration of the term "exemplar" and its use in the present program is warranted.

As used here, exemplars are short, fictional descriptions of humans or animals interacting with their physical and social environment. For example, the following

exemplar is from a textbook written by Miller (1980):

> Joe's TV set went on the
> blink during the NFL playoffs,
> so he tapped it with the palm
> of his hand. Immediately,
> the picture cleared up. Now,
> whenever the picture goes bad,
> he taps the set."

In programmed exemplar training, the exemplar would be presented as above, and the student would be asked a number of fill-in-the-blank questions requiring an analysis of the behavioural contingencies involved. The types of questions asked would depend on the stage of training where the exemplar appeared. Questions on exemplars near the beginning of training would be heavily prompted with cues directing the student's attention to those elements in the exemplar critical for an accurate analysis. As the training progressed, fewer prompts would be presented, so that, nearing the end of training, students would be analyzing the exemplar solely on the basis of the information contained within the exemplar.

The use of exemplars to promote concept formation (i.e. the ability to identify stimuli belonging to the same stimulus class, and discriminate these stimuli from stimuli belonging to another stimulus class), was discussed by Miller and Weaver (1976). Miller and Weaver employed what they termed "concept programming," which combines the use of exemplars with programmed instruction to promote the

learning of behavioral concepts. Miller and Weaver then conducted three experiments to determine the effectiveness of this method in promoting concept formation. Their first experiment demonstrated that Miller's textbook "Principles of Everyday Behavior Analysis," which utilized concept programming as an essential element, produced concept learning. Their second experiment demonstrated that it was specifically the concept-programming component of the text that was a crucial element in the acquisition of these concepts. Their third experiment compared their text with a "traditionally" written psychology text. They found that students obtained better results following their study of the programmed text. In summation, Miller and Weaver demonstrated the combined effectiveness of exemplar training and programmed instruction in promoting concept formation in students studying behavioural psychology.

Exemplars provide an interesting form of training for the student. Organisms are continually interacting with the environment, and other organisms continually observe and participate in these interactions. By requiring the student to analyze exemplars representing some of these "real life" exchanges, we are presenting the student with stimuli which textually represent those which they might observe in their daily lives, thus increasing the probability that their behaviour analytic skills will generalize. For example, most students have observed someone banging on the television set (as described in the exemplar provided above) or have engaged in this behaviour themselves. Following training, and analysis of the exemplar, the student may be able to apply behaviour analysis to similar instances of their own

or others' behaviour in the natural environment. This would be an example of generalization.

Concepts Addressed in the Present Program

There are two important reasons for choosing to develop a program around the four processes of positive reinforcement, negative reinforcement, positive punishment and negative punishment. The first is purely an issue of practicality: these four concepts are commonly taught in all beginning behavioural psychology classes and provide the foundation on which some of the more complex concepts (e.g. 3-term contingencies, chaining, shaping) rest. The development of computerized forms of programmed instruction to teach students to discriminate among these four procedures could be of great value to professors in behavioural psychology, by freeing up valuable class time to discuss more difficult concepts, demonstrating practical applications. and by building the conceptual foundations for these more complex discussions and demonstrations.

Secondly, there are some difficulties encountered in the teaching of these four principles which have not been alleviated by traditional teaching methods. For example, a common order for the presentation of behavioural concepts in psychology texts is 1) Positive Reinforcement, 2) Negative Reinforcement, and 3) Punishment. This sometimes leads to confusion, as negative reinforcement and punishment are two concepts which present particular difficulty to the student. One reason for this, suggested by McConnell (1990), is that there are surplus

meanings associated with the terms "negative" and "punishment." Tauber (1990) suggested that many students pay more attention to the word "negative" than to the word "reinforcement." As well, difficulties arise out of the apparent imbalance between reinforcement and punishment, as there are normally two kinds of reinforcement taught and only one kind of punishment taught. As well, where both positive and negative punishment are taught, the surplus meaning of positive is another source of potential difficulty. It is for this reason that one of the purposes of the present research is to apply programmed instruction to teaching these concepts.

While I was grading student papers analyzing exemplars similar to those in Miller's "Principles of Everyday Behavior Analysis," it became apparent that students also have difficulty making the distinction between the behavioural and stimulus functions of events, particularly when the same event has both functions. This difficulty has a critical effect on the student's performance, as correct analysis of the exemplar depends most on the student's initial identification of the behaviour of importance, as does subsequent analysis of the response - stimulus contingency.

The present program attempts to alleviate these difficulties by providing a structure which will build on the student's behaviour analytic skills in a hierarchical manner. In the next section I will describe the present program's format, and provide the rationale for why its structure may best rectify these problems.

Program Sequence: Underlying Rationale

As mentioned earlier, the objective of this program is to teach students the concepts of positive reinforcement, negative reinforcement, positive punishment, and negative punishment. In doing this, a secondary but related objective is to alleviate the difficulties students encounter when trying to discriminate between the concepts of negative reinforcement and punishment, and to avoid potential difficulties in the discrimination between positive reinforcement and positive punishment. In this section I will discuss the development of an instructional field for these four concepts, and describe the difficulties students encounter when trying to discriminate between negative reinforcement and punishment, due to the control these stimuli have acquired over alternate and competing responses (e.g. "bad", "aversive").

Instructional Field

The first step is to identify the objective, i.e., in behavioural terms, the target behaviour. For the purposes of this program, the target behaviour was defined as follows: Given a behavioural exemplar, students will be able to identify the exemplar as being illustrative of either positive reinforcement, negative reinforcement, positive punishment or negative punishment.

Given this target behaviour, the next step was to determine what the student must possess in his/her behavioural repertoire in order to successfully attain this

target behaviour. A component analysis of the behaviours involved in the effective discrimination of these concepts revealed that the student must be able to identify:

1) the behaviour of interest, as well as pertinent stimuli;
2) the contingencies between stimuli and behaviour;
3) the difference between the addition and subtraction of a stimulus contingent on a behaviour;
4) whether the behaviour increased or decreased in frequency as a result of that contingency; and
5) the appropriate label for the contingency described in the exemplar.

