The Role of Establishing Basic Skill Sets in Generating Novel Responding

A Conceptual Analysis

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(Note to self)

- Higher-order units can become units themselves: much of our motor behavior has become integrated into units (reaching, throwing, jumping, speaking)

Goals

- A) To understand the two origins of adaptive behavior
  - 1) Repeated cycles of variation and selection
    - Innate (Natural Selection)
    - Acquired (Shaping) [Historically over-emphasized]
  - 2) Instructed behavior (one-trial learning)

  - Note that this is not the usual distinction between learned and innate behavior

Goals (cont'd.)

- B) To understand the constraints in each case
  - 1) Innate behavior (Why don't chickens have arms?)
    - Genetic variation (cf: recurrent laryngeal nerve)
  - 2) Shaped behavior (Why can't I dance Swan Lake?)
    - Behavioral variation
  - 3) Instructed behavior (Why can't I read novels in Russian?)
    - "atomic" repertoires – the classes of basic skills
    - Note to self: emphasize that it's not the skill, it's the skill under control of a discrete antecedent.

- This talk is mostly about Item B3: An inventory of the types of instructed behavior, the prerequisites for them, and the implications for training.
- But they should be seen in light of a general principle that provides a comprehensive and parsimonious understanding of behavior.
- It is this that distinguishes behavior analysis from other disciplines.

- An inescapable fact: All adaptive behavior ultimately arises from trial and error
  - Imagine waking up on a distant planet where nothing works the way it does on earth. Your accumulated knowledge would be useless. Analyzing the structure of the world around you would be useless. Reasoning would be useless. Only through trial and error could you learn anything useful.
- Evolution and shaping both exploit this fact and are therefore powerful explanations of complexity in behavior.

The power of selection processes to produce complexity

- A computer simulation:
  - Words: Can monkeys, given time, write Hamlet?
  - DNA bases: Can monkeys, given time, sequence your DNA?
- Take-home point: Selection processes have nearly unlimited power to produce complexity.

If

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people

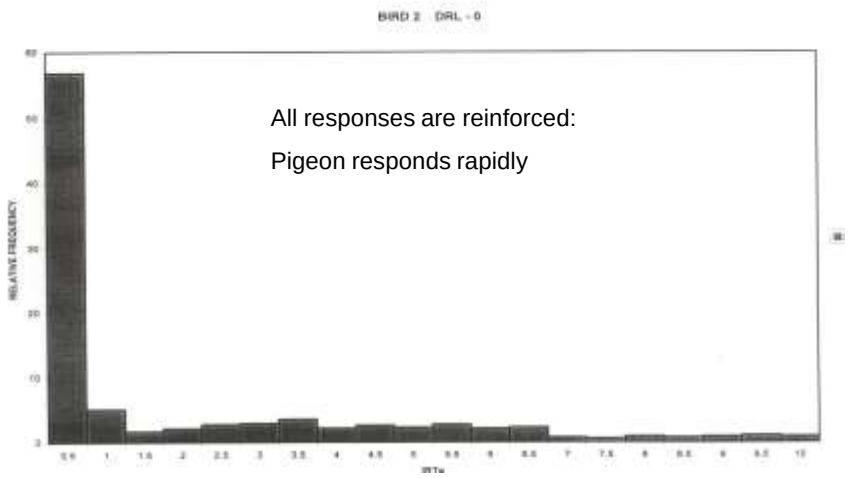
wrote one 50-character sentence every second since the dawn of the universe, they would just now be exhausting all the possible permutations.

This illustrates the relative power of variation and selection as an explanation of adaptive complexity.

