STRATEGY IN STUDIES OF ATTENTION:
A COMMENTARY ON D. I. MOSTOFSKY'S ATTENTION:
CONTEMPORARY THEORY AND ANALYSIS¹

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"Attention" is an old-fashioned word struggling to find a place in modern science without much success. The word applies to many phenomena that are difficult to connect, such as, for example, levels of sleep and discrimination reversal. Mostofsky's new compendium on attention might have given cohesiveness and new direction to the field, as was done by his compendium on stimulus generalization. We were disappointed, therefore, to find so many chapters of a traditional sort, with heavy emphasis on reviewing literature that has changed little since last it was reviewed. By our own understanding of "attention", the collection leaves out exciting research developments of the last two decades. Where is a chapter dealing with the Hubel and Wiesel type of stimulus classification (Hubel and Wiesel, 1962)? Where is a chapter dealing with operant conditioning of neural units (Fetz, 1969; Fox and Rudell, 1968)? Where is a chapter dealing with abrupt shifts in attention and errorless training (Schusterman, 1967)? Where is the conception of attention as something taught rather than something immutable to be measured? The editor has selected, in many cases, what is stable and unexciting in the field of attention, leaving out new and challenging developments.

On the positive side, we find: the chapter by Jenkins and Sainsbury, which is an outstanding piece of work; a charming last view of E. G. Boring as he struggles to organize the history of the field; Berlyne delivering a provocative tongue-lashing to psychologists who

feign total ignorance of the central nervous system; and Thompson and Bettinger reporting an elegant functional analysis of the behavior of association cortex in cat.

Attention, Discrimination, and Stimulus Control

Attention is not yet a scientific word, and convincing arguments can be made for dropping it from the language of the behavioral scientist. But the word persists and, at times, is the only word that exactly communicates an idea. Taking a relaxed attitude, as Mostofsky has done, and defining attention as whatever-is-being-done-in-the-name-of-attention, proves chaotic. A rigorous operational attitude leads to defining attention as stimulus control or discrimination (Skinner, 1953; Ray, 1969). Defined as stimulus control, the word "attention" is obviously unnecessary. Perhaps we can discover its special meaning by considering the circumstances that provoke scientists to use the word.

As used in everyday language, attention refers to a critical relation between environment and behavior. "He is paying attention" means that *something* is determining his behavior, even though we do not know what it is. This is the crucial problem for the behavioral scientist, because he also *does not know what it is*. All the scientist knows is that certain stimuli correlate with certain behaviors. From this he infers (usually inaccurately) to what an organism attends. Because stimuli are infinitely reducible into unthought-of properties, attention can be to just a small feature or an elusive quality. However, we need a word, like "attention", to refer to what we *wish* to measure: the irreducible stimulus-response relation; we need the word "discrimination" to refer to what we *actually* measure: changes in response probability with changes in stimulus. The phrase "stimulus control" has been used sometimes to mean the irreducible stimulus-

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response relation (attention) and sometimes to mean an observed correlation (discrimination). The word "attention" refers to a scientific quest, and not to the realities of the laboratory.

We might expect, therefore, that a book about attention would be concerned with analyzing stimulus control into its critical elements, gradually paring away irrelevant features of stimulus and response. The Jenkins-Sainsbury and Thompson-Bettinger chapters are the best examples to be found in the Mostofsky book. The majority of the chapters, however, investigate discriminations without analysis of either stimulus or response, and the word "attention" seems inappropriate to describe their field of interest.

Scattered in the book are references to attention as a "state of the organism". Naturally, an attending organism is in a state of attention, but the state includes the stimulus and response. It is not possible to condition or to measure attention disembodied of its essential elements, the stimulus and response. Just as training the mental muscle is a fiction, training attentions skills is an imaginary process. The chapter by Honig is particularly confusing on this point, because it combines a careful empirical analysis with a tendency to view attention as something independent of particular stimuli and responses: "One attentional process is selective, . . . the other kind of attentional process, . . . , would have to be a general "alerting" of the organism to external stimuli (p. 236)." If attention is discussed without reference to specific stimuli and responses, it is easy to miss internal contradictions like the *interaction of independent stimuli*; ". . . the degree of overlap, or redundancy, in the presentation of cues from the dimension of generalization and from the independent training dimension (p. 233)."

Consulting the Experimental Subject

A characteristic of some experts in attention is a flight from the real phenomena of stimulus control to well-behaved systems in other dimensions. We are offered several models (Lovejoy, 1968; Sutherland, 1964; Jerison's chapter) that are logically well ordered and have little to do with the illogical data of attention. The flight-from-facts practised by scientists has been skillfully described by Skinner (1958), who observed that rewards of

logic often exceed the rewards of truth. The scientist's love of order is often his own worst enemy, and Mostofsky's book contains some instances.

