

The Speaker as Listener: The Interpretation of Structural Regularities in Verbal Behavior

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Regularities in word order not specifically addressed by Skinner require behavioral interpretation if our field is to become more influential among students of language. Three such phenomena are briefly described in traditional structural terms and are offered as test cases: subtle differences in dative verbs, transformational traces, and the formation of compound nouns. It is argued that the variables that control such regularities derive from the speaker's repertoire as listener. Intraverbal frames are established as verbal responses in the listener through reinforcement by parity. Transitions from element to element in such frames are controlled, moment to moment in time, partly by the speaker's responses as a listener to his or her own verbal behavior. Although this account offers only a tentative interpretation of grammar and syntax in a limited domain, it suggests that the conceptual tools of behavior analysis are adequate to the task of explaining even the most subtle of grammatical rules.

Science serves us in two ways. First, it underpins our mastery of the physical and biological world: We should not like to do without our vaccines, antibiotics, semiconductors, or internal combustion engines. But perhaps an even more important service is to resolve mysteries about nature. Science offers beautiful, elegant, and, often, deeply satisfying explanations for complexity and order in nature, and if forced to choose, we might prefer to live in a cave, with our understanding intact, than in a wonderland of gadgets, benighted by superstition.

The two functions often differ in the importance of details. Further advances in immunology may rest upon minutiae such as the configuration of a protein or a sequence of DNA bases. Small errors in technique or deviations in procedure may be disastrous. In contrast, consider Darwin's theory of evolution, surely one of science's most elegant and intellectually gratifying saltations. Although the theory rests on a wealth of detailed observation and experimental analysis, its extension to the interpretation of nature is often vague and uncertain. For example, we account for the marvelous simi-

larity between the viceroy and monarch butterflies by noting the adaptive advantage to the tasty viceroy of looking like the bitter and poisonous monarch, and we suppose that the appearance of the former species was shaped by eons of differential predation. We have little, if any, direct evidence to support this account, but we nonetheless find it a satisfactory resolution of the mystery of mimicry (cf. Brower, 1988). Furthermore, we would not be much embarrassed if future work suggested that the account was entirely wrong, that, in fact, it was the monarch who mimicked the viceroy owing to some adaptive advantage of the latter species not now appreciated. It is the evolutionary principle that we find so satisfactory, not the particulars. Or perhaps we should say that it was the principle that was mysterious to begin with.

Thus, to resolve a mystery, it is sufficient to point out at least one path along which nature might have traveled to reach a given point. The discovery of a second path is not equally exciting. Analogously, we may be baffled to see a magician produce a seemingly endless supply of rubber balls out of thin air. If we notice that they could be passed to him by a confederate sitting behind a screen, our astonishment dissolves,

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for we have now identified a possible explanation; we might be wrong (perhaps he draws them from his sleeve) but no longer are we mystified, for we have reduced the supernatural to the natural.

Complex human behavior remains one of the mysterious frontiers of science, and the task of displacing occult and superstitious interpretations is formidable. A common tactic is to infer a neural mechanism with just those properties necessary to explain the behavior under study and then to assert that this mechanism is innate. For example, the rapid and nearly universal acquisition of a fluent verbal repertoire by children has invited speculation that there is a language acquisition device, a neural module that was selected by evolution because of the obvious adaptive advantage accruing to verbal organisms (Chomsky, 1980). Such an explanation has enormous appeal; it invokes only familiar principles and natural phenomena, and it appears to resolve the mystery at a stroke. It is only when we examine the proposal in detail that we notice that the evolutionary account is as baffling as the original mystery: What, precisely, has been selected, and what program of evolutionary contingencies might have selected it? But so tentative is the nature of scientific interpretation and so complex is the subject that many thoughtful scientists find such explanations satisfying.

Skinner's interpretations of complexity are distinctive in resolving perplexity while avoiding circularity: The terms of his analyses are well rooted in an empirical science and pose no evolutionary conundrums. Thus, self-awareness – seemingly the province of an executive homunculus – is interpreted by describing classes of contingencies by which a community shapes self-descriptive behavior (Skinner, 1945), and verbal behavior itself is interpreted by identifying classes of verbal operants and the independent variables of which these classes are a function (Skinner, 1957). But Skinner's interpretations of verbal behavior have not been influential outside his field. As noted above, one's first naturalistic explanation for a phenomenon dulls one's urgency to find alternatives; because many scientists appear to be satisfied with nativist claims about lan-

guage, there is little incentive for them to struggle with the unfamiliar language of behavior analysis in search of another account (cf. Hineline, 1980, 1992). Furthermore, one of the most conspicuous properties of verbal behavior is its structural regularities, or grammar, and it is this property that has excited the greatest wonder among linguists and philosophers. Skinner's interpretation of grammar is both difficult to understand and hard to generalize to novel cases. Those who have studied language in greatest detail have identified verbal phenomena that seem to defy explanation in Skinner's terms.

Unfortunately, there is little that behaviorists can do about the appeal of alternative paradigms except to wait for the self-corrective machinery of science to reveal the vacuity of the nativist account and so reinstate the sense of mystery. Indeed, fleshing out the evolutionary interpretation of structural models of language is a central preoccupation of contemporary linguists and philosophers (e.g., Chomsky, 1980; Pinker, 1994; Pinker & Bloom, 1990). As discussed elsewhere (Palmer & Donahoe, 1992), this effort is futile, because the essentialistic units of analysis of structural accounts are incommensurate with phenomena shaped by contingencies of selection. Ultimately structuralism will exhaust itself, and selectionist approaches will be viewed with renewed interest.