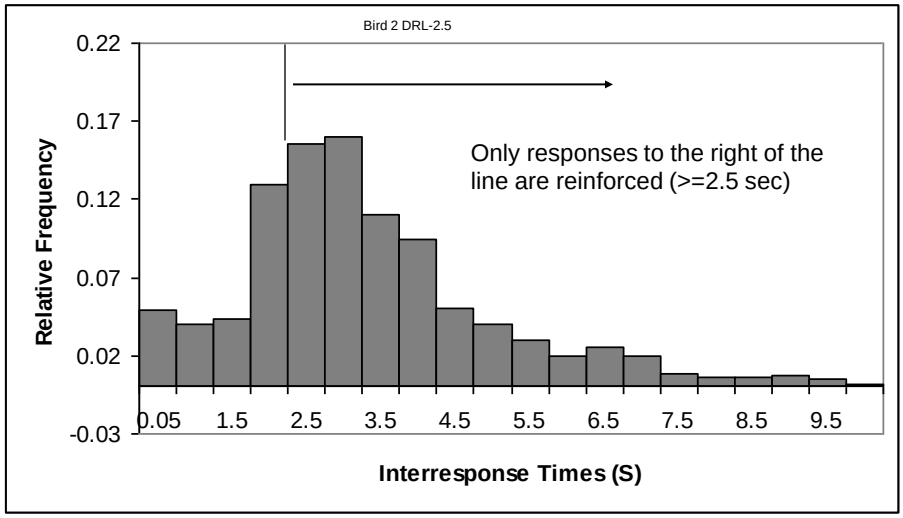
Individual Adaptive Behavior Arising from Cycles of Variation & Selection

- Shaping
  - Behavior varies, but it has some typical value (an “average”).
  - When one variant is reinforced, it becomes more common. It becomes the new typical value.
  - When a new variant is reinforced, that becomes the new typical value.
  - By gradually changing the reinforcement criterion, behavior can move to more and more unusual values.
- Examples:
  - Pigeon DRL example
  - Rat progressive force example
  - Video examples

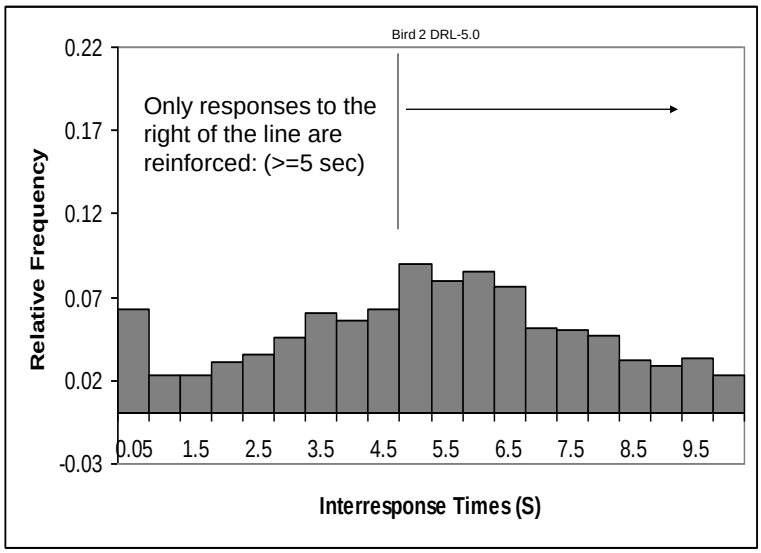
Reinforcement as a selection process: Note variability in behavior



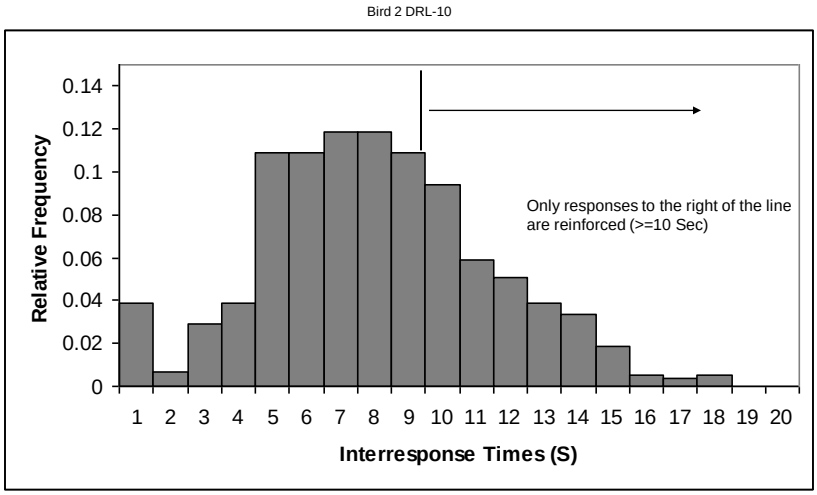
Effect of differential reinforcement on distribution DRL-2.5S



