The Role of Automatic Reinforcement in Shaping Speech

David C. Palmer
Smith College

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Overview

- Language acquisition; nature of the problem:
    - Neither genes nor environment seems to be adequate
- Explanation: “Automatic” reinforcement
- Types of automatic reinforcement and their roles
    - Unconditioned – role in babbling
    - Conditioned – preference for familiar sounds
    - Reinforcement by matching – shaping of verbal conventions
- Empirical work
- Comparison of various “pairing procedures” to establish speech sounds as reinforcers for children who vocalize at very low rates.
- Automatic reinforcement in other domains

Nature of the problem

(1) Parents provide little explicit language instruction to kids.

(2) Children's behavior is sensitive to very subtle rules, rules that their parents are not even aware of.

How can children learn complicated behavior without being taught?

(1) Brown & Hanlon (1970)

- Parents tend to explicitly correct errors of fact, not errors of grammar.

- “Mommy not a boy, he a girl.”
  - [Parents gush]
- “Walt Disney comes on Sunday.”
  - [Parents correct: “No, no. Walt Disney is on Tuesday.”]

Ernst Möerk's Reanalysis of data

- Showed that parent-child interactions were actually loaded with natural contingencies of reinforcement.
- But fine-grained shaping of grammar was still a mystery.
- This is a formidable problem for an empirical theory of how language is acquired and used.

(2) Language appears to be rule-governed, but the rules seem to be extremely subtle.

- Examples of puzzling grammatical distinctions in English (derived from Steven Pinker, 1994)
  - I gave the manuscript to the library
  - I donated the manuscript to the library
  - I gave the library the manuscript
  - I donated the library the manuscript

  - The fourth sentence is “ungrammatical” in the sense that it sounds wrong to many native speakers. Why?

Another example

- We sent a package to the boarder.
- We sent a package to the border.
- We sent the boarder a package.
- We sent the border a package.

  – The fourth sentence “sounds wrong.” Why?

- It is obviously not the case that parents sit all children down and instruct them thus:

- “Now Sarah, the words ‘give,’ ‘donate,’ and ‘send’ are all in the dative case, and they can take both a direct object and an indirect object. The direct object can come in either order for ‘give,’ but for donate the direct object must come first, while for ‘send,’ the indirect object can come first provided that it is a person and not a location; otherwise the indirect object must come second.”

- Even if parents did this, kids wouldn’t pay any attention.

Possible explanations

(1) Nativism: A major theme in theories of language acquisition

- Noam Chomsky, influential, if not dominant, for 50 years:
  - Language is sophisticated, and is acquired rapidly and uniformly, despite wide differences in nurturing environment
  - The kinds of regularities one finds in language seem to be unlearnable: There just isn't enough evidence in the child's verbal environment to shape the subtleties of language.

Suggestive empirical evidence
Peter Gordon's (1986) "mud-eater" experiment

- (Adult): "This monster eats mud; he is a mud eater. What kind of monster is he?"
  - (3-yr-old child): "a mud-eater."

- Right. He eats mud; he's a mud-eater. This monster over here eats mice. He's a —
  - a mice-eater.

- Right. He's a mice-eater. This one eats books; he's a —
  - book-eater.

- Children as young as 3 drop the ‘s’ at the end of regular plurals before making a compound noun, but they happily make compound nouns out of irregular plurals.

- Gordon’s conclusion:
  - The grammar of language is innate. We don’t learn grammar: It unfolds, triggered by critical experiences. There must be an inborn “language acquisition device” that guides learning.

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)

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Problems with the theory

- The first problem with such terms isn't that they are incoherent, but that they have not been derived from an experimental science.
- They are intended to be taken as structures or features in the nervous system, but they make no reference to neurons, synapses, glial cells, blood vessels, spinal fluid, neurotransmitters, and the other elements of the nervous system.
- It is left to someone else to solve the problem of how these terms can be translated into neurological facts. (The credit card problem.)
- So it's not an explanation but a hypothesis designed to fit the facts.

More problems with the theory

- Innate behavior can be complex, but it is relatively inflexible, whereas language is extremely variable.
- The theory derives all of its force from arguing that the alternative is impossible. That's a dangerously weak argument, because it depends on one having a perfect grasp of the alternative.
- No one has any idea how such a device might actually work or how it might have evolved.
- Analogy of fielding a baseball: The child learns to speak; he doesn't learn the rules.