Meanwhile, it is the problem of interpreting grammar to which we can most profitably direct our efforts. Skinner has made an extraordinary contribution to our understanding of the variables of which verbal behavior is a function, but I believe the task has been left unfinished. It is the goal of this paper to extend or supplement Skinner's interpretation of grammar. I begin by identifying several examples of verbal behavior, culled from the literature of linguistics, that are difficult to explain from a behavioral perspective. I then identify several independent variables that are, in my view, insufficiently developed in *Verbal Behavior* (1957) and that appear to be relevant to these examples. I do not claim that the present effort is adequate to the interpretive task I have undertaken. I wish merely to begin the

task of identifying the most challenging examples of grammatical phenomena and explicating a behavioral interpretation. When we have identified all relevant independent variables, we will be in a position to offer tentative interpretations of any verbal phenomenon, and we can claim to offer a resolution of the mysteries of language that does not itself raise as many questions as it answers.

In keeping with the foregoing remarks, I will occasionally adduce evidence with a degree of rigor that falls far short of that required by an experimental analysis but which, I believe, is suitable for identifying variables for use in behavioral interpretations. In *Verbal Behavior* (1957) Skinner chose, wisely I think, to omit empirical data entirely, lest it mislead the reader about the interpretive nature of his enterprise. In what follows, some experimental models will suggest themselves as will some possible refinements through adaptive network simulations, but this paper remains largely interpretive.

Before dwelling on obscure verbal phenomena that are difficult to explain, we should reflect how effortlessly Skinner's analysis accounts for most verbal behavior. Tacts, mands, textual, echoic, intraverbal operants, and descriptive autoclitics cover much of the domain of interest. When verbal behavior tracks public events, as it does, for example, when an announcer broadcasts a basketball game, even Skinner's harshest critics are likely to admit that his account appears to be adequate, for the relationship between the behavior and its controlling variables is conspicuous. However, verbal behavior is often part of a conversational give-and-take in which the controlling variables are not just environmental events and prior verbal stimuli, but, to put it loosely, the speaker's understanding of what has been said. Suppose, for example, Mary says, "When I was preparing dinner, I spilled most of the spaghetti into the sink," and John replies, "Did you scald yourself?" Here John's response is not simply a unitary discriminated operant under control of Mary's statement as a discriminative stimulus. Indeed, he might never have heard that arrangement of verbal operants before. Rather,

his response is a unique string of verbal responses apparently "constructed" on the spot. But what are the controlling variables? The setting itself is likely to exert only a very general control over verbal behavior. That is, we will be disposed to discuss some topics at home, others at work, and so on, but there may be little in the immediate setting that would evoke questions about scalding oneself. Mary as an audience will likewise exert general control, but such control will be insufficient to account for the present example. Clearly Mary's statement is relevant, but John's response is not merely an intraverbal, an echoic, a mand, a tact, or other response directly under the control of her verbal statement.

John's response is easily understood when we accept that Mary's verbal behavior initiated a cascade of covert "listener behavior" in him. Listening is not merely bombardment by auditory stimuli; it is action (cf. Skinner, 1957, pp. 138-146, 1980, p. 273), and it is this action that provides the controlling variables for John's subsequent verbal responses.

LISTENING AS ACTION

The daydreaming student is hearing the lecture but is not listening. When we listen to an auditory stimulus we "follow along"; each auditory stimulus evokes appropriate conditioned behavior, commonly covert, that is prepotent over competing behavior at that moment. Perhaps the evoked behavior is merely echoic, as it is apt to be if we are struggling to follow the lofty discourse of a speaker whose erudition exceeds our own. Perhaps it is intraverbal, as, rushing ahead, we covertly finish the utterances of a hesitant speaker. Perhaps it is a flight of conditioned perceptual behavior as the speaker transports us to another time and place. (We devour books for the very purpose of evoking such behavior in ourselves.) When evoked listener behavior is covert, it is out of reach of an experimental analysis, but it is the defining feature of radical behaviorism that it nevertheless attempts to interpret such private events according to established principles of behavior. It is essential that we do not shrink from this interpretive task, because our most cherished moments are

likely to lie beyond a satisfactory experimental analysis. Consider a passage from Thoreau's journal (December 25, 1851), in which he reports private behavior evoked, in this case, by a visual stimulus. It is the power of such sentiments that supplies the life blood of mentalistic paradigms in psychology:

I, standing twenty miles off, see a crimson cloud in the horizon. You tell me it is a mass of vapor which absorbs all other rays and reflects the red, but that is nothing to the purpose, for this red vision excites me, stirs my blood, makes my thoughts flow, and I have new and indescribable fancies, and you have not touched the secret of that influence. (1984, pp. 155-156)

But how near Skinner comes to touching the secret of that influence, for the phenomena reported by Thoreau are all behaviors, and he has been helpful enough even to identify the evoking stimulus. However speculative our inferences of Thoreau's conditioned emotional responses, conditioned seeing, covert verbal behavior, and the shaping of a self-descriptive repertoire by his verbal community, how bold and full-bodied our account stands in comparison to an arid parsing of parts of speech putatively selected from a hypothetical lexicon and arranged by a unknown grammatical module in an invented world of the mind!