In analyzing the behaviours this way, a natural order of instruction emerges, whereby each subsequent component behaviour builds upon behaviour learned previously. For example, in order to be able to identify a contingency between a stimulus and behaviour, the student must first be able to identify the correct behaviour and stimulus involved in the contingency. Therefore, a logical sequence for the instruction of these concepts would be to teach the student to discriminate between examples of behaviour and stimuli (Unit 1), and then to introduce the concept of contingency (Unit 2). Before I discuss the logical order of the remaining concepts, it is necessary to discuss the second objective mentioned above: Alleviating the difficulties students experience when trying to discriminate between negative reinforcement and punishment.

Negative Reinforcement and Punishment

As mentioned earlier, the concepts of negative reinforcement and punishment are especially challenging to students first learning this terminology. Two reasons for this, suggested by McConnell (1990) and Tauber (1990) are that 1) due to most students' extensive history with these terms in a variety of alternate contexts, the terms "negative" and "punishment" have come under the control of a variety of stimuli, including terms such as "bad" or "aversive," and 2) these terms have acquired stronger stimulus control over the responses "negative" and "punishment" than the behavioural stimuli of whether a stimulus has been added or subtracted contingent on a behaviour, as in the case of "negative", or whether the behaviour increased or decreased as a result of the behaviour/stimulus contingency, as in the case of "punishment." The order of the remaining units was designed to avoid the difficulties associated with this lack of stimulus control within the behavioural context, and to balance the student's exposure to reinforcement and punishment by making the distinction between two types of reinforcement and two types of punishment.

One unit is programmed to teach the discrimination between reinforcement and punishment. Within this particular unit, students are required to make a judgment based solely on what happens to the organism's behaviour as a result of the contingency between the stimulus and behaviour. This strategy is coupled with the use of "paradoxical" exemplars, such as an instance where spanking results in an increase in behaviour, or where the presentation of candy results in a

decreased frequency of behaviour. These two strategies are employed so that the surplus meaning of punishment as necessarily involving an intuitively aversive contingency is weakened through extinction, and guidance of the student's response is brought under specific control of whether or not the behaviour increased or decreased as a result of the behaviour/stimulus contingency. Following exposure to many exemplars, both "typical" and "paradoxical," this relationship should acquire strong stimulus control over the student's response "punishment" or "reinforcement," thus eliminating difficulties arising from the surplus meaning of the terms "negative" and "punishment."

An additional aspect of the program was designed to further guard against the surplus meanings associated with the term "negative." To this end, one unit initially teaches the discrimination between stimulus addition and subtraction using the additional cues of mathematical symbols (+) and (-). The rationale for using these symbols is as follows: The mathematical symbols (+) and (-) have already acquired strong discriminative stimulus control over the verbal responses of "addition" and "subtraction" (e.g. in elementary school and highschool math), and do not pose difficulties due to surplus meanings within this context. The student is trained with the symbols (+) and (-) until his/her response comes under the control of whether the exemplar contains an example of the addition or subtraction of a stimulus contingent on a behaviour. By employing this strategy, the surplus meanings associated with the word "negative" is completely avoided (i.e. the discrimination training between stimulus addition and subtraction is

carried out initially without the introduction of the terms "negative" and "positive", so that the alternative stimuli which occasion these terms do not occur.)

Although it would be possible, and arguably clearer, to teach the students to only use the mathematic symbols and to completely avoid the terms "positive" or "negative," it would not be practical with respect to the terminology widely used by professors and authors. Therefore, in the final unit, the student is gradually taught to label (+) and (-) as "positive" and "negative" respectively. This is done by bringing the response of "positive" and "negative" under the control of the mathematical symbols (+) and (-), which not only share a history of stimulus control over the responses "addition" and "subtraction" but also with the responses "positive" and "negative" (e.g. electrical charges). Once these symbols acquire control over the responses "positive" and "negative", they are gradually faded out until the student's behaviour of answering "positive" or "negative" is under the exclusive control of whether or not the stimulus was added or subtracted contingent on the behaviour. Because the stimulus addition or stimulus subtraction contingency already exerts strong stimulus control over the behaviour of answering (+) or (-) as a result of the training, and since the context for the term "negative" is strictly one of the operation of stimulus subtraction, it is hoped that other responses to the term "negative" (due to surplus meanings) will be less likely to occur.

For the reasons discussed above, the present program employs the following sequence in teaching these concepts:

Unit One: Discrimination between behaviour and stimulus

Unit Two: Contingency

Unit Three: Discrimination between reinforcement and punishment

Unit Four: Discrimination between the addition and subtraction of a stimulus contingent on the behaviour

Unit Five: Discrimination among and identification of positive reinforcement, negative reinforcement, positive punishment, and negative punishment

Method

Subjects

All subjects were from the general population, had some previous experience with behavioural terminology, but were not fluent. There were 14 subjects in total, eight women and six men, ranging in age from 20 - 48 years. At the time of the study, two subjects were completing M.A. degrees, six had completed B.A. degrees, four had completed college diploma programs, and two had graduated from high school. All subjects completed the program and received a ten dollar gift certificate from a local business. The degree of computer experience ranged from someone with limited knowledge of the computer keyboard to someone with training in the field of computers.

Apparatus

This program of instruction was developed and implemented using a program called PC/Pilot, version 4.1 on an IBM computer (486), with a 14" standard-sized VGA colour monitor and standard keyboard set-up. The PC/Pilot program is an authoring language which allows for text presentation, storage and evaluation of input, and branching contingent on the outcome of this evaluation.

Procedure

Subjects worked through the program one at a time, allowing changes to be made to the program based on each subject's feedback. There were no time

limits suggested, and subjects were permitted to take voluntary breaks. In some cases, the experimenter sat diagonally behind the subject as he/she worked through the program, and in other cases did not, depending on the subject's expressed level of comfort prior to starting the program. The subjects were not given any verbal instructions, but were required to read a brief introduction describing the progression of each unit in terms of pretest, training, posttest, as well as the overall progression of the five units in the program. This introduction also served to familiarize the subjects with the computer keyboard, and to any keys which the subject would be required to press in order to answer the questions posed by the program.

