PRELIMINARY GRANT PROPOSAL

Automaticity in Complex Skill Development

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Barrett (1981) surveyed the literature of applied behavior analysis and developmental disabilities and found that the vast majority of studies on skill development measured accuracy or absence/presence of skill while ignoring the temporal dimensions of performance (i.e., response latency or rate). By and large, investigators of verbal learning have also ignored the temporal dimensions of responding, primarily because of the technical problems of recording latencies (Runquist, 1966). Investigators of reading skills, memory, and other cognitive processes have measured response latencies in an effort to determine the speed of cognitive processing (Theios, 1973). By far the most polific use of response rate and latency measures, outside of operant conditioning, has been in the study of motor skills (e.g., Fitts, 1954). But somehow these latter research efforts have not made an impact on day-to-day educational practice, especially with developmentally disabled. Even though there is ample literature to show that response rate on specific skills is a sensitive index of child development (Connolly, Brown & Bassett, 1968; Haughton, 1981), even prenatal development (Edwards & Edwards, 19), diagnostic/prescriptive assessment and instructional measurement procedures with the developmentally disabled consist almost exclusively of absence/presence or percentage correct evaluations.

It seems natural to ask whether the assessment and/or training of increased rate or short-latency performance might be generally useful in habilitation of the developmentally disabled. In this regard, we emphasize two sets of findings that are of theoretical or hueristic significance and place our research interests in a broader context of human learning research.

In paired associate verbal learning tasks, those few investigators who have bothered to measure latencies have observed that they decrease in an orderly way during trials beyond 100% accuracy (Osgood, 1946; Judd & Glaser, 1969; Peterson, 1965). Without a measure of the temporal dimension of responding, this continued learning beyond the usual 100% accuracy measurement ceiling would be beyond evaluation. However, by using time measurement, it is possible to assess directly the effects of so-called "overlearning trials," rather than simply to infer some change from correlated improvements in retention. The implication, then, is that rate or latency measures provide a much-needed sensitivity to changes in performance which may be important in instructional efforts to improve retention, generalization, and/or maintenance of skills.

LaBerge & Samuels(1974) found that when subjects reached a certain level of performance (i.e., response rate or latency), reading became "automatic." That is, the subjects were able to read with characteristically brief response latencies even in the presence of previously distracting stimuli. The authors couched their discussion in terms of attentional channel capacity. They suggested that at a certain level of performance, the reader no longer needs to attend to the performance exclusively, but can direct attention elsewhere while continuing to read (a common problem with day-dreaming readers!) Thus, automaticity in skill may be thought of as the performance level at which the skill becomes "second nature" and at which attention is thereby free for activity other than the mechanics of the now automatic skill. In the context of an instructional program, we might expect a skill that had become automatic to be more easily combined with other skills than a non-automatic skill. On the other hand, it is possible that a skill could become "too automatic" or stereotypic, especially in the case of the developmentally disabled. Therefore, automaticity as a facilitator o skill combination might be an optimal range of performance, below which and above which combination of skills would be less efficient.

These two findings -- on latency as a measure of overlearning and on automaticity -- provide a conceptual framework within which to study the effects of rate or latency training on the acquisition and development of complex skills. They are especially relevant to work with the developmentally disabled whose skill performances often differ from those of normal children and adults in rate, but not accuracy (Barrett, 1979).

It is worth noting that Herbert and DeVries (197) have pointed out the facilitative effects of exercise, "practice," and diet on so-called "hypokinetic disease" (i.e., gradual reduction in behavior rates) in the aged. The developmentally disabled (especially those with Down's Syndrome) have often been compared along a variety of dimensions with the aged. We might ask, with this comparison in mind, whether rate-building techniques might have similar facilitative effects with the developmentally disabled, and especially Down's Syndrom subjects, who are known to exhibit premature aging.