Listening, then, is action, and in conjunction with other variables, will exert control over our subsequent verbal behavior. One might object that, because listener behavior is itself controlled by public antecedents, ultimate control lies in the environment, and that to speculate about private events as controlling variables draws our attention away from observable and manipulable variables. But observable and manipulable variables are only an arbitrary subset of all relevant variables, and may or may not offer a sufficient foundation for a plausible interpretation. When they are clearly insufficient, as in the present case, it is appropriate, for interpretive purposes only, to infer a role for private events. Our account will not have the status of an experimental analysis; it will merely identify one set of variables, perhaps one among many, that might plausibly explain the behavior in question and, by doing so, resolve a scientific mystery.

Returning to the task of interpreting our

hypothetical verbal exchange, in response to Mary's comment, John may have imagined Mary straining spaghetti with the lid of the pot, and owing to his own similar experiences he may have felt a conditioned emotional response appropriate to being burned. His subsequent verbal behavior is controlled, not entirely by Mary's verbal behavior, but also by his responses to her verbal behavior. So understood, Skinner's interpretive tools seem fully adequate to explain the performance. Here any difficulty in explaining John's response arises from the obscurity of the relevant controlling variables, but it does not arise from an inadequacy in our conceptual armory. That is, it is a simple fact that many variables controlling verbal behavior are out of reach of direct observation, but this is a limitation for anyone who studies verbal behavior, behaviorist and linguist alike, and we need not be embarrassed by the speculative nature of our account. No one can do more.

However, some verbal phenomena are puzzling, not simply because the controlling variables are covert, but because it is difficult to imagine what the controlling variables might be. Regularities in order and inflection – the domain of syntax – offer a rich supply of examples. Skinner has proposed various classes of autoclitic responses to account for such regularities. It was not his purpose to provide an account of every imaginable case, but to offer examples of the types of variables to be considered, leaving the extension to other cases as exercises for the reader. Nevertheless, they are formidable exercises indeed; applying them to many novel cases is no easy matter.

Grammatical regularities are commonly trivial, and one might object that the satisfaction of interpreting them does not repay the effort. After all, we are often unaware of them until they are pointed out to us, regularities vary from one verbal community to another, and practices change from time to time within a verbal community. Their importance lies in their challenge to our ability to explain them. The momentum of much of modern linguistics rests on the assumption that they cannot be explained in behavioral terms, and it is not obvious that this assumption is wrong.

THREE LINGUISTIC PUZZLES

The Dative Case

Consider the grammarians' dative case, in which verbs have both direct and indirect objects (Pinker, 1989): The words *donate* and *give* are roughly synonymous, and in some contexts, both responses might be strong and roughly equipotent. Thus we might find ourselves saying either of the following:

I donated my grandfather's diary to the historical society.

I gave my grandfather's diary to the historical society.

Under the same conditions, we might find ourselves casting it in a slightly different form:

I gave the historical society my grandfather's diary.

Here the variability in form is presumably under control of trivial variables. However, we are unlikely to find ourselves using the alternative form with *donate* as the verb:

I donated the historical society my grandfather's diary.

As listeners and readers, such constructions sound strange; as speakers, we emit such constructions only under special conditions, for example, as sequences of echoic or textual responses, but not as spontaneous verbal behavior.

In grammatical terms, *donate* must be followed first by its direct object and then its indirect object, whereas *give* permits the terms to occur in either order. This is, of course, simply a formal description of the regularity, not its explanation. But what is the behavioral translation of the rule and of grammatical terms like *verb* and *indirect object*? What variables control our speech, moment to moment in time, so that we sometimes use *give* in either construction but not *donate*? How can the rule be rewritten in terms of discriminative and motivational variables?

It is implausible to assume that parents or teachers have explicitly inculcated the rule. Most adults are unaware that there are differences in the regularities of verbs and their objects. Moreover, as all parents and teachers know, exhortation about rules rarely has a conspicuous effect on children. More plau-

sibly, we might note that in our verbal community we have heard *give* in both constructions, but we have heard *donate* in only one. Surely the distinction is arbitrary; if the verbal community reversed the usage of the two words we would find our intuitions reversed. But there are difficulties facing this proposal. First, although it is undoubtedly true, it is vacuous unless we ask more of our interpretation. The mystery remains intact: How does a history of exposure to examples emerge as a controlling variable at the time of our own speech? We do not merely repeat what we have heard; we use the terms productively, in novel combinations of direct and indirect object. We can make up nonsense like, *I gave Biddle the boodle*, and it will sound fine to our listener.

A second difficulty is that exposure to a verb in only one construction is not adequate to block its use in the other. We can, by fiat, make up a novel verb such as *to Mir*, meaning to bounce a radio message off the Russian space station. If we now use it in examples such as, *I Mirred the invitation to my cousin*, we are still likely to find acceptable the alternative form, *I Mirred him the invitation* (Gropen, Pinker, Hollander, Goldberg, & Wilson, 1989). It appears to be the case that neologisms, by default, permit both constructions (as do, e.g., *fax* and *E-mail*). The problem deepens: What are the controlling variables at work when a novel word is invented that permit it to take its place in an orderly string, whereas a more familiar word sounds strange in that string?