Following the introduction, the subject progressed through each of the five units. A piece of paper and a pencil were provided to subjects who did not want the experimenter to remain with them while they worked through the program. This was done so that the subject could write notes about any sources of confusion in the program, ambiguous exemplars, etc.. Subjects with whom the experimenter remained were encouraged to keep an open dialogue with the experimenter concerning any sources of confusion, etc. (an exception to this was any request from the subjects for assistance with questions posed by the program). Subjects progressed through a ten-item pretest (no feedback), a training session involving exemplars (feedback), and a ten item posttest (no feedback) for each of the five units. When they had completed the program, they were asked to discuss their experiences concerning the program and material in

general with the experimenter (this was true whether or not the experimenter had remained in the room while the subject was working through the program). Following each subject's progression through the program, the notes collected during this time were entered into the computer, along with all of the subject's answers to the questions in the program, which were stored in the computer's database as he/she worked through each question. These answers and feedback were then analysed, and appropriate revisions to the program were made contingent on the outcome of this analysis. When these revisions were completed, the next subject was run through the program. This procedure continued until subjects were, in the author's judgment, consistently performing with few errors on the posttests for all units. In practice, this criterion was judged to have been satisfied when scores were generally in the 90% - 100% range, with no scores below 80%.

Progression: Within Each Unit of Instruction

Within each unit of instruction, the student follows a carefully structured progression of material. In this section I will give an overview of this progression, and describe the kinds of interactions the student encounters as he/she progresses through the program.

Pretest

Following a brief introduction, defining the terms involved in the unit, the

student progresses to a pretest, which allows the researcher to ascertain the student's discrimination performance prior to instruction. There are ten exemplars in the pretest, and students are asked to analyze them and enter their answers on the keyboard. Feedback is not given during the pretest. Following the student's input to one question, the computer progresses to the next question. For example, an item on the quiz for Unit Three: Reinforcement and Punishment would appear to the student as follows:

> *The dog barked into the metal pipe and it echoed back to him. Now the dog spends most of his day barking into the pipe*
>
> *With respect to the dog's behaviour, is this an example of reinforcement, punishment, or unknown?*
>
> *Answer:*

The student responds by typing his/her answer onto the keyboard and pushing the enter key. The computer database then stores this answer for later evaluation. Following completion of the pretest, the student progresses to the training portion of the unit.

Training

During the training portion of the unit, the student is exposed to a number of exemplars, similar to the exemplars the student has already encountered in the

pretest. However, in the training portion, the student is asked specific questions concerning the analysis of the exemplar, facilitated by prompts that are intended to bring the student's behaviour under the control of the critical components of the concept under consideration. These prompts are gradually faded as the training progresses, until the student is analyzing the exemplar based solely on the information contained within the exemplar. For example, an exemplar in Unit One: Behaviour and Stimulus might appear with the following question format near the beginning of training:

Amy tripped on her shoelace, and Dan laughed.

With respect to Amy, tripping is an example of ___________

*(Ask yourself, is an organism saying or doing something?)**

**student would have had experience with the definition of behaviour by this point*

Nearing the end of training, however, no prompts are given, and the student must respond if the element contained in the exemplar is an illustration of behaviour or stimulus with respect to a particular person or animal, based solely on the information given in the exemplar.

When the student types an answer on the keyboard during training, the computer gives immediate feedback in the form of, "Right. It would be an example of behaviour" or alternatively "Try again. Remember our definitions? When an organism says or does something as opposed to an event in the environment that can affect an organism, we have the concept known as ______________." The student enters his/her new answer, and is again given

immediate feedback. The student can not progress to a new exemplar until he/she has answered the current exemplar correctly. Each time the student answers incorrectly, he/she is looped back into the exemplar, and the question is asked again, this time with more prompting. Following successful completion of training, the student then progresses to the posttest.

Posttest

The posttest is identical in format to the pretest and is presented in order to gain feedback on the student's progress over the training portion of the unit. It consists of ten novel exemplars, and the student is required to analyze the exemplar based solely on the information contained within the exemplar. Again, no feedback is given. Following the posttest, the student progresses to the next unit of instruction.

Presentation of Information Cumulatively

Each unit's information builds upon that provided in previous units. Therefore, in the first unit, students are responsible for the analysis of an exemplar based on the identification of behaviour and stimulus, while, by the fifth unit, students are responsible for the identification of an exemplar as positive reinforcement, negative reinforcement, positive punishment, or negative punishment, but are required to analyze the exemplar using all of the concepts presented previously. Each unit asks the student specific questions regarding

information presented in a previous unit. For example, in Unit Two: Contingency, the student is asked to identify the behaviour and stimulus first, before he/she identifies the contingency between the two. This not only makes sense logically, but as discussed below, it serves a practical evaluative purpose in the fifth unit.

Parallel Progressions: Within and across units

The order of the units reflected a natural sequence, whereby information contained in subsequent units was directly dependent on the mastery of information presented in previous units. This progression is paralleled within each unit, as students are required to answer questions in the same order as the concepts appeared across units. Therefore, in Unit Five, students would progress through an exemplar prompted with the following questions:

What is the behaviour of interest?	(Unit One)
What is the stimulus?	(Unit One)
Identify the contingency...	(Unit Two)
Does the behaviour increase or decrease?	(Unit Three)
Stimulus added or subtracted contingent on behaviour?	(Unit Four)

This parallel progression emphasizes a logical approach to the analysis of the exemplar, and gives the student a general formula for analyzing examples of behaviour.

Results and Discussion

Overall, the use of principles of learning coupled with exemplar training and student-centered methodology ultimately resulted in a consecutive number of subjects performing at a minimum of 80% correct on all posttests, and more frequently at the 90% or 100% level. The importance of using student feedback and evaluation to revise the program was evidenced by an overall trend of improved performance from earlier to later subjects.