Further shift to DRL-5



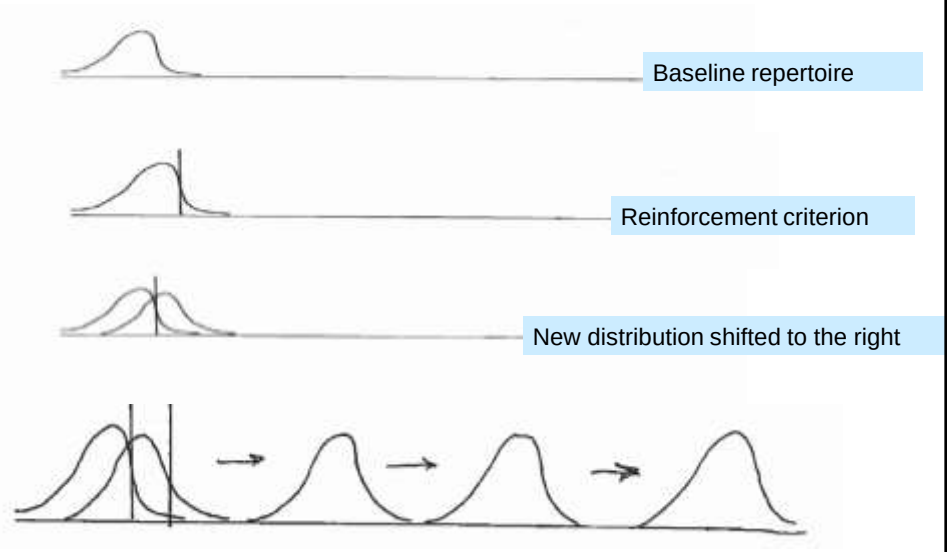
Shift to DRL-10



More examples of shaping

- "Stretching the ratio"
- Rat as body-builder
- (video examples)

Shaping: a schematic representation



Over (perhaps many) successive cycles, distribution may be far removed from the baseline distribution.

The appeal of shaping and natural selection as explanations of behavior

- Adequacy, simplicity, and extraordinarypower

- But….

Most human behavior is not shaped

- In principle, we could shape the behavior of a feral child so that he or she writes Hamlet:

BARNARDO: Who's there?
FRANCISCO: Nay, answer me. Stand and unfold yourself.

But it would take (almost) forever.

Human behavior is distinctive in that adaptive behavior often occurs in a single trial in the absence of shaping.

(If all novel behavior could be shown to derive from shaping, everyone would be a behaviorist!)

Contingency-shaped vs. Rule-governed Behavior

- In 1966, Skinner distinguished between behavior that is shaped through successive approximations to a target behavior and behavior that is instructed.
- A "rule" is a verbal statement that directly evokes adaptive behavior in some context:
  - "Grip the handles together and pull on the cord to start the lawnmower"
  - "Hit CTL-ALT-DEL to get to the password page"
  - "First remove the frame of the air-conditioner and place it in the open window."
  - "Shake your cell phone if you want to turn it into a camera."
- Often the behavior occurs correctly on the very first occasion.
- If reinforcement follows, the context will tend to exert some control over the behavior, even in the absence of the rule. That is, initially the behavior requires an instructor, but eventually the behavior can transfer to the natural context.