Transformational Traces

Another linguistic puzzle concerns evidence of syntactic transformations. By moving some words around and making a few other alterations, one can change a declarative statement into a question, or an active sentence into a passive sentence. Thus we can transform *He drove his kids to school today* into *Did he drive his kids to school today?* or *Where did he drive his kids today?* It is a staple assumption of linguistics that speakers actually perform such rearrangements as they speak, and the task of identifying transformations and the rules governing them has been a preoccupation of the field. From a behavioral perspective this is an odd exer-

cise, for to trace one sentence back to a second does not seem to be an advance, unless we can already explain the second sentence. If we can explain a declarative sentence by reference to independent variables, why can we not explain the question or passive sentence by reference to similar variables? Humans are undoubtedly capable of transforming one expression into another, as we do when we solve problems in algebra or in word games, but there appears to be no such explicit problem-solving behavior when we ask questions.

However, linguists have discovered some curious regularities that seem to support the claim that questions are derived from declarative sentences (e.g., Crain, 1994). In so-called *wh*-questions (those that begin with *where*, *what*, *who*, *when*) the *wh*-term is assumed to replace a word and to move to the front of the sentence. Thus, in the following example, *her* is replaced by *whom*, and the latter term is moved to the first position with an appropriate auxiliary verb.

I took her to the movies.

I took whom to the movies?

Whom did I take to the movies?

Moreover, when *whom* is moved, it is said to leave a "trace" in the sentence in the location from which it was moved:

Whom did I take [t] to the movies?

Such traces do not appear when the sentence is spoken, but they make themselves felt in other ways. For example, one of the findings of research in linguistics is that it is ungrammatical, or at least it sounds wrong, to contract expressions that span a trace (Crain, 1994). Thus in casual discourse we contract *want to* to *wanna*, but not if a trace intervenes. For example, the question

Who do you want to help [t]?

will usually be pronounced,

Who do you wanna help?

Here, the term *who* represents the object of *help* and so leaves a trace at the end of the sentence, where it does not interfere with the contraction. But consider a case in which the term *who* represents the object of *want*. Note that

Who do you want [t] to help you?

is not commonly pronounced

Who do you wanna help you?

Needless to say, the terms of this analysis have no parallel in a behavioral account, but we are not therefore absolved from explaining the behavior.

Compound Nouns

A third linguistic puzzle, and the last that I will describe here, concerns the coining of novel compound nouns from corresponding verbs and direct objects. Someone who repairs furnaces is called a furnace repairman. Analogously, we might whimsically call someone who feeds pigeons a *pigeon feeder*, and someone who greases ball joints a *ball joint greaser*. Experiments with children have revealed that they too are adept at coining compound nouns. In a study by Gordon (1986), children were shown puppets of various monsters and invited, through modeling, to give them compound names. For example the experimenter might say, "This monster eats mud; he's a mud-eater. This monster over here eats sand. What kind of monster is he?" whereupon the child, as young as 3 or 4 years old, would respond, "A sand-eater." The dialogue might continue:

This kind of monster eats mice. He's a –
A mice-eater.

This monster eats rats. He must be a –
A rat-eater.

Most of the children in this study respected this convention: mass nouns, such as *mud*, *sand*, or *flour*, and irregular plural nouns, such as *mice*, formed compounds unaltered. One might notice the relevance of echoic control here: *eats mud* evoked *mud-eater*; *eats mice* evoked *mice-eater*. However, when the experimenter modeled a regular plural noun, children dropped the *s* and formed compounds with the singular noun. *Eats rats* evoked *rat-eater*.

This is a curious finding, and one for which I find no obvious behavioral interpretation. That is, I believe that a behaviorist would be unable to offer a prediction about the behavior of the children in this study except by consulting his or her own ten-

dency to respond one way or the other. The term *rat-eater* is newly coined by the child, and is at least partially under echoic control, but what variables govern the production of novel forms? However puzzling it might be from a behavioral perspective, linguists are untroubled. The principal investigator argued that the data point to the role of innate mechanisms in language, and another prominent linguist claimed that the results followed from a model of structure and process:

The theory of word structure explains the effect easily. Irregular plurals, because they are quirky, have to be stored in the mental dictionary as roots or stems; they cannot be generated by a rule. Because of this storage, they can be fed into the compounding rule that joins an existing stem to another existing stem to yield a new stem. But regular plurals are not stems stored in the mental dictionary; they are complex words that are assembled on the fly by inflectional rules whenever they are needed. They are put together too late in the root-to-stem-to-word assembly process to be available to the compounding rule, whose inputs can only come out of the dictionary. (Pinker, 1994, p. 146)

It is not the model itself that is astonishing but that it is offered as an explanation.

But ridiculing the work of others is a pastime that should be reserved for those who can do better. I have described three verbal phenomena culled from countless examples in the linguistics literature for which a behavioral interpretation is not straightforward: fussy verbs in the dative case, the blocking of contractions by transformational traces, and constraints on the formation of compound nouns. The examples themselves are of no consequence. Whether we can predict this or that verbal construction is of little interest in itself. However, the adequacy of an entire approach to understanding complexity is at stake. Do we have a stock of interpretive tools that we can bring to bear on these problems?