Besides the lure of imaginary models, there is another trap to avoid: boycotting the experimental subject. The experimental subject threatens our preconceived and neatly arranged ideas about stimulus classification. In a single session, a subject can turn logic to chaos by responding systematically to only *part* of a "dimension" (Stoddard and Sidman, 1971). The subject often does not agree with the experimenter about dimensions. If we persist in labelling stimuli according to the experimenter's system of classification, we make it difficult to discover the subject's system of classification.

If we are not careful, we may completely eliminate the subject's role in defining stimulus classes. It is currently popular to design experiments that organize stimuli by *a priori* dimensions, to test the subject, and to *forget to correct* the original assumptions about dimensions in the light of the subject's behavior. For example, it is currently popular to design experiments around "orthogonal" dimensions (*cf.* Honig's chapter, p. 214). Orthogonality, in the sense of independence, can be put to experimental test. If we observe that a subject changes behavior to one stimulus and not to another, the stimuli are functionally independent for that subject at that time. Orthogonality measured by test describes the *subject's* organization of stimuli rather than the experimenter's. Honig's chapter, for instance, includes a thorough organization of stimuli. The stimuli are arranged to provide "inter", "intra", and "extra" dimensional discriminative stimuli, and certain discriminations are "dimensional acquisition" while others are not. This is experimenter organization of stimuli. Honig's subjects indicate a different organization when they behave as if few stimuli or dimensions were independent. Honig's research is creative and raises important questions about stimulus commonalities. But his treatment does not yet take into account the clearly different systems of stimulus classification used by an experimenter and his subjects.

Elsewhere in the Mostofsky book, we find authors explicitly questioning their own prejudices about stimuli and stimulus control. For example, Jenkins and Sainsbury originally de-

fine "distinctive feature" to suit their own notions, but immediately remind the reader that the experimental subject will define what it considers distinctive. This flexibility leads to subject-defined stimulus features.

Attention in Perpetual Change

Rapid change is characteristic of life. An active fire is described as alive with lights. Psychology is a science of living things and has had to deal with continuous, and often irreversible, change. To do this requires the most sophisticated methods. In this century, methods for studying changing systems have increasingly relied on empirical observation: change is studied by direct and continuous observation while leaving behind explanatory forces, like hunger, that cannot be directly observed. The power of functional analysis in psychology has been long demonstrated (Skinner, 1938), and it is sad to see how seldom the approach is applied to studying attention. The majority of papers in Mostofsky's book rely on static concepts of analysis that are legacies from experiments on nonliving things. In this tradition are the concepts of the "pure" independent variable (there may be no such thing in biology), the endlessly repeatable event with its reliability index, and the "group" organism, which cancels out the behavior of its members.

The concepts of independent variable, reliability index, experimental and control group are ideally suited to the study of stable phenomena. But attention is famous for instability and needs other experimental concepts. The key to rigorous study of change is functional definition. A familiar example of functional definition is the definition of reinforcer: a consequence that accelerates behavior. Functional definitions are peculiar because they are not independent of experimental results, but they are nonetheless rigorous. Without functional definition we cannot study attention, because we cannot distinguish between a stimulus (any physical event) and a controlling stimulus (functionally defined by its effect on behavior).

Functional definitions are well suited to dealing with the continuous process by which behavior interacts with its consequences to produce new units of stimulus and response. This dynamic interaction was described by Skinner (1935) as the generic nature of stim-

ulus and response. The difficulty of the concept has delayed its application to much of the literature in discrimination and attention. Instead, we read (Broadbent's chapter) that it may be the stimulus or the response that is selected by an organism, implying a fixed population of stimulus and response units. Another possibility is that stimulus and response units are continuously created by an organism's interaction with its environment. Broadbent's kind of approach is amply represented in attention literature, but the field needs more examples of functional analysis that follows stimulus-response units through periods of transition.

The Validity of Stimulus and Response

Unfortunately, the mere temporal coincidence of a stimulus and response does not prove that they are related (Ray and Sidman, 1970). An infinite number of stimuli may be present during a response, and a single association is not enough to define a controlling relation. When a response has been made many times, certain features of the environment may continue to correlate with it while others do not. Even with a perfect correlation, it is possible that stimulus control is exerted by a small feature of the correlating stimulus (Reynolds, 1961; Jenkins-Sainsbury chapter; Touchette, 1969). There is obvious value in isolating the critical feature for the sake of predicting behavior in a changed environment. So long as a correlating stimulus can be changed in one aspect and not another, it is necessary to know which features actually control a response.

The same considerations apply to defining the controlled response. A stimulus may control one or several aspects of a response, its duration or force or placement, *etc.* . . . It is easy to eliminate irrelevant features of a response compared to irrelevant features of a stimulus, since the subject selects its own response and we can easily observe the new topography. The subject has no comparable way to eliminate irrelevant stimulus features, because these are imposed by the experimenter. Irrelevant stimulus features are eliminated by experimenter trial and error. In the Mostofsky book, the process of analyzing stimulus and response units is conducted expertly by Jenkins and Sainsbury and by Thompson and Bettinger.