Basic research on the acquisition, generalization and maintenance of complex skills (chains or sequences of behaviors) has obvious implications for clinical application and instructional design. Most self-care skills involve sequences of connected movements in which each movement (which may itself involve several simultaneous response components) or its effect functions as a discriminative stimulus for the next response in the chain. The same is true of many vocational, social, and play skills. Likewise multiple-step imitation or instruction-following involve response chains and often require those chains to be emitted only after observation of (or listening to) a series of stimuli that appear in a particular order. Many academic and cognitive skills (spelling, calculation, etc.) are complex chains of behavior. In fact it is fair to say that the greater proportion of human skills are compounds of behavioral elements connected in various sequential and/or concurrent configuartions.

Behavioral chains may be either relatively homogeneous or relatively heterogeneous, depending on the topographies (or dynamic forms) of their elements. For example, Mackay ( ) has studied a category of homogeneous chains in which each response is a panel-press and instances of N-element chains differ only in the location of the panels and the order with which the subject presses them. On the other hand, Lowry (1981) is studying heterogeneous chains of the variety originally taught to animals in operant conditioning laboratories (Skinner, 1938). Here, in addition to sequence and location variables, instances of N-element chains differ from one another insofar as their elements vary topographically. Thus, a heterogeneous chain is one which includes a series of different movements varying on such dimensions as force, precision, and range of motion required for execution.

From an instructional viewpoint, when the elements of a compound are topographically identical or homogeneous, the trainer need only insure that the subject is proficient in performing that single topography prior to work on the sequence. In heterogeneous chains, however, where there may be individual subject differences in the acquisition and/or proficiency of specific topographies, the trainer's task is a great deal more complicated. In the heterogeneous case, failure to acquire or become proficient in only one of a series of element topographies might constrain or prevent acquisition of the entire compound. To the degree that one element is dysfluent or lacking in automaticity, it will place a ceiling on the performance of the entire compound. It may retard acquisition of the sequence by requiring an inordinate degree of attention, thereby reducing attentional capacity for the sequence a systematic program of research questions and designs. A great deal of our own recent applied work with the severely handicapped has emphasized component skill rate-building. And many teachers have given anecdotal reports of large facilitative effects. But there is at present no systematic body of data on the effects of changes in component skill performance rates on acquisition, proficiency and generalization of composite skills in the developmentally disabled. And in the context of a program of research on the acquisition of complex discrimination and behavior sequences, it seems most appropriate to investigate such effects. We therefore propose to examine the effects of changes in latency or response rate of behavioral elements on the acquisition, assymptotic performance levels, and generalization of several categories of behavioral chains.

Method

Subjects

Subjects for this research will include a full range of ages and levels of cognitive functioning. We will employ "normal" adults and children in order to obtain normal performance standards and learning rates, and developmentally disabled individuals, especially severely and profoundly retarded residents of the Fernald State School and students from a number of community educational agencies. A significant portion of these are expected to be Down's Syndrome cases.

Apparatus

There will be two basic types of apparatus for the experiments. One will be an IBM microcomputer with its high resolution color graphics and printing capabilities. We intend to use variants of Mackay's ( ) trials procedures, but will require a capacity for high-speed presentation of visual displays to extend the latency/frequency ceilings beyond those allowed by slide-projected visual stimuli. By superimposing plexiglas press-panels over the video display provided by the computer, and constructing an appropriate interface, it will be possible to present sequences and/or arrays of stimuli at high pace and to allow press-panel responding similar to that used in Mackay's experiments. This first apparatus, then, will be used for investigating homogeneous chains, and in the context of a program project will also allow Mckay to extend the dimensions of his own paradigm in a collaborative sharing of the equipment.

The second apparatus will serve as a basis for the analysis of heterogeneous chains. It will consist of an experimental enclosure and console to which multiple operanda, requiring a variety of topographies, may be attached. Topographies will include arm or leg extension, aiming toward and touching targets, and twisting and squeezing, as well as a variety of other elemental movements. The operanda will be adjustable on the dimensions of force, precision (target or operandum size), and/or range of motion so that each elementary topography will actually be represented by a class of responses with varying requirements. This apparatus will allow us to design multi-element chains of various lengths and sequences, adjustable in ways which will allow us to alter response rates by changing physical parameters. It will also enable us to design programs of practice and proficiency-building on specific elements in isolation.