A BEHAVIORAL INTERPRETATION OF THE THREE LINGUISTIC PUZZLES

I have found it to be a helpful exercise to speculate how one might model verbal constructions using adaptive networks that implement behavioral principles (e.g., Donahoe, Burgos, & Palmer, 1993;

Hutchison & Stephens, 1987). Such models leave no room for vague assumptions about the adequacy of an interpretation; all relevant units of analysis, independent variables, and behavioral processes must be identified. I discuss three such variables and interactions among them that I believe play an important role in determining the orderly arrangement of verbal operants, or, in traditional terms, grammar. All three are distinguished by their reference to the role of speaker-as-listener. The first variable is the intraverbal control exerted by "frames" over the grammatical structure of an utterance; the second is the discriminative control exerted by the auditory properties of the speaker's own verbal behavior as he or she speaks (i.e., the role of speaker as listener); the third is the "automatic" shaping of verbal responses toward parity with practices of the verbal community, mediated by the speaker's repertoire as listener. Together with Donahoe, I have discussed the first and third points elsewhere (Donahoe & Palmer, 1994, pp. 312-317; Palmer, 1996), and Skinner (1957) discusses all three. Automatic reinforcement has received attention by Sundberg, Michael, Partington, and Sundberg (1996) and by Vaughan and Michael (1982). The contribution of the present exercise is to invoke these variables in the interpretation of new types of problems, problems in which their role is not obvious. I will elaborate them by example in discussing the three linguistic puzzles described above.

The Dative Case

The dative case is puzzling because we fluently adopt nonsense words or novel words in either of two constructions, but we balk at giving similar latitude to familiar words like *donate*. One must suppose that prolonged exposure to a word in just one form would bias our ear eventually against the alternative form. This, at least, is an empirical question. One might expose subjects to repeated examples of novel verbs, such as *to Mir*, in just one construction and evaluate whether the other construction "sounds wrong," and, if so, under what conditions of exposure (cf. Gropen et al., 1989). The external validity of such a study would be

uncertain, but the results might be suggestive, and as I mentioned earlier, in the interpretation of complexity, we may need to be satisfied with imperfect empirical data. But even the predicted outcome of such a study merely renews the question of the behavioral processes at work.

Intraverbal frames. I propose that repeated exposure to examples of grammatical constructions establishes intraverbal frames, that is, units of listener behavior that consist of sequences of both fixed and variable verbal elements. For example, repeated exposure to dative constructions might establish as a unit an intraverbal frame, *donate X to Y*, where X and Y have certain prosodic, temporal, and semantic properties but are otherwise free to vary from one example to the next, according to the context. Thus, on one occasion we might say, *I donated money to the United Way*; on another we might say, *I donated the manuscript to the library*.

In order for the notion of an intraverbal frame to have any explanatory power, it is necessary to specify the variables that govern the transition from one element of the frame to the next. For example, what controls the response *to* in the frame *donate X to Y*? If X is a variable, why does not *to* intrude at the earliest possible opportunity, forming nonsense like *I donated my to the historical society*? As indicated above, X must have certain prosodic, temporal, and semantic properties, and it is these properties that control the transition to *to*. Regarding prosodic properties, notice that *my grandfather's diary* is said with a pattern of intonation that is independent of the phonemes themselves; the same pattern can be detected if we elect to donate *Aunt Mabel's silver chalice*. As for temporal properties, X cannot be indefinitely long or the intraverbal control of *to Y* will be lost. As for semantic properties, X must be something that can sensibly be donated. The prosodic and temporal properties of a response are physical dimensions and thus are objective candidates for controlling variables. Thus the element *to* is not directly controlled by *donate* but by *donate* followed by another verbal stimulus with a certain pattern of emphasis and duration. We can see the degrading of intraverbal control by inserting a relative clause of great length: *I*

donated my grandfather's diary that he began when he was just a boy living in a small New England town after the Civil War to the historical society. Here, all intraverbal control over the indirect object has been lost. Here, also, the behavioral interpretation parts ways with a linguistic interpretation, for the linguist's grammar places no restrictions on the length of relative clauses that intervene between a verb and its indirect object.

The speaker as listener. The temporal and prosodic properties of the variable terms in such constructions are stimulus properties and are therefore objective enough, but what of the semantic properties? The meanings of words are not physical properties of a stimulus; rather, they lie in the unique history of contingencies for each individual. They emerge as controlling variables for ongoing speech only in the form of behavior evoked by words as stimuli. Thus *donated my grandfather's diary* is not just a string of sounds; it evokes appropriate behavior in the listener. The appropriate behavior may very well be covert, but when emitted, it can enter into controlling relations with other behavior. Thus the auditory stimuli *donate my grandfather's ...* do not, by themselves, evoke relevant behavior, but the stimuli *donate my grandfather's diary* do. The incomplete phrase is presumably not entirely devoid of discriminative effect; we may fleetingly "think of" our own grandparents, for example. But the full phrase *donate my grandfather's diary*, owing to our history, will evoke a member of a constrained class of relevant behavior. That is, it means something relevant to us in the present context. It is some aspect of this relevant behavior (that aspect that means "something donatable") that serves as one of the controlling variables for the transition to the next elements in the intraverbal frame *to Y*. The appeal to a common behavioral effect of the variable X is not entirely gratuitous. After all, the novelist makes a living by evoking common behavior in his or her readers, a feat that would hardly be possible if verbal operants did not have reliable covert effects on listeners in a verbal community.