Tables 1 and 2 show the subjects' performance scores for the pretest, exemplar training and posttest for all five units. However, before I discuss the data in detail, Column 2 in Table 2, labelled Test Preceeding Traditional Instruction (TPTI), warrants a brief explanation. Initially, the program sought to demonstrate the relative effectiveness of traditional instruction versus programmed instruction. Therefore, the program was set up in such a way that the TPTI was presented prior to a brief instructional section meant to illustrate the traditional teaching method. The Pretest was then presented in order to ascertain the subject's ability to analyze exemplars following the "traditional" method of teaching. However, as can be seen in Table 2, the TPTI was eliminated and the traditional method of instruction was incorporated into the beginning of the exemplar training after the fourth subject. This occurred for two reasons: First, the extra time demanded of the subject in order to include this extra test led subjects to report that the session was so long as to be fatiguing, perhaps affecting their performance on subsequent units; secondly, it was the

opinion of this experimenter that this kind of comparison was premature, in light of the immature state of the program itself. Therefore, when I am discussing the pretest data obtained from the first four subjects I will be referring to those numbers in the TPTI column (Column 2), and when I am discussing pretest data obtained from the remaining ten subjects, I will be referring to those numbers in the pretest column (Column 3). The exemplars analyzed by the first four subjects in the Pre-pretest (TPTI) and those analyzed by the remaining subjects in the pretest were identical; therefore, the possible confounding of exemplar difficulty is eliminated. As well, both sets of scores demonstrate the subject's ability to analyze the exemplars without prior experience or training; this eliminates possible confounding due to the practice effect. This was also a concern when we looked at the Posttests for these first four subjects, as these subjects received additional exposure to exemplars due to the additional training provided by the "traditional" method of instruction, and practice with the extra quiz. However, when we look at the Posttest scores for these subjects, and compare these with those for the remaining subjects, there is no noticeable difference suggestive of a practice effect.

As mentioned above, progressive "student-centered" changes to the program appeared to enhance its effectiveness as a teaching tool. As is apparent in Table 1, the overall percent correct on the Posttest for the last five subjects ranged from 92% to 98%, showing an overall increase in performance and in consistency compared to previous subjects. Rather than provide a lengthy chronological record

Table 1

Percent correct across all five units

Subjects	Pretest	Posttest	Change
1	52	58	+6
2	92	88	-4
3	50	74	+24
4	88	88	0
5	64	84	+20
6	64	74	+10
7	68	90	+22
8	70	74	+4
9	68	86	+18
10	66	92	+26
11	70	94	+24
12	76	96	+20
13	76	94	+18
14	82	98	+16

TABLE 2A

Subjects' number of correct responses for pretest, exemplar training and posttest for Behaviour vs. Stimulus

Subjects	TPTI	Pretest	Training/25	Posttest	Change
1	5	6	21	8	+2
2	10	10	23	10	0
3	7	7	22	8	+1
4	9	10	21	10	0
5	N/A	6	25	10	+4
6	N/A	8	23	10	+2
7	N/A	10	24	10	0
8	N/A	7	22	10	+3
9	N/A	10	25	10	0
10	N/A	10	24	10	0
11	N/A	8	24	10	+2
12	N/A	10	24	10	0
13	N/A	9	25	10	+1
14	N/A	10	24	10	0

TABLE 2B

Subjects' number of correct responses for pretest, exemplar training and posttest for Contingency

Subjects	TPTI	Pretest	Training/25	Posttest	Change
1	4	2	18	6	+4
2	10	10	20	10	0
3	8	3	16	5	+2
4	5	8	18	10	+2
5	N/A	6	20	8	+2
6	N/A	4	20	7	+3
7	N/A	4	22	10	+6
8	N/A	6	19	6	0
9	N/A	10	22	10	0
10	N/A	4	22	9	+5
11	N/A	5	23	9	+4
12	N/A	6	21	10	+3
13	N/A	4	24	9	+5
14	N/A	6	23	9	+3

TABLE 2C

Subjects' number of correct responses for pretest, exemplar training and posttest for Stimulus Addition and Subtraction

Subjects	TPTI	Pretest	Training/25	Posttest	Change
1	6	7	19	3	-4
2	7	9	20	5	-4
3	6	6	20	8	+2
4	6	10	23	8	-2
5	N/A	7	25	8	+1
6	N/A	6	22	5	-1
7	N/A	6	24	6	0
8	N/A	9	21	5	-4
9	N/A	6	19	6	0
10	N/A	7	22	8	+1
11	N/A	8	24	9	+1
12	N/A	9	23	9	0
13	N/A	10	24	10	0
14	N/A	10	25	10	0

TABLE 2D

Subjects' number of correct responses for pretest, exemplar training and posttest for Reinforcement vs. Punishment

Subjects	TPTI	Pretest	Training/25	Posttest	Change
1	7	7	23	7	0
2	8	10	25	10	0
3	2	5	25	10	+5
4	5	7	25	9	+2
5	N/A	7	23	10	+3
6	N/A	5	22	8	+3
7	N/A	8	24	10	+2
8	N/A	5	25	10	+5
9	N/A	2	25	9	+7
10	N/A	5	24	9	+4
11	N/A	6	25	10	+4
12	N/A	6	24	9	+3
13	N/A	7	25	10	+3
14	N/A	6	25	10	+4

TABLE 2E

Subjects' number of correct responses for pretest, exemplar training and posttest for Positive Reinforcement, Negative Reinforcement, Positive Punishment, and Negative Punishment

Subjects	TPTI	Pretest	Training/25	Posttest	Change
1	7	4	30	5	+1
2	6	7	42	9	**+2**
3	3	4	47	6	+2
4	8	9	38	7	-2
5	N/A	3	45	5	+2
6	N/A	9	50	7	-2
7	N/A	6	48	9	+3
8	N/A	8	53	6	-2
9	N/A	6	49	8	+2
10	N/A	7	56	10	+3
11	N/A	8	57	9	+1
12	N/A	7	54	10	+3
13	N/A	8	51	8	0
14	N/A	9	55	10	+1