- Rule-governed behavior "short-circuits" the long and difficult process of shaping, and as a consequence, its importance in human affairs is incalculable.
  - It requires a rich repertoire of elementary responses, each under control of a verbal antecedent
    - ("grip the handles," "pull the cord," "remove the frame," etc.)
  - The verbal instructions bring the behavior out in special permutations.
  - It is our first example of the permutations of an atomic repertoire.

Schematic representation of one-trial learning:
Big leaps in topographical variation in a single step.
Shaping is “short-circuited.”

- In both natural selection and shaping, new variations emerge as slight modifications of existing forms.
- In instructed behavior, new variations leap across organisms.
  - The “teacher” learns slowly through trial and error
  - The “student” learns from the teacher in a single trial
- Analogy: Want your child to look like Brad Pitt? Don’t wait for natural variation; just move some DNA bases around.
- The behavioral “trick” is that elementary units of behavior can be arranged in any permutation, provided each is evoked by a distinctive stimulus.

- A non-human example (video)

A fundamental economy: Exploiting the power of permutations

- As in the case of rule-governed behavior, much human behavior is a permutation of pre-existing building blocks. The building blocks must be either shaped or inherited, but once in the repertoire can be combined to create new behavior very quickly.
- This is a fundamental economy that nature has exploited at every level of complexity.

The power of permutations: Analogy of the atom

- Atoms are the building blocks of nature. A few dozen types of atoms can be combined in endless permutations to generate all of the fantastic variety of the universe around us.
- Quartz: SiO_2
- Feldspar: $KAlSi_3O_8$
- Calcite: $CaCO_3$
- Bone: $Ca_{10}(PO_4)_6(OH)_2$
- Haemoglobin: $C_{2952}\ H_{4664}\ O_{832}\ N_{812}\ S_8\ Fe_4$

DNA & RNA exploit just four elements

- Adenine: $C_5H_5N_5$
- Guanine: $C_5H_5N_5O$
- Cytosine: $C_4H_5N_3O$
- Thymine: $C_5H_6N_2O_2$
- Uracil: $C_4H_4N_2O_2$

- C, H, N, & O are the building blocks of DNA.
- DNA builds RNA which builds amino acids.
- Amino acids are the building blocks of proteins.
- Proteins are the building blocks of our bodies.

- Protein synthesis is “instructed” permutation

Amino Acid	RNA codons
Isoleucine	AUU, AUC, AUA
Leucine	CUU, CUC, CUA, CUG, UUA, UUG
Valine	GUU, GUC, GUA, GUG
Phenylalanine	UUU, UUC
Methionine	AUG
Cysteine	UGU, UGC
Alanine	GCU, GCC, GCA, GCG
Glycine	GGU, GGC, GGA, GGG
Proline	CCU, CCC, CCA, CCG
Threonine	ACU, ACC, ACA, ACG
Serine	UCU, UCC, UCA, UCG, AGU, AGC
Tyrosine	UAU, UAC
Tryptophan	UGG
Glutamine	CAA, CAG
Asparagine	AAU, AAC
Histidine	CAU, CAC
Glutamic acid	GAA, GAG
Aspartic acid	GAU, GAC
Lysine	AAA, AAG
Arginine	CGU, CGC, CGA, CGG, AGA, AGG
Stop codons	UAA, UAG, UGA

- Again and again, we see that nature exploits nested examples of building blocks. Complex things are built up from a relatively small set of simple parts.
- Much complex human behavior is built up from a relatively small set of behavioral "atoms" (Skinner, 1948).
- And as in the case of elementary particles, elementary units can be combined into larger units that then can serve as elements of still larger units.

"Atomic Repertoire" defined

- Elementary units of behavior, each under control of discrete stimuli that can be arranged in virtually any permutation to induce corresponding novel permutations of behavior on a single trial (or a few).