Why do I insist that it is the responses evoked by X and not the stimulus properties of X itself that serve as controlling vari-

ables for *to Y*? Because the stimulus properties of *X* are arbitrary and bear no consistent relationship to the other elements of the intraverbal frame. A particular *X* may be an element of this frame for the very first time. (*Yeltsin is planning to donate the space station Mir to the Smithsonian.*) That is why it is an intraverbal frame and not just an intraverbal chain. Our responses, however, must share a common dimension: Roughly speaking, possession of *X* is being transferred from one agency to another, and our responses as listeners are appropriate to that state of affairs. Thus the element, *X*, may vary from one utterance to the next, but moment to moment in time the frame *donate X to Y* unfolds in an orderly way, under control of temporal, metrical, and semantic variables.

Summary. To clarify, I am suggesting that the speaker evokes listener behavior in himself as well as others, and that this behavior is crucial in controlling the flow of subsequent verbal behavior. It may seem absurd to suggest that the speaker's responses to his or her own verbal behavior are important, because although a statement may be news to a listener, surely the speaker knows all about it already. To put it roughly, the speaker is already thinking about his grandfather's diary when he embarks on his utterance; the listener knows nothing about it. However, the variables that impel someone to embark on an utterance are relatively global and are not available to differentially guide the behavior moment to moment in time. That is, they have no explanatory force with respect to the transitions from one element of an intraverbal frame to another. It is true that the speaker may respond very differently to his or her own verbal behavior than will a naive listener. The behavior evoked in the speaker will be under joint control of global variables and specific verbal stimuli and will presumably be particularly strong (cf. Lowenkron, 1991). Whether the absolute strength of the evoked behavior is relevant is unclear, but a change in strength of the relevant behavior must occur if it is to control a transition in the intraverbal frame.

I have called such units *intraverbal frames*, because an invariant and dominant feature of such frames is intraverbal control. In

discussing such frames, Skinner (1957, pp. 336-339) has variously called them autoclitic frames, skeletal intraverbal responses, and partial frames. I have resisted using the term *autoclitic frame* only because I am unsure whether Skinner meant the term to apply as broadly as I do, namely, to any sequence of responses in which some terms are fixed and some are free to vary phonetically but are restricted in other ways.

I speculate that such frames are continually being conditioned, that even a single example may contribute to the conditioning of a frame, because it is a common observation that, in conversation, the use of a distinctive term or construction by one party will be picked up by the other party. If this is true, then frames are ubiquitous. Moreover, the linguists' awe at the infinite scope of language is inappropriate. We use the same stock frames over and over again, with variability arising from the context.

How does the notion of intraverbal frame apply to the present problem? *Donate* is a member of only one intraverbal frame, one that controls behavior incompatible with *donate Y X*, whereas *give* is a member of at least two. We have heard countless instances such as *give him the ball*, *give the letter to the mailman*, *give Sue some milk*, and so on. Because *give* is a common word, it is almost certainly a member of many other intraverbal frames as well. We hear (and say) *Give me the orange*, *Give me the spoon*, *Give me the sponge*, and many other examples strengthening the frame *Give me X*. Novel verbs are not members of frames, and thus there is no intraverbal strength favoring one construction over another.

Transformational Traces

Comparable considerations might explain our reluctance to contract words across a transformational trace, our second linguistic puzzle. *Want to go*, *want to stay*, *want to come*, *want to help*, all strengthen the frame *Wanna X*. In contrast, *who do you want?* and *what do you want?* may be invariant intraverbal chains, hence unitary verbal operants. *Who do you want to help you?* includes the intraverbal chain, not the intraverbal frame. This proposal is admittedly post hoc and speculative, but it accounts for the facts

without recourse to hypothetical constructs and processes. The matter is not entirely closed to empirical inquiry. If the proposal is true, we might find subtle phonetic differences between the first three words of *Who do you want to help you?* and *Who do you want to help?* because putatively they comprise different verbal operants.

Supporting Evidence

Neural network simulations. Several lines of evidence offer tentative support for the foregoing analyses. Elman (1995) has simulated the acquisition of intraverbal frames in a neural network model. It is true that his model was not tightly constrained by principles of behavior, but the critical features of his simulation are independent of his learning algorithm. Elman exposed his network to a very large number of examples of a few grammatical constructions, which, according to the present analysis, would be interpreted as intraverbal frames. The task of the network was to predict the next word at every time step. With experience, the network was able to predict appropriate transitions in intraverbal frames, even when particular examples were novel. In one example the trained grammatical construction was of the form, *The man who Sarah likes brought wine*, that is, a simple declarative sentence with an embedded relative clause. When the network was exposed to the string *The boys who Mary ...*, the class of all singular verbs (and no other words) was potentiated. Exposure to *The boys who Mary chases ...* potentiated a class of plural verbs, in agreement with the subject, *boys*. The critical feature of this demonstration is that repeated exposure to an intraverbal frame can lead to appropriate control that spans variable or novel elements. That is, control over the number of the final verb was determined by the number of the subject (*boys*), regardless of the content of the relative clause. Thus there is little reason to doubt that intraverbal control can span variable elements in human verbal behavior as well.