(2)The alternative approach

- There is no special grammar faculty.
- Grammar emerges from experience just like other complex behavior, through shaping.
- Innate contributions, apart from morphological features, might not be unique to language:
  - E.g., heightened sensitivity to social cues; ability to learn and imitate temporal patterns (prosody); ability to regulate breathing while speaking; ability to discriminate auditory matches; sensitivity to multiple control and joint control.
- Innate morphological features:
  - E.g., facile tongue and lips; elongated pharynx

Our default explanation for complex behavior is shaping.

- Shaping is a selection process like evolution.
- Conceptual models of evolution are capable, in principle, of generating any conceivable sequence of DNA bases.
  - So in principle it is an extremely powerful explanation for complexity in biological forms
- Conceptual models of shaping are capable, in principle, of generating any conceivable pattern of behavioral elements.
  - So in principle it is an extremely powerful explanation for complexity in behavior.

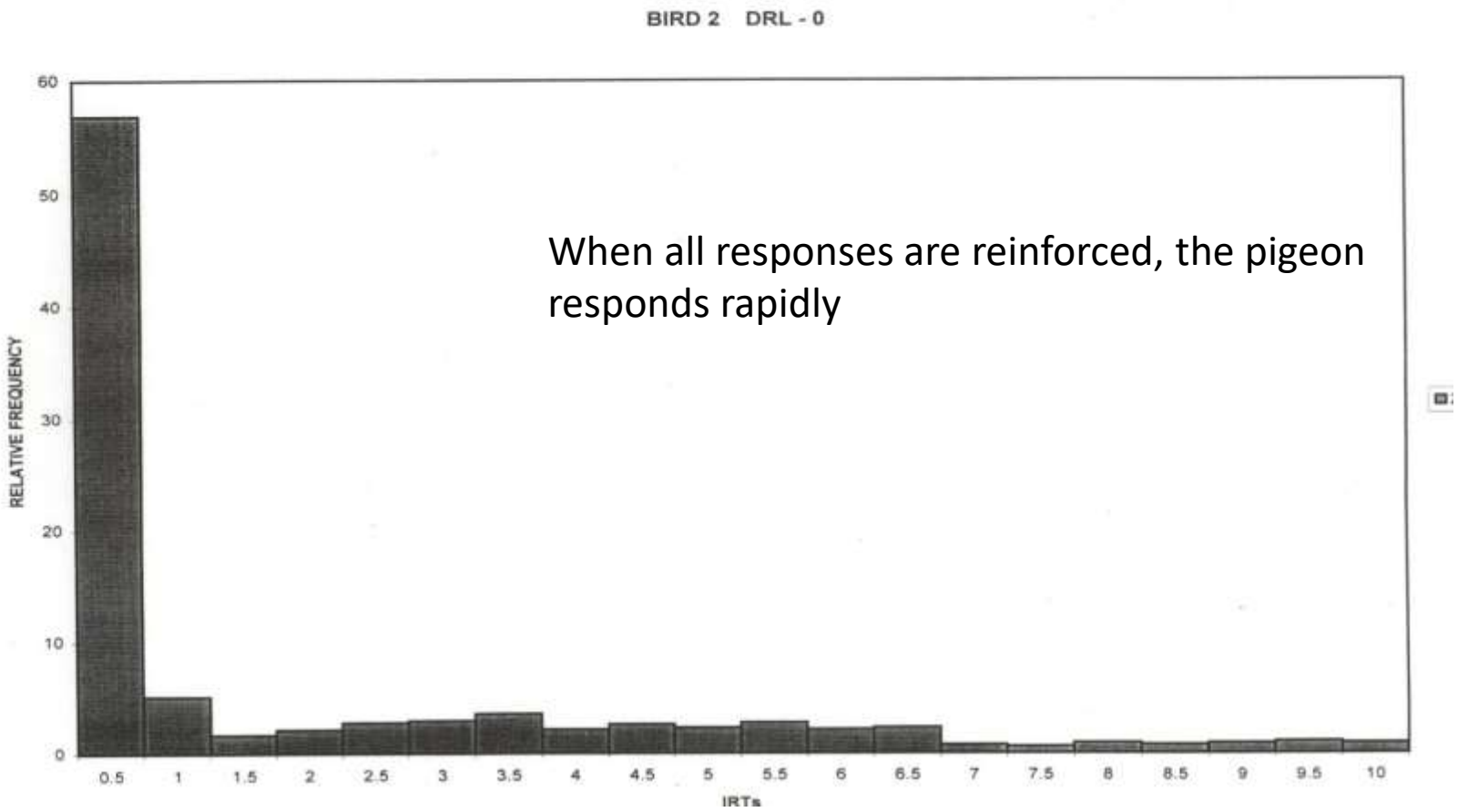
Shaping as a selection process:

- Behavior varies
- Reinforce variants that more closely approximate a target response.
- Those variants are “selected” by reinforcement (i.e., they occur more frequently)
- New variations emerge around that new value.
- Repeat, gradually moving the behavior closer and closer to a target.
  - Examples of shaping in animal behavior
  - Example: Can a pigeon be trained to pause 5 seconds between pecks?

Baseline: All pecks are reinforced

Result: Very short pauses between pecks, but note the variability

Y-axis: Proportion of total pecks

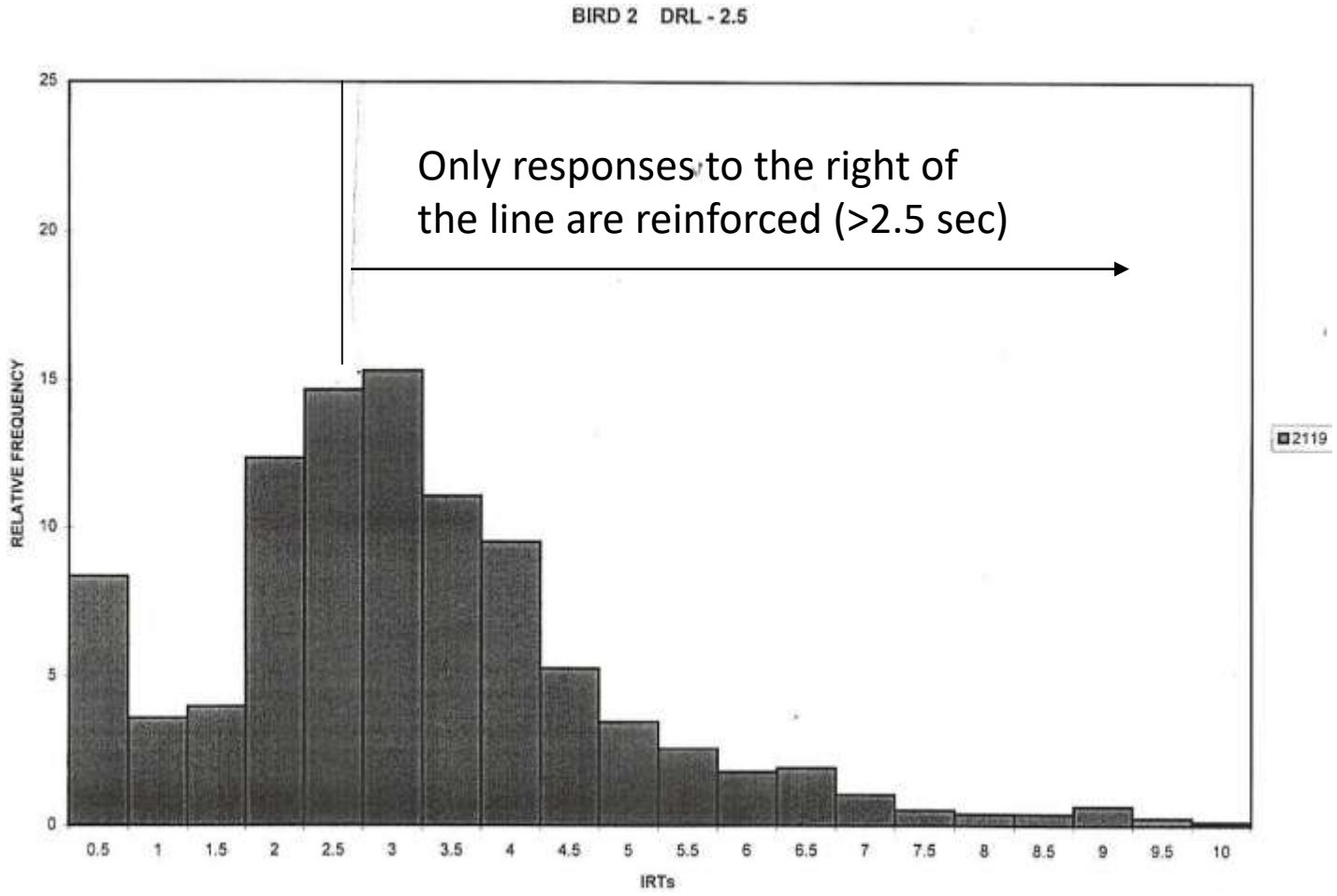


When all responses are reinforced, the pigeon responds rapidly

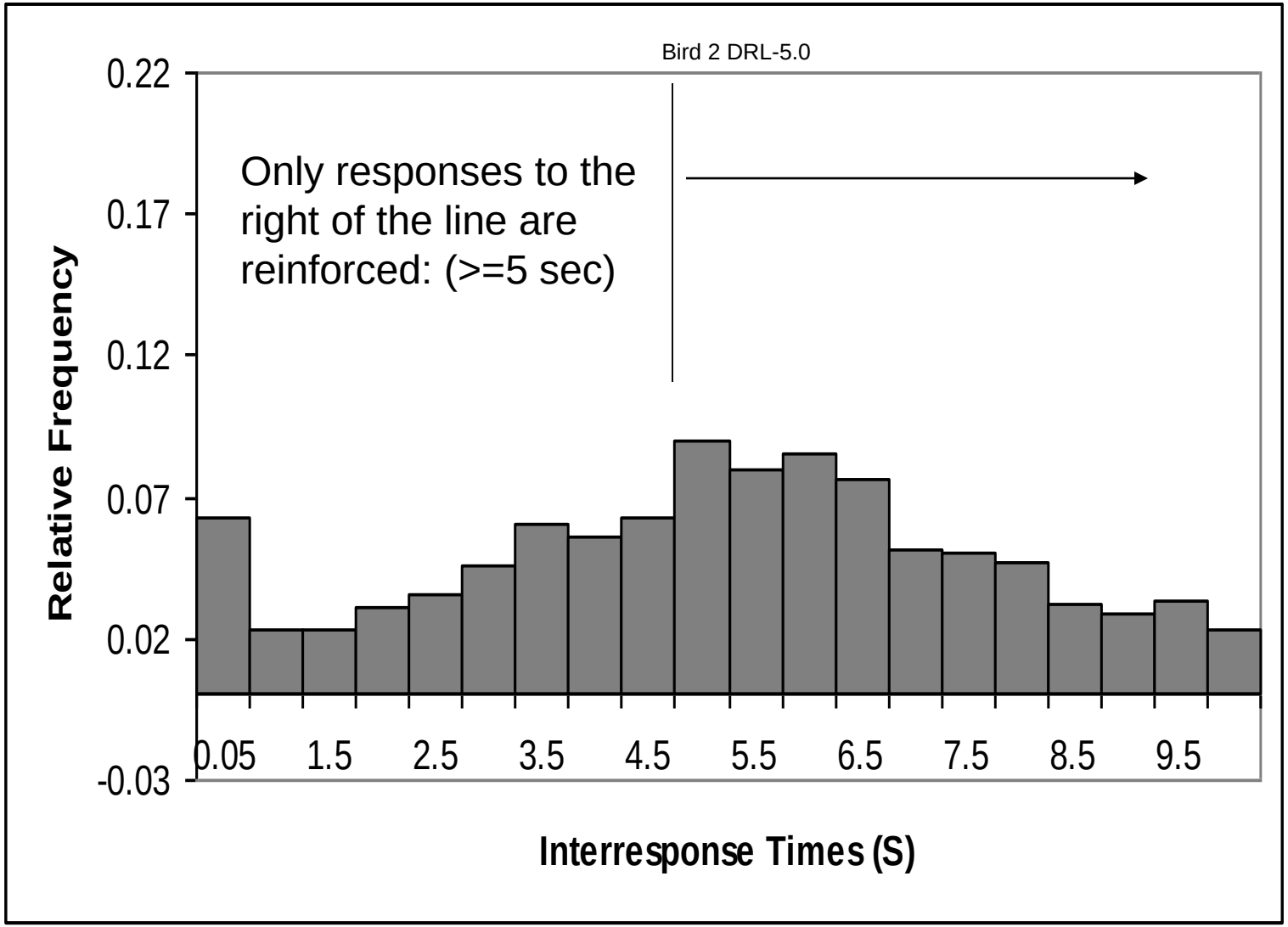
X-axis: Length of pauses between pecks in seconds

Pigeon must pause at least 2.5 seconds between pecks in order to get food (called “DRL-2.5 sec”).