Table 3

Summary of changes made to the program as a result of student feedback

Problem	Solution
Structural Errors:	
Ambiguous exemplars	-used student feedback to determine specific cause of misinterpretation -omitted/rewrote exemplar/section -re-tested
Unclear instructions	-used student feedback to determine ambiguity -added instructions to introduction, and provided clear models of desired behaviour within the problem section -re-tested
Computer screen organization	-used student feedback to target problem frames -rearrange programming variables to allow for a greater variety of situations (e.g. extra space for answer, multiple questions)
Motivation	-merged instructional parts of program ("traditional" and "PI") to decrease length -varied subject matter in exemplars -program (in practical application) will be spread out over more sessions

Table 3 - cont'd

Stimulus control	-used student database to determine patterns of incorrect responses -included S- exemplars in contingency unit to avoid chronology over function problem -required students to identify stimulus itself before continuing with analysis
Competing responses - supplementary stimuli	-used student database and verbal feedback from students to determine patterns of incorrect responses -reversed order of reinforcement/punishment unit and stimulus addition/subtraction unit so that the resulting behaviour was excluded -re-tested

of all these changes, I will instead discuss the types of changes which emerged as a result of this process, give examples where appropriate, and discuss their relevance within the context of the data. A summary of the changes involved is presented in Table 3.

In general, the sources of subject errors leading to changes in the program could be divided into one of the following five categories: structural errors; errors due to fatigue; inadequate stimulus control; inadequate transfer of stimulus control during fading; and competing responses controlled by supplementary stimuli.

As is implicit in student-centered methodology, in addition to identifying a source of error, it is necessary to specify its solution, and demonstrate a resulting improvement in performance. Occasionally, these improvements are obvious, and can be readily attributed to the modification in the program. Far more often, however, there is little more than a general, positive trend in the data, the cause of which is not self-evident. Many times two items were altered simultaneously, so the resulting effect on the data could be reflecting either one or both. With this in mind, I will identify those changes in performance which appeared to be a direct result of specific manipulations in the program, while more general or equivocal trends will be discussed in reference to simultaneous changes in the program, some combination of which may have also been responsible for the trends in data. As well, I will discuss any notable data due to individual circumstances which may have affected the overall trend in data.

Structural Errors

Structural errors refer to errors resulting from ambiguous or poorly worded exemplars, unclear instructions, or deficiencies within the structure of the computer program itself. These errors were most commonly detected and revised while working with the first five subjects, and occurred very rarely over the remainder of the study. Although relatively simple to correct, these errors proved aversive to the subjects, and affected their performance.

One such error due to ambiguity occurred in the unit covering the addition and subtraction of a stimulus contingent on a behaviour. Here, subjects were required to analyze the exemplars in order to determine whether the stimulus had been added to or subtracted from the organism's environment contingent on the organism's behaviour. The following type of exemplar proved difficult for the subjects to analyze, due to its ambiguous meaning:

> The raccoon crawled onto the thin branch. The branch made a snapping sound and fell to the ground. Now the raccoon never crawls onto thin branches.

Subjects had difficulty answering questions about this kind of exemplar as it was not immediately clear to them whether the stimulus was in fact the "snapping" noise (which would require the subject to answer "addition"), or the branch falling to the ground (which would require the subject to answer "subtraction").

Ambiguous exemplars such as this one were relatively easy to detect, as subjects usually expressed their confusion openly (such as asking which "consequence" I was looking for). As well, in analyzing the subjects' data, it became clear that the subject was able to answer the preceding and subsequent exemplars correctly, suggesting that the speed of the fading procedure was adequate for this section, and that appropriate stimulus control had been established. Although errors due to ambiguous exemplars could be found in several parts of the program, they were most commonly of the kind cited above, and, as a result, the unit most affected by these ambiguous exemplars was the unit covering the addition and subtraction of a stimulus contingent on a behaviour. Over the first four subjects, one exemplar in each of the pretests, two in the training section, and three in the posttest were altered due to ambiguity in the writing. The improvement in the training and posttest scores for this unit over the first four subjects (see Table 2) is consistent with the assumption that these alterations made the program more effective. Although this initial improvement was followed by a drop in posttest scores, this subsequent decline in performance can be attributed to other major changes in the program, arising from the decision to drop "traditional instruction" as a separate section, together with the subsequent quiz. This will be discussed later in detail.

Unit One: Behaviour versus Stimulus, was unique, in that the only changes required involved ambiguous exemplars. Errors due to ambiguity in this unit typically arose because an exemplar described the behaviour of more than one

person. This generated confusion as to which person's behaviour was of interest. For example:

"Amy tripped over her shoelace, and Dan laughed"

It is not clear which organism's behaviour should be targeted. In cases like this, any errors that were made were due to the subject targeting Dan's behaviour instead of Amy's, as intended by the author. The data revealed that the only error the subject made was to target the wrong person, treating Dan's laugh as the behaviour and Amy's tripping as the stimulus, instead of the other way around; that is, if a subject targeted Amy's actions as behaviour of Amy's, Dan's laugh is correctly analyzed as a stimulus for Amy, and vice versa. Over the first four subjects, one exemplar in each of the pretests, two exemplars in training and one exemplar in the posttest was changed due to this type of ambiguity (i.e. the organism of interest was specified). Following these changes, subject performance improved; the number of errors in training were reduced over all subjects except for #6, while no further errors were made on the posttest (see Table 2A).

Errors of this kind dramatically support the importance of student-centered methodology. In the present case, many of these ambiguities were not initially clear to me, since I not only had experience with the material, but was approaching it with a repertoire which is vastly different from that of the target population. While I could recognize that some of the exemplars were clearly

ambiguous upon their identification by the subject, there were as many other exemplars which appeared adequate to me until a novice subject described how he/she had come to his/her answer, this ambiguity leading the subject to emit an unexpected, but often not completely incorrect, alternate response.