Human simulations. Gropen et al. (1989) showed that the semantic interpretation of a word enters into controlling relationships in intraverbal frames. They invented a number of nonsense verbs, like *tonk*, and pre-

sented them to subjects in a written scenario. Some scenarios indicated that the verb denoted a transfer of possession from one person to another, and other scenarios suggested other meanings of the verb. Subjects were asked to rate how natural the verbs sounded in various constructions including the dative, for example, *Fred tonked Mary the house*. Such constructions were rated as more natural if the scenario presented the verb as a transfer of possession than if it was given other meanings. They also found that one-syllable nonsense verbs in such constructions were rated higher than polysyllabic verbs, presumably a generalization from the fact that in English many short verbs (of Anglo-Saxon origin) can enter into such constructions, whereas longer verbs (deriving from French) tend to require the direct object first.

Thought experiments. Perhaps a more compelling demonstration of the role of semantics in controlling the transitions in intraverbal frames is offered by Pinker (1989, p. 48). Only the fourth example, below, sounds odd.

John sent a package to the boarder.
John sent a package to the border.
John sent the boarder a package.
John sent the border a package.

Pinker notes that in the "double-object" form of the dative in which the preposition *to* is omitted, the indirect object must come into possession of the item, not just be the goal to which it is delivered. The other form of the dative is more permissive. This subtle semantic distinction appears to be sufficient to differentiate the last two examples. Note that, because the respective indirect objects are homophones, the semantic content is determined by the setting; thus our grammatical intuitions are controlled by context, not just by the syntactic structure of the strings. Verbs cluster in groups according to such pragmatic matters, and membership in these clusters predicts the rules of their use.

Delayed auditory feedback studies. Evidence from auditory feedback studies supports the proposal that the responses evoked by the speaker's own verbal behavior are important in the stimulus control of subsequent verbal responses. When subjects listening to their own speech through speakers or head-

phones hear the signal briefly delayed, speech is greatly disrupted, if not prevented entirely (e.g., Fabbro & Daro, 1995). Speech is disrupted even if the delayed signal consists of nonspeech sounds, such as a buzzing noise, suggesting a role for prosodic control of speech (Howell & Powell, 1987). Unfortunately, most studies of delayed auditory feedback obtain experimental control over the verbal behavior of their subjects by requiring them to read lists of words or recite well-practiced intraverbal chains. Thus the data bear only indirectly on the moment-to-moment stimulus control of intraverbal frames.

Compound Noun Formation

Our third puzzle, that of explaining the formation of novel compound nouns, also appears to involve an intraverbal frame. In our examples, each response was an instance of the frame, *X-eater*, where *X* is provided by the context and is presumably at least partly under echoic control. However, the echoic control is modified by grammatical considerations: irregular plurals are echoed intact (*mice-eater*), but the regular plural nouns appear in the intraverbal frame only in their singular form (*rat-eater*).

Skinner has suggested that, in behavioral terms, regular plural nouns, when "used to describe the world," can be seen as the conjunction of two tacts, one of which is under control of an object or feature or state of affairs and the other of which, the ending *-s*, is a minimal tact under control of the property of plurality. In the present context, neither the object (say, a rat) nor its plurality is present as a controlling variable, so the tact relation is presumably not relevant. True, hearing *rats* may evoke behavior that serves as a controlling variable for the tact *rats*, but there is no apparent reason why such behavior should vary with the regularity of plurals. However, echoic control alone is not adequate to explain the behavior, because the only relevant variable in echoic control is response topography.

It is easy to underestimate the complexity of the behavior in question. It is clearly not a simple discriminated operant: It is a rare child who has been asked to emit such a response before under those conditions.

Rather, the response has the hallmarks of problem solving. That is, the experimenter's question sets the occasion on which a particular response will be reinforced, but the target response is not in the subject's repertoire as a discriminated operant under those conditions. In general, when we are faced with a problem, we must engage in collateral behavior to supplement the stimulus control of the context. The target response is a product of the joint control of the context, the statement of the problem, and the stimuli generated by collateral behavior (see Donahoe & Palmer, 1994, pp. 270-295, for an elaboration of these points). It is likely that some collateral behavior occurs in the task under study, but it is unclear what that behavior is or why it controls the target response in the systematic way that it does.

In the present context, the behavior of the experimenter in modeling the formation of compound nouns must not be overlooked. In the absence of the modeling we might expect children to respond to a puppet that *eats mice* with, say, *cat* rather than *mice-eater*. But even the simplest examples of following a model require a complex interpretation. Typically, the reinforcer in modeling is not primarily social but is "automatic." That is, the subject is reinforced directly by evidence that his or her behavior is like that of the model; social approval is not always necessary. In verbal behavior this is especially important, because children typically are effective listeners before they are skilled speakers. That is, they respond appropriately to verbal constructions that are not in their repertoire as speakers. To the extent that children possess a repertoire of listener behavior, and to the extent to which children find the parity of their verbal behavior with that of their community to be reinforcing, shaping of their speech can be automatic (Palmer, 1996). Under such conditions, shaping of verbal behavior occurs continuously and automatically, every time the child speaks; the verbal community does not need to arrange explicit contingencies to teach every verbal distinction. This may explain the rapid acquisition of an orderly verbal repertoire in children in the face of surprising indifference by adults to the grammatical errors in their speech (Brown & Hanlon,

1970). This is not to deny the powerful contingencies in parent-child verbal relationships (Moerk, 1983), but merely acknowledges that such interactions seem insufficient to account for all of the subtle properties of verbal behavior.