Atomic repertoire

- $S^D_1 \longrightarrow R_1$
- $S^D_2 \longrightarrow R_2$
- $S^D_3 \longrightarrow R_3$
- .
- .
- $S^D_{10} \longrightarrow R_{10}$
- .
- .
- .
- $S^D_N \longrightarrow R_N$

Legend
S^D = "discriminative stimulus" (a signal to do something)
R = "response" (a coherent unit of behavior)

Example: Dial 658-7214

S^D	R
6	Press 6
5	Press 5
8	Press 8
7	Press 7
2	Press 2
1	Press 1
4	Press 4

Compare with chaining

- “Dialing home” [for a disabled child] is a classic classroom example of a task for which backward chaining is appropriate:
  - Dial 4
  - Dial 14
  - Dial 214
  - Dial 7214, etc.
  - Each new element becomes the occasion that evokes the subsequent element.

- Each response sets the occasion for a familiar and well-practiced behavior, which is followed by a natural reinforcer.
  - Compare with forward chaining.
  - Note that in either case, individual responses are probably modeled or instructed, not shaped.

- But teaching the atomic repertoire would be far more versatile (provided that the textual stimulus were always available)

Novel permutation of S^Ds

S^D_{17}, S^D_4, S^D_{121}, S^D_{62}

R_{17}, R_4, R_{121}, R_{62}

Novel permutation of Rs

(e.g.,10,000,000 7-digit phone numbers with just 10 atomic responses
cf: 22 amino acids and 4 RNA bases)

Transcription

(copying text, taking dictation, etc.)

S^D	R
A	"A"
B	"B"
C	"C"
"big"	"big"
Etc.	

Given a repertoire of a few dozen characters, a person with a transcriptive repertoire can copy an infinite number of novel texts on the first try (possibly without error)!

Taking dictation requires much more training. The "economics" are different, but the principle is the same. (Dictating to one's self is an especially complex case.)

- 1) Selecting phone keys under control of written or spoken numerals
  - 10 atomic responses.
- 2) Writing letters (or selecting them from a keyboard) under control of written, printed, or spoken letters (or words, etc.)
  - 26 atomic responses.
- These two very elementary repertoires yield an unlimited number of potentially adaptive permutations of behavior.

- (Selection-based vs. topography-based responding differ, but those differences can be ignored in the present discussion. And both can be considered transcription for present purposes.)

Echoic Behavior

S^D	R
"ah"	"ah"
"ee"	"ee"
"ba"	"ba"
Etc.	

- Children with normal hearing typically learn to faithfully imitate speech sounds and can soon echo syllables, words, phrases, etc.
- But the repertoire is limited to sounds similar to those in their own language.

Implications

- 1) Novel forms can be acquired immediately and spread widely.
- 2) Echoic behavior facilitates conformity of pronunciation within a culture.
- 3) Echoic behavior can be automatically reinforced (assuming normal hearing).
- 4) Echoic behavior (covert or otherwise) transduces auditory stimuli into motor responses. This permits almost automatic "transfer of knowledge."
  - I say, "Bobby Fischer died in Iceland." Provided you were covertly echoing what I said, you now know that fact, at least for a while.

- [Prosody?]

Textual behavior

(Reading, out loud or silently)

S^D	R
a	"ay"
e	"ee"
ba	"ba"
hot	"hot"

S^D : pseudohypoparathyroidism

R: "pseudo…hypo…para..thyroid…ism"

Etc.

Implications

1) Like an echoic repertoire, a textual repertoire can transduce text into motor behavior, more or less immediately, with the added advantage that time is not a constraint. Textual stimuli can affect behavior for thousands of years.

2) Like transcription and echoic behavior, textual behavior can be emitted with no understanding of what is being said. We can faithfully transmit coded messages, sheer gibberish, or even sound out (or spell out) phrases in foreign languages that use a common alphabet.

3) Permits rapid transmission of cultural practices.

Imitation

S^D	R
I clap	You clap
I wave	You wave
I lift my left arm	You lift your right arm
I make the sign for ‘play’	You make the sign for ‘play’
Etc.	

Implications

- Rapid transmission of adaptive behavior
- Need not require language
- Transmission need not be “intentional”

Rule-governed behavior (again)

- Motor behavior under verbal control.

S^D	R
"Add 2 c. flour, sifted"	[corresponds]
"Insert #10 screw into pilot hole"	
"Knit two, purl two"	
Etc.	