Another source of subject error was insufficient or unclear instructions in the program. For example, in the stimulus addition/ stimulus subtraction unit, the subject was required to type in either the + or - symbol (instead of the words "addition" and "subtraction") whenever appropriate, in both training and testing conditions. In the introduction to the program, the student was introduced to these keys and instructed to use these symbols whenever required; however, possibly because these instructions were given so far in advance, the students failed to use these symbols when they became appropriate. The result was that during the first few frames of the training section, errors were made not due to the subject's inability to correctly analyze the exemplars, but purely because the subject's answers did not match the symbol demanded by the computer's program. This source of error emerged quite quickly as a result of the subject's show of frustration, as well as in the recorded data, which suggested that the subjects were answering correctly in terms of a conceptual analysis, but had simply not followed instructions concerning the format of the response. One interesting observation made regarding the subjects' confidence in the correctness of their answers was that, despite the feedback they received, subjects were so confident that their responses were correct that they systematically tried a variety of spellings (e.g.

"addition", "adition", "add", "adding") rather than changing their answers to "subtraction". This brings up important questions regarding the universal importance of immediate feedback, and seems to support Holland's (1965) suggestion that where information is less difficult and where students can be reasonably certain of the "correctness" of their answers, immediate feedback does not play as important a role as it does in programs with more difficult concepts.

This format source of error was alleviated by retaining the initial introduction explaining the progression of the program and the importance of various keys within the various units, and by adding an additional set of instructions to the stimulus addition/stimulus subtraction unit itself, outlining the specific keys important to this unit. Instructions were given not only prior to the pretest, but just prior to the onset of the training session as well. Subjects were then reminded as they started each section about the variety of answers which would be required of them for the following section.

These corrections resulted in an increase in correct responses for the initial frames in the training sequence of Unit Three. It reflects the programmed criteria, since the subjects were, in fact, conceptually correct prior to the changes in instructions. Therefore, the more important change that resulted from this correction was reflected in the subjects' motivation to complete the program. Prior to the correction, subjects displayed signs of frustration and expressed reluctance to continue the unit. In effect, the subjects' responses were undergoing extinction in the presence of the stimuli presented by the exemplar, and their

behaviour was typical of the course of extinction (e.g. entering the same word repeatedly at a fast pace, followed by variants of the initial response, or spelling changes, and eventually stopping completely). Once the corrections were made, subjects no longer demonstrated these behaviours, and finished the unit without incident. Although a dramatic change was noted in the first few training frames following this correction, the stimulus addition/stimulus subtraction unit nonetheless failed to show an overall increase in performance (Fig. 2C). This was due to some other difficulties which arose in the program, which will be discussed in detail below.

One final set of structural errors that occurred was due to difficulties with the PC/Pilot software. One example of this was in Unit Two: Contingency. In order for information to remain on the screen, it is coded into a special window and thereby remains on the screen until new information replaces it. This allows the subject to re-read the exemplar as needed, while answering a number of questions which change in succession beneath this window. Although this was adequate in most circumstances, it sometimes proved to be inconvenient when there were a number of questions regarding a single exemplar. Initially the window containing the exemplar was fixed and the questions were underneath the window. Because the window requires certain dimensions, the space is somewhat limited for the questions and subject's responses. Typically this wasn't a problem as subjects were able to provide the correct answer on the first or second attempt, at which time the bottom of the screen would clear and a new question would be presented.

However, in some cases, the answer required more than one response to a question, or the subject was having difficulty with a particular question, and would try a number of different answers. This caused the initial question to scroll off of the limited screen and leave the subject without a reference point. Understandably, this caused the subjects a great deal of frustration. To solve this, it became necessary to place each individual question within the window with the exemplar, and to include the exemplar in every new window frame. Although more time-consuming for the programmer, this allowed the subject an unlimited amount of space to answer without the inconvenience of losing the question, and so lessened the frustration of the subject as he/she progressed through the unit. It also decreased the number of errors due to guessing when the subject could not recall the initial question.

In general, the errors cited above were corrected within the first five subjects, and as mentioned above, occurred very rarely over the remainder of the subjects. Although errors of this kind do not necessarily result in a significant amount of student error on the conceptual level, they can dramatically affect the program's schedule of reinforcement.

Motivation

Another source of error occurred as a result of subject fatigue/motivation. Initially, each unit began with a pre-traditional-instruction pretest, which tested the subject's ability to analyze exemplars prior to any training. The subjects then

progressed to a training session which was illustrative of a traditional approach (e.g. definitions followed by explanation). Following this, the subjects were given another pretest, which tested the subject's ability to analyze exemplars following traditional methods of instruction but prior to programmed instruction. The subject then proceeded to the programmed instruction portion of the program. Following this, the subject was given a posttest to test his/her ability to analyze exemplars following a programmed instruction method of instruction. These five steps occurred for each of the five units in the program.

Notes written by the first four subjects suggested that by the time they began the fifth unit, they had lost their "focus," as the program was "extremely long for one sitting." These comments were supported by my observations of their behaviour while running through the program. I observed that subjects were, on average, taking less time to read the exemplars despite the fact that the exemplars in the final unit were longer than those in the other units. I also observed shorter latencies between reading the question and the onset of typing. When I consulted the computer database, there were substantially more spelling errors during the fifth unit than in any other unit, but there was also evidence of guessing (i.e. typing in various combinations of words and letters, sometimes repeated later). Although the data for these four subjects does not provide clear evidence for the effects of fatigue/motivation with consistency (see Table 2E), my observations and the computer records suggested the influence of fatigue/motivation on the subjects' performance over the five units in the program, and so warranted

change. To reduce this and other sources of error, the traditional method of instruction and the corresponding quiz were eliminated. As mentioned above, this decision was also justified on the grounds that a comparative study of the relative effectiveness of traditional versus programmed instruction was premature, considering the immature stage of this program. In total, this effectively removed 10 additional sections from the program and reduced the program's running time from over 3 hours to 2 hours. Although I believe this condensation of the program relieved some of the motivational errors, there continued to be evidence for a deterioration in performance, apparantly as a function of the passage of time.