Questions and Paradigms

1. Are there systematic differences in performance rates or latencies between subjects of different levels of handicap across a broad variety of response topographies?

   A. Obtain timed samples on a set of topographies and response requirements from a range of normal to handicapped subjects.

   B. Analyze for relative performance levels between groups and across response topographies. Previously collected data of this type on pre-academic skills (Barrett, 1979) and fine motor skills (Binder, 1981) have revealed that as skills become more developmentally refined or complex, differences among levels of handicap widen. These descriptive data will establish performance norms and will calibrate the various topographies along the latency/frequency dimension.

2. Does latency/rate training of chain elements affect rate of performing the whole chain?

   A. Teach an N-element homogeneous or heterogeneous chain.

   B. Continue to measure it at each session, using its self-paced rate as a baseline .

   C. Begin rate/latency training which, if successful, will accelerate the subject's rate of performing the element(s) in isolation.

   D. Continuing to measure the chain performance, look for a concurrent acceleration in its rate.

   E. Return to baseline condition by discontinuing rate/latency training, and look for effects on chain performance .

   This design was successfully employed by VanHouten (1979) in an investigattion of arithmetic skills.

3. Using the same design as in #2, but altering element response rates by mechanical adjustment of response requirements rather than by training, what will be the form of the facilitative or inhibitory effect? We would expect a change in level of chain performance in comparison with the baseline. But there could also be a change in trend if alterations in the difficulty of the element(s) also change the subject's rate of improvement. Can we mimic training effects through mechanical adjustment? This question is relevant for the design of prosthetic environments (Lindsley, 1964). It also will indicate whether or not we can quickly gather a large amount of data of element/chain relationships by mechanical adjustment which is quicker than training.

4. Do deficits in multiple elements in a chain accumulate in their inhibitory effect, or does the least fluent simply set a ceiling? By combining multiple elements at calibrated proportions of deviation from a standard, we can examine functional relationships between those deficits (or mechanically imposed "handicaps") and the proportional decrement produced in the chain as a whole. This procedure will be straightforward in work with either normal adults or children or with previously trained disabled subjects.
5. Does training a more rapid observing response in Mackay's sequence reproduction procedure increase retention from the observation phase across the retention interval to the reproduction phase?
   - A. Train subjects on a series of Mackay's sequences (e.g., 5).
   - B. Pre-test the pace at which subjects can press panels as they light up both in sequence (tracking) and with repeated illumination of a single light.
   - C. Test for retention interval by using Mackay's procedure and testing reproduction at increasing times between observation and reproduction. When accuracy breaks down, define that as maximum retention.
   - D. Train short latencies for tracking and single-panel pressing.
   - E. Repeat C to determine whether there is an increase in speed of performing the entire task and/or improved retention.
   - F. Repeat C, but with a ceiling placed on latency so that observing speed is constrained. Determine whether this disrupts retention observed in E (if there was an improvement).
6. Does element fluency improve chain acquisition? Design still under consideration.
7. Do higher frequency criteria for performance in Mackay's paradigm facilitate generalized sequence reproduction? Design still under consideration.

Tentative Budget

First Year

Personnel	
Systems Analyst	$20,800
Half-time Secretary	8,000
Research Assistant half-time	9,000
Equipment	
Microcomputer system components	10,000
Operanda parts, etc	3,000
Dual trace scope and logic analyzer	1,400
Letter quality printer	2,500
Supplies	
Discs, tapes, wire, tools, etc	2,000
	56,700

Second Year

Personnel	
Systems Analyst	$20,800
Secretary	8,800
Assistant full-time	19,800
Equipment	
Peripheral equipment updating, etc	2,000
Supplies	
Same as first year	2,000
	53,400

Third Year

Personnel	
Systems Analysts	$20,800
Assistant	21,780
Secretary	9,900
Supplies	2,000
	54,480

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