Can vary across any topography and can ultimately be of almost any size.

Implications

- Transmission over great time periods and varied contexts ("Thou shalt not steal")
- Can be memorized as verbal behavior and used to control one's own behavior ("Turn right at the Mobil station.")
- No connection between magnitude of stimulus and amplitude of response. ("Build a wall along the border.")

Descriptions (tacting)

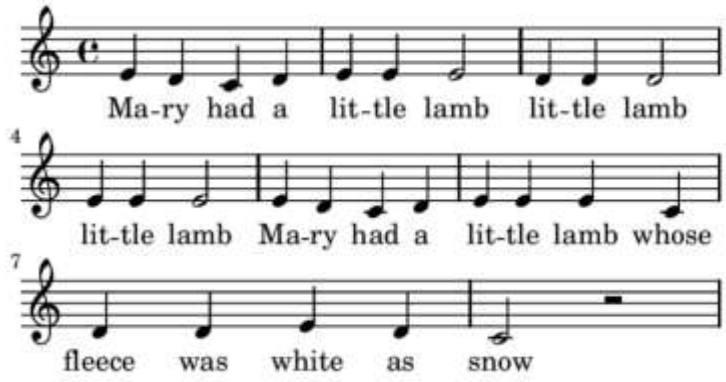
S^D	R
chair	"chair"
box	"box"
bird	"bird"
bird	"small"
bird	"Catharus *guttatus*"

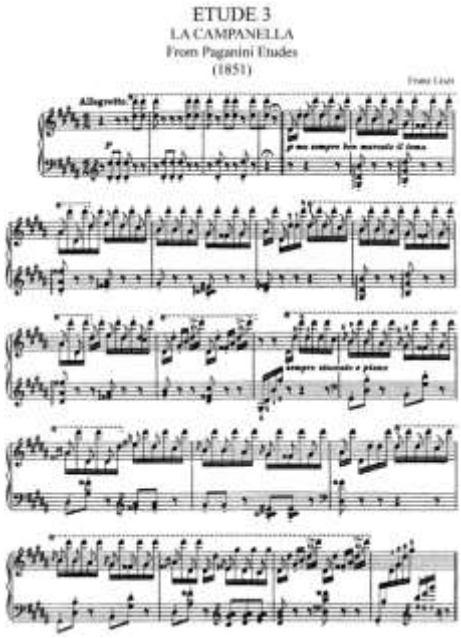
Implications

- Usually acquired for benefit of listener. Permits effective action in listener even though separated by time and space.
- Can be combined into descriptions of any level of complexity and detail.
- Idiosyncratic – depends on history.

Miscellaneous examples

- Reading musical scores
- Playing a tune by ear
- Painting by numbers
- Morse code
- Semaphore
- Traffic lights
- Smoke signals
- Computer code





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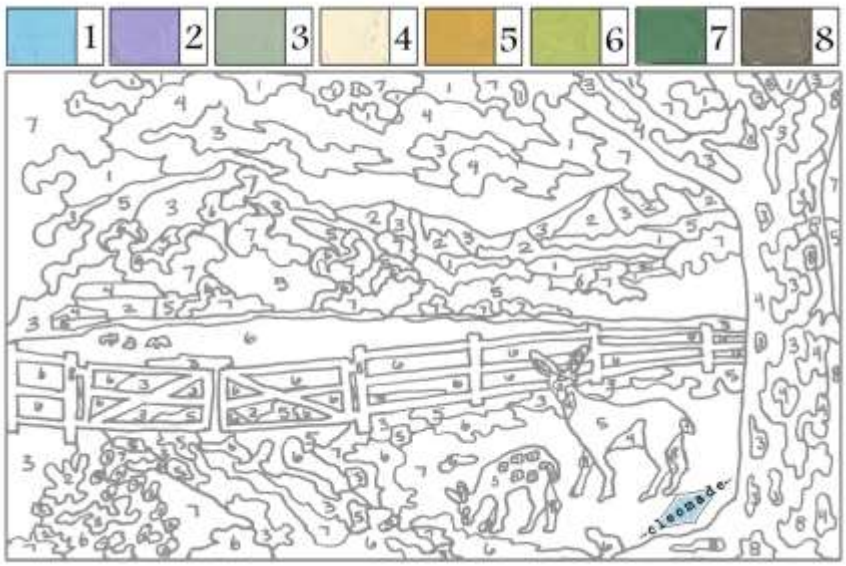