Subject 13 appeared to provide a particularly striking example of motivational-like effects which dramatically affected her performance and consequently, the general trend of the data. Due to scheduling, the only time this particular subject was able to run through the program was late in the evening. In Table 2A: Behaviour versus Stimulus, subject 13 obtained 100% correct on the posttest. In Table 2B: Contingency she scored 9 out of 10 correct. Subject 13 then performed at 100% correct on each of the posttests for the reinforcement versus punishment and stimulus addition/subtraction units. However, in the final unit she failed to make the criterion of 90% correct, receiving 80% instead. Her performance in this unit (see Table 2E) would not appear to accurately reflect her ability to analyze the exemplars, as this unit is essentially a summary of the skills she accumulated in the first four units. This was supported by my observations of

her behaviour while working through the program, and by the computer's records of her responses. Spelling mistakes, half-finished words and irregular spacing were characteristic of her responses in the fifth unit, while in the previous units this was rarely a problem. She expressed that she was fatigued several times, but declined my offer to reschedule. Her data are interesting because they illustrate the importance of taking regular breaks and the effects of fatigue/motivation on subject error. In addition, when this program is used for educational purposes, errors due to fatigue/motivation could be reduced even further by spreading the training over several sessions. Although the effectiveness of the program as a teaching tool is not known under these conditions due to time restraints with regards to subject availability, there is reason to believe that dividing the program into its existing units would be beneficial to the student without detracting from the program's overall effectiveness.

Stimulus Control

Initially, when subjects were taught to identify a stimulus in Unit Two: Contingency, it followed this format:

(A) When the baby bird chirped, (B) its mother gave it some food..

With regards to the baby bird's behaviour, what is the stimulus?

Subjects were responsible for identifying the stimulus in terms of A or B. Because students often have difficulty with the concept of contingency, exemplars in Unit Two: Contingency were chosen to be simple and clear, and to conform to

the definition given in the unit. In attempting to meet this objective, I inadvertantly restricted the exemplars to those illustrating stimulus addition. Because all of the exemplars in Unit Two consisted of a behaviour followed by the presentation of a stimulus, function (behaviour versus stimulus) was confounded with chronological order (behaviour, then stimulus). This allowed chronological order to acquire stimulus control over subject's responses when they were required to identify the stimulus. This did not create any difficulties in Unit Two; however, it led the subjects to erroneously identify the stimulus removal as the stimulus when examples of stimulus subtraction were introduced in the unit covering stimulus addition and subtraction. For example:

> *Mr. McCrachen sprayed Tigger, the cat, with a hose. Tigger jumped behind a trash can and no longer got sprayed.*

Stimulus control by the event that followed the behaviour led the subject to erroneously identify the stimulus as "no longer got sprayed", rather than "the spray". Exposure to stimulus subtraction contingencies in Unit Two would have prevented this problem, and reduced the many errors in caused in the unit covering stimulus addition and subtraction.

Another apparent effect of the failure to introduce stimulus subtraction exemplars in Unit Two was the tendency for the subjects to specify the contingency in stimulus subtraction exemplars as the "presentation" of the absence of the stimulus. When questioned about the above exemplar, for example, subjects would report that when Tigger jumped behind the trash can, "dry" was

added.

It was important to train the subjects to identify the directly observable stimulus in stimulus subtraction contingencies, if these misinterpretations were to be avoided. Unit Two: Contingency was therefore re-programmed to include exemplars containing stimulus subtraction. To avoid confusion, I discussed contingency in terms of stimulus change, whereby the addition or subtraction of the stimulus occurred following the behaviour, thus keeping consistent with the definition given in the unit. As well, I discussed the difference between the stimulus and stimulus change in Unit Two, and reviewed this in the subsequent unit on stimulus addition and subtraction, rather than covering it later in the program. Another important change made to the program was the requirement that subjects type in the specific stimulus, rather than entering A or B. This ensured that before the subject progressed any further in the analysis, they had identified the stimulus itself. This effectively reduced many of the previous errors due to the identification of the removal of the stimulus as the stimulus, as well as errors due to misinterpretation (i.e. "dry" was added). Subjects who progressed through these units a second time following these changes reported that although the concept of contingency now seemed more difficult to understand, once they understood contingency it was then easier to discriminate between stimulus addition and subtraction. These comments seem to be supported by the subsequent data.

Competing Responses controlled by Supplementary Stimuli

Initially, Unit Three taught the concepts of reinforcement and punishment, and Unit Four taught the concepts of stimulus addition and subtraction contingent on a behaviour. These units were arranged in this way because it was thought that this would most effectively facilitate the fading procedure with regards to the subjects response of "-," then "negative." However, because the units were arranged in this way, and because reinforcement and punishment had already been taught previously, Unit Four exemplars naturally contained the resulting behaviour; that is, the exemplars in Unit Four specified whether or not the behaviour increased or decreased as a result of the behaviour/stimulus contingency. For example:

> *Everytime Rufus sat down, Bob gave him a cookie. Now Rufus never sits down.*

Because the subjects were required to specify the stimulus (as a result of prior revisions - discussed above) prior to answering whether or not the stimulus had been added or subtracted contingent on the behaviour, it was observed that subjects could correctly identify the "cookie" as the stimulus. However, they sometimes continued their analysis by answering, for example, that the cookie was subtracted contingent on the behaviour. This was puzzling because if the subjects' behaviour was under the control of the appropriate stimuli (i.e. the

"cookie" and the question, "Was this stimulus added or subtracted contingent on the behaviour?") there would be no other appropriate response except for "addition." Following my discussions with some of the subjects, it seemed that the subjects were emitting the following behaviours: First, identification of the behaviour (correctly - subject's behaviour under control of the question, and of the appropriate behaviour contained in the exemplar); second, identification of stimulus (correctly - subject's behaviour under control of the question and of the appropriate stimulus contained in the exemplar); third, identification of reinforcement or punishment (correctly - subject's behaviour under control of the question and whether or not the behaviour increased or decreased as a result of the contingency); fourth, identification of stimulus addition or stimulus subtraction (incorrectly - subject's behaviour under control of the stimulus and whether the organism's behaviour increased or decreased as a result). This became especially clear when one of the subjects explained the above exemplar in the following way:

> "Sitting is the behaviour, and the cookie is the stimulus. It's a contingency. He doesn't sit anymore, so it's punishment. Because he doesn't sit anymore, he doesn't get any more cookies so the cookies, I mean the stimulus, was subtracted."