Jenkins and Sainsbury show, by changing response definition, that a sharp and a zero discrimination can be traced to the same stimulus-response relation. This conceptually simplifies a collection of facts in the finest scientific tradition: an imperfect stimulus-response definition gives way to a more accurate one.

Thompson and Bettinger show, by comparing several measures of electro-cortical stimulus and response, that neural units in association cortex of cat respond to the adding together of stimuli in three modalities and are modulated by frontal shock. This finding specifies a stimulus that fits the classic concept of summation and, more importantly, identifies pathways from the frontal to association areas for those who deal with the nervous system directly.

As stimulus-response relations are discovered and refined, fretful scholars may wonder which ones are really "attention". The orienting reflex seems to generate this sort of concern (Mostofsky, p. 13). The orienting reflex, or "what-is-it" reflex, was originally described by Pavlov, and is now studied with more sophisticated instrumentation. If attention is the search for valid environment-behavior connections, it is absurd to propose that a particular response is the most relevant. Many responses will be studied and discarded as the best biologic categories are sought. The question concerning the orienting reflex seems to be its validity as a response controlled by a definable property of the environment.

Evidence indicates the orienting reflex is important, since there are inescapable regularities between environment and the reflex syndrome described by Luria and Homskaya in their chapter. A provocative feature of the syndrome is the suggestion that the brain responds to novelty. What part of the brain responds, where the brain begins or ends, and what objective criteria define novelty are not discussed. These questions require further analysis. It is also provocative that the frontal area is implicated, for the second time in the book (*cf.* Thompson and Bettinger), as the modulator of an environment-behavior connection.

If a true connection exists between the orienting reflex and certain features of the environment, then analysis of both stimulus and response features will make the control

more obvious and confirm that critical features have been identified. Understanding stimulus control of the orienting reflex may prove important to the study of discrimination acquisition and shift.

Explaining Attention

To explain attention, it is more important to establish that controlling relations are valid at the behavioral level, than to leap to an imaginary nervous system to account for whatever-it-is-convenient-to-account-for. Theories of attention can insidiously lead to a science of imaginings, such as, for example, a system of analyzers (Sutherland, 1964) switched in and out to account for selective attention. Also popular are imaginary observing responses (Jerison's chapter) that account for data. These imaginary observing responses should not be confused with the real thing: an overt response reinforced by discriminanda (Holland, 1958; Wyckoff, 1952). Because stimulus control is accompanied by private sensations, there may be a tendency to look inside for explanations. There is a big difference between really looking inside to observe neural events (Hubel and Wiesel, 1962) and imagining an inside. Precisely because they are imagined, fictional nervous systems are reasonable. Imaginings are based on what is already known and do not confront us with unfamiliar principles or relationships. It is this reasonableness that can give fictional nervous systems such long life.

It is not necessary to go inside to observe stimulus control. Valid stimulus-response units can be discovered for the behaving organism, if we do the necessary work. The experimenter in attention learns to distinguish his *experimental* stimuli from those used by his subject. When experimental stimuli are discriminated by the subject, the experimenter knows he has captured critical features in his experimental stimuli, but does not know what these features are. The experimental stimuli are fractionated, pulled apart, and varied to isolate their critical features.

There is very little analysis of stimuli in current discrimination studies. Historical precedent may have created this situation. In operant analysis, a false step was taken in the language of discrimination learning. It was predicted that reinforced responses would

tend to reoccur to stimuli *present* when the response was reinforced (Ferster and Skinner, 1957). Things fall into place when "stimuli present. . ." is changed to "stimuli *controlling*. . ." at the time of reinforcement. There is ample evidence that stimulus control is shaped by its consequences. If an organism is controlled by both color and form, but only control by color is reinforced, the organism is more likely to attend to (be controlled by) color in future and to disregard form. This selection of reinforced stimulus control will happen even when both stimulus features have been discriminated in the past and both features impinge on the same receptor (Ray, 1969). The "operant" for stimulus control research is the stimulus-response *relation*, not the stimulus-response coincidence.

To distinguish a controlling stimulus from a coincidental stimulus, we have to ask the one controlled, the experimental subject. We ask by arranging an environment filled with features to which the subject can *selectively* respond. To the extent that an experimenter limits the subject's choice, he deprives the subject of his communication device. The range of features the experimenter presents, his lack of prejudice, and his imagination will all hasten valid measurement of stimulus control. There is no substitute for the educated guess, but emphasizing variety of test features increases the chance of a lucky guess about controlling features. The greatest hindrance to stimulus control measurement is a permanently organized system of stimulus classes that does not change as dictated by the subject.

The Mostofsky compendium has tradition to back its emphasis on experimenter organization of stimuli. However, the tradition of studies in attention is holding the field back and is not compatible with empirical observation of stimulus control. It is encouraging, therefore, that at least two chapters in this new book represent the modern trend toward empirical stimulus organization based on environment-behavior correlations.

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