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Not Rembrandt, but a big leap from baseline behavior

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- For adaptive behavior to occur in a single trial, all that is required is someone who already knows how the world works to arrange the S^Ds in the appropriate configuration.
- In all cases of atomic repertoires, variability in behavior is a simple function of variability in controlling stimuli. (Directed variation vs. random variation.)
- Such behavior should be viewed as a way of explaining response variability in the context of selection contingencies. It "short-circuits" the shaping process.
- A consideration of atomic repertoires is uniquely useful for interpreting certain cases of complex behavior, such as delayed observational learning.

Origins of atomic repertoires*

- Incidental learning
  - Imitation
  - Echoic behavior
  - Tacting

  Imitation and Echoic behavior: Can occur in some other species

  Tacting: Unique to humans

- Systematic instruction
  - Transcription
  - Textual behavior
  - Rule-governed behavior

  Transcription and Textual behavior: Schooling

  Rule-governed behavior: Ubiquitous

*Typical origins: Categories are not rigid

The role of automatic reinforcement in atomic repertoires

- Babies are born ignorant. The surest way to a happy result is to do what their elders do.
- The result: Evidence of “matching” becomes a reinforcer.
- Permits the automatic shaping of behavior.
  - Metaphor of the xylophone: Matching is automatically reinforced.
  - Must have the relevant “receptive” repertoire first.
- Relevant to imitation, pronunciation, grammar, spelling, reading, tacting, recall, etc.
- Atomic units can emerge directly or as the common components of larger units.

Paradigmatic example: "Generalized Imitation"

- Baer & Sherman, 1964, coined the term to cover the following observation:
  - When a variety of imitative responses are directly trained, some untrained imitative responses, of different topography, can occur as well.

- Note that this is an observation, not an explanation. <u>But it is widely accepted as an explanation</u>
  - If we could show that training a certain number of exemplars of imitative behavior, or that training such exemplars to a certain criterion of success, invariably led to generalized imitation, then it would stand as an inductive principle, but this is not the case.
- Limits: we can only imitate behavior for which we have the requisite atomic units
- Even so, a complex sequence may need to be gradually built up of these atomic units (picking out a tune on a piano).

Baer & Sherman, 1964

"The increase in imitative bar-pressing was taken to indicate that a generalized similarity of responding between puppet and child could be a reinforcing stimulus dimension in the child's behavior."

Baer & Deguchi, 1986

Proposed that "similarity" becomes a conditioned reinforcer and *shapes up* imitative behavior. (I have called it *achieving parity.*)

- Example: If you play a few notes on a piano and give a child a xylophone, he can eventually pick out the tune. The term "eventually" is revealing: Generalized imitation is a process not a leap.

- This suggests that imitation does not just "happen;" it emerges through successive approximations. It is a process, not a unit of behavior.
- Like all shaping, the initial repertoire, step sizes, and discriminability of relevant variables are important, and this is what explains variability in generalized imitation.
- But the notion of "generalization" is no longer relevant. Behavior does not spontaneously leap across wide topographical discontinuities. It appears to do so only because we have not looked for "mediating" events.

Variables that affect instructed behavior

The grain of atomic repertoires

The fundamental unit: $S^D \longrightarrow R$

- The *grain*: How precisely does the discriminative stimulus constrain the topography of the response?
- Some atomic repertoires permit great variability, others very little

Great variability (atomic repertoire is crude)

Imitation
Rule-governed behavior
Tacting

Little variability (atomic repertoire is precise)

Echoic responses
Transcription
Textual responses

(Also, reading musical scores, playing a tune by ear, etc.)