In other words, the subject's behaviour was partially under control of what happened to the behaviour as a result of the stimulus/behaviour contingency and the subject was assuming that if Rufus now no longer sits down, there is no opportunity for Bob to give Rufus a cookie contingent on his sitting down, so

therefore the cookie has been subtracted. This prompted me to look back in the computer database and examine the subjects' responses to exemplars like the one presented above. The database showed that in exemplars containing the addition of a stimulus where the result is that the behaviour decreased, and in exemplars containing the subtraction of a stimulus where the result is that the behaviour increased, there was a substantially larger error rate than with those exemplars involving stimulus subtraction/behaviour decrease or stimulus addition/behaviour increase. If these errors had in fact been due to the subjects' behaviour being under the control of these supplementary stimuli, these results are what we would expect: In the case where the stimulus is added and the behaviour increases as a result, this faulty reasoning would still result in a correct response; a correct response would also be expected if the stimulus was subtracted contingent on the behaviour and the behaviour decreased as a result. I was able to recall two additional subjects whose data suggested that their answers were based on this reasoning, and after a brief review and a couple of exemplars my suspicions were confirmed.

This prompted me to reverse the order of Unit Three and Unit Four, so that stimulus addition and subtraction would precede reinforcement and punishment. I was not sure how this reversal would affect the fading procedure with regards to "-" and "negative," but I decided to proceed with the reversal and closely observe its effect on the fading procedure.

The purpose of the reversal was to isolate stimulus addition and subtraction

contingent on the behaviour, prior to introducing reinforcement and punishment. It was hoped that the subjects would more effectively come under the control of appropriate stimuli, (i.e. whether the stimulus was added or subtracted contingent on the behaviour) when additional stimuli (such as what happened to the behaviour as a result) were eliminated, removing sources of control over incorrect responses. It was reasoned that once the subject's behaviour was firmly under the control of appropriate stimuli, the subject would then move ahead to Unit Four covering reinforcement and punishment, and would no longer make incorrect responses in the presence of these additional stimuli.

As can be seen in Table 2C, the data for subjects 13 and 14 (following the reversal) does not show a substantial increase in correct responses, in part because the scores at this stage of the program's development were already quite high. However, I recalled subjects 8 and 9, as mentioned earlier, and re-ran them through Stimulus Addition and Subtraction, and found that subject 8's score increased on the posttest from 5 out of 10 correct to 9 out of 10 correct, with a score of 24 on the training section. Subject 9's score increased on the posttest from 6 out of 10 correct to 9 out of 10 correct, and the number of correct responses in the training session increased from 19 to 23. Understandably, these increases must be treated with caution, as none of the other subjects re-ran parts of the program. But the increase is encouraging, particularly when coupled with the accompanying feedback that these subjects provided. It was encouraging to note that the subjects reported that they found the unit less aversive than they

had previously, and said that on the whole, the entire analysis "made more sense", now that it was in the present order. As can be seen in Table 2E, it was interesting to note that this reversal did not seem to have any deleterious effects on the subjects' scores in Unit Five: positive reinforcement, negative reinforcement, positive punishment, and negative punishment; this once again illustrates the importance of student feedback on the development of an effective teaching tool.

Conclusions

Overall, the use of principles of learning, exemplar training and student-centered methodology resulted in an effective, efficient tool for teaching students the concepts of positive reinforcement, negative reinforcement, positive punishment and negative punishment. The process of student-centered methodology clearly illustrated the importance of developing programs which allow students to interact individually with the instructional agent. The idiosyncracies of each individual learner, as seen through the data, my direct observations and each student's feedback, illustrated once again why it is not only difficult, but often impossible to teach these concepts to a wide body of students. It is impossible for the lecturer to attend to each individual's unique learning needs. And without the valuable, ongoing interaction which occurs between the programmer, the computer and the individual student, it is not feasible to identify many of the difficulties students may be experiencing with the material along the way. One valuable lesson I learned while programming is that you can not reliably predict how the student will interpret the material. The changes that emerged in the program often came as a surprise to me, only becoming clear once I had the opportunity to listen to the student describe his/her chain of behaviours. Unfortunately, most professors do not have the time or means to extract this information from all of his/her students. Therefore, this program is useful not only for practical purposes (as a teaching tool), but also as a means of clarifying

areas of student difficulty for lecturers.

Exemplars provided the student with fictional, life-like examples of behaviour to analyze, ideally allowing the student to generalize these analytic skills to his/her natural environment. The exemplars also appeared to be an entertaining means of teaching the concepts, evidenced by subject feedback both during and following the program, which enhanced the program's reinforcement value and prompted the students to continue the program.

Although this program may provide useful information regarding some of the difficulties that arise when developing a teaching tool, each programmer will likely encounter his/her own set of difficulties, even when developing a program for similar subject matter. As objective as the programmer may attempt to become, the program is still an extension of the programmer, and so reflects the writing styles, biases and teaching styles of the individual programmer. As a result, for some programmers the structural errors may emerge as more or less important and there may be differences in the speed of fading, or the degree of stimulus control acquired. This provides a very strong argument for the use of student-centered methodology every time a program is developed, for the benefit of the programmer him/herself and for the students who will subsequently be using the program.

Future Considerations

Although this program is far from complete, it provides future researchers with a solid foundation from which to carry on further studies. Future research may focus on the relative contributions of each principle of learning, on the comparative teaching effectiveness of a sound program of instruction versus "traditional" instruction, on the degree of generalization from exemplars to "real-life," or on the development of other behavioural concepts.

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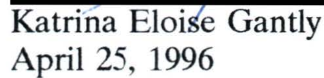
Author 

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