I make a distinction here between reinforcement by the stimulus properties of a child's speech and reinforcement by parity of his or her speech with that of the verbal community. As Sundberg et al. (1996) have shown, verbal stimuli that arise from one's own speech can serve a reinforcing function if they have been established as conditioned reinforcers by pairing with other reinforcers. Thus a child might say *Good boy* because the phrase has already been established as a conditioned reinforcer, and uttering the phrase produces the reinforcing stimulus. Reinforcement by parity is an entirely different matter. A child might practice *Disgusting boy!* even though it is a conditioned punisher, because he or she is approximating the behavior of a respected model. That is, it is not the stimuli themselves that are reinforcing but the parity that is reinforcing.

The following demonstration illustrates the process of shaping by parity: I programmed the keys on a computer keyboard to play tones of different frequencies when pressed. There was no orderly relationship between frequency and key position. A woman was asked to play the tune, *Mary Had a Little Lamb*. Notice that the tune was in her repertoire as a listener; that is, she could identify it when she heard it, she could complete a musical phrase if it were interrupted, and so on. But, owing to the unsystematic relationship between keys and tones, the motor task was not in her repertoire; the performance had to be shaped. She entered the following characters; the italicized characters produced the tune correctly, with one error:

JKHGFL;HGGFDSRNGFDYDFGHJKLHGFDLK
HFD*FHHHFFHLK*KHFD*FHHHFFHFD*

Shaping was accomplished solely by her motor behavior producing stimuli that corresponded to a pattern that was familiar to her. Parity was established as a reinforcer by the demands of the task; it was evident that the tune itself was not a powerful reinforcer to her.

In order to assess the role of modeling in the formation of compound nouns, I replicated Gordon's (1986) procedure, with modifications, with a child who was 3 years 11 months old. At every opportunity I praised the child's performance, but I modeled behavior that differed from hers:

This is a monster that eats mud. He is a mud-eater.
This monster eats mice. He must be a -
A mice-eater.
That's right. He's a mice-eater. Now this monster over here eats books. He's a -
Book-eater.
Yes. That's right, he's a books-eater. This monster over here eats chipmunks. He must be -
A chipmunk-eater.
Right. He's a chipmunks-eater. This one eats marbles -
He's a marble-eater.
Yes. He's a marbles-eater. How about this one. He eats candles. He's a -
A candles-eater.
Right. He's a candle-eater. This one eats spiders. What's he?
A spiders-eater.
Good. He's a spider-eater. Now ...
You say "spider-eater" but I say "spiders-eater!"

This demonstration draws our attention to several facts. First, the expressions *good*, *right*, and *yes* had no apparent reinforcing effect on the particular form of the child's verbal behavior in this context. This is important only in reference to simple-minded criticisms of behaviorism that assume that only such gross interventions are reinforcing. Certainly under other motivational conditions, these expressions might be powerful reinforcers indeed, but here they serve merely as a social grace, and the child appears to respond to them as such.

Second, when I modeled a particular construction, the child's behavior eventually conformed to that construction, attaining parity, and was presumably reinforced by doing so. Third, the child modeled the behavior productively; that is, she did not repeat the examples presented to her; rather, she extended the pattern to novel examples.

Lost in the child's history are the variables that controlled her responses *book-eater* and *mice-eater*, but we can speculate that exposure to examples of *books-eater*, and so on, established a new intraverbal frame, *Xs-eater*, in her repertoire as a listener. Reinforcement by parity was sufficient to establish it, at least in the narrow context of this demonstration experiment.

This account is speculative, and, worse, it is not entirely adequate. It does not explain the baseline difference between irregular and regular plurals, for example. However, the demonstration shows that this difference is not immutable; moreover, it suggests that the origins of the difference lie in the types of variables considered here. Children are sensitive to discrepancies between their verbal behavior and that of the verbal community, not just in vocabulary and pronunciation, but in intraverbal frames and relational autoclitics, and achieving parity with the adult community in this regard is reinforcing. We can speculate about variables in the child's history that might have controlled her baseline performance. Such variables, however remote, at least have the virtue of being real. Given the speed with which the altered repertoire was acquired in the present demonstration, all talk of the "structure of the mental dictionary," "innate constraints," and so on, seems, to put it politely, premature.

CONCLUSION

Behaviorism is distinguished by a taste for operational definitions, observable measures, reliable data, and tight experimental control. We take pride in these features of our paradigm, and rightly so. However large the gap between what we know and what we would like to know, behavior analysis offers science's most complete explanation for behavioral complexity in nature, because the terms of its explanation are firmly rooted in the embracing field of biology and, by extension, all natural science. It may appear that I have cut myself off from this scientific bedrock, for I have indulged freely in speculation, anecdotal data, and inferences about unobservable behavior, and have barely alluded to controlled experiments. I would be chagrined by these considerations if I did not believe that complex verbal phenomena represent one of our most formidable challenges. At this stage of our understanding, we are like evolutionary biologists speculating about detailed mimicry in butterflies. Hard facts are elusive, but offering interpretations that exploit only familiar principles can serve to bring the unfathomable into the

domain of the merely marvelous. Behavioral interpretations of complexity need not be correct in every detail; they serve us well if they show that our conceptual tools are adequate to resolve the most formidable problems encountered in the field of interest.

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