- Note difference in grain between signing and speech (imitation/rule governance vs. echoic)

The role of multiple control in atomic repertoires

- The grain of an atomic repertoire can be crude when behavior is multiply controlled.

"Grab the handle and pull up."

Vs.

"Whistle this tune."

- That is, often contingencies of reinforcement can be satisfied, even if atomic repertoire is crude.

"Pick up the pencil"

Versus

"Move your hand forward 13.7 inches; lower it 4.3 inches; move your index finger toward your thumb 0.48 inches….. etc."

"Pick up the pencil"

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- As a consequence, imitative, rule-governed behavior, and tacting tends to be crude. We can't execute them precisely, because the contingencies have never demanded tight stimulus control.

Observational learning

- Delayed observational learning is a formidable puzzle for behavior science: What exactly is it that controls the target behavior at the moment it occurs?
  - Scenario 1: I see a man open a door, rummage around, and emerge with a hammer. The next day, when I need a hammer, I go to the door, open it, and find the hammer.
  - Scenario 2: I see a man pick up an oboe and play a haunting tune. The next day, when someone ask for a haunting tune, I pick up the oboe, but I am unable to play a haunting tune.
- Psychology tends to emphasize our successes, without attending to our failures.

An interpretation of observational learning

1) At the moment of observation, the observer engages in tacting, imitative behavior, echoic behavior, textual behavior, or some other atomic responses (perhaps covert) under control of the model.
   (This solves the problem of the 'first instance.' The target behavior does not appear spontaneously in the observer's repertoire. It has occurred before—at the time of observation.)
2) The atomic behavior must be reinforced at that moment.
3) The behavior is then under control of some critical features of the context
4) At a later time, when those critical features recur, the behavior comes to strength.

Demonstrations

- 1) "What's the capital of X?"
  - Distinction between those who engage in atomic responses and those who don't
- 2) Cyrillic text example

  подчеркну некоторые важные его особенности, которые чаще всего игнорируются или неправильно понимаются. Я покажу не только то, что популярная
  - Distinction between presence and absence of relevant atomic repertoire
- 3) Ballet example
  - Difference in grain of atomic repertoires
- 4) Imitation example
  - Interplay of two atomic repertoires

Relevance to generalized operants

- Directed variation permits large jumps in response topography.
- We acquire generalized operants only to the extent that we have the relevant atomic repertoire.
  - Imitation (imitating a cook vs. e.g. an artist, acrobat, musician)
  - Echoic (Mandarin)
  - Textual & Transcriptive behavior (Russian)
  - Rule-governed behavior (Ballet, gymnast, military cadet)
  - Tacting (Same)
  - Identity matching (art expert)

Implications for training

- Inventory the responses of the child in each atomic repertoire at a level appropriate to the functioning of the child.
    - Motor deficits implicate imitative, transcriptive, and rule-governed repertoires.
    - Articulatory deficits implicate echoic responses
    - Intellectual deficits implicate textual responses
  - In each case the problem may lie partly in a failure of automatic reinforcement.
    - Is “matching” an automatic reinforcer? If not, why not? Can it be made to be an automatic reinforcer?
    - Are competing reinforcers simply more powerful? Can automatic reinforcers be supplemented?

Implications for training

- For “missing” responses, are they typically acquired through instruction or incidental contingencies?
  - If instructed, the problem is fairly clear: contingencies have either been missing or ineffective
  - If incidental, one must look for reasons that automatic reinforcers are not in effect for the child. If this can be fixed, there will be a great economy.

Limitations and risks

- Atomic repertoires are useless if there is no “instructor” to arrange cues.
  - May be textual
  - May be oneself
- Can limit variability
  - “I never learned this”
  - Inappropriate persistence when contingencies change

Conclusion

- Three types of behavior:
  - Innate
  - Shaped
  - Instructed
- Understanding their separate roles and domains is a prerequisite for effective analysis and intervention.