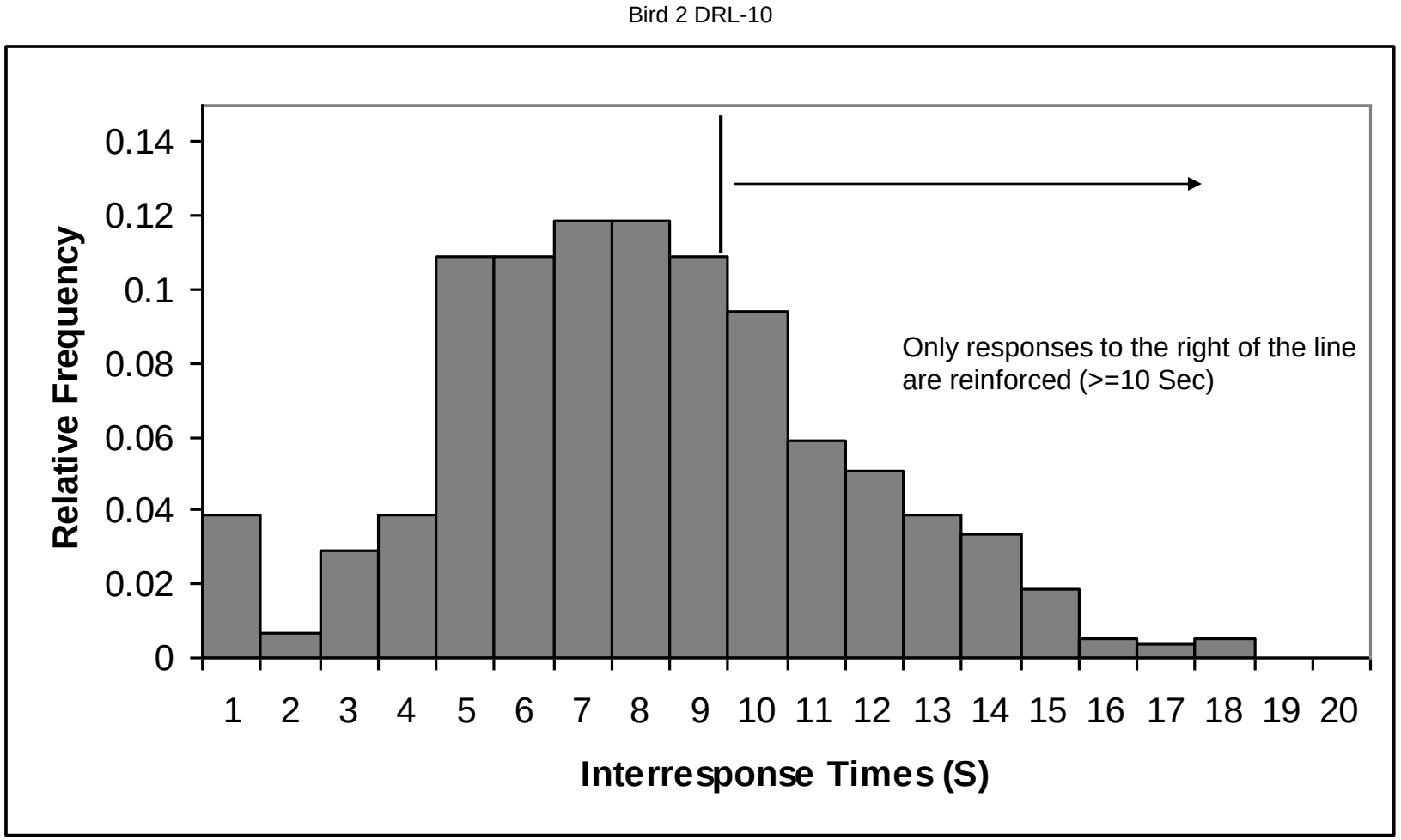
Pauses of that length are relatively “selected” by reinforcement (mode: 3 sec)



Only 5-second pauses reinforced (Note: mode shifts to 5 sec)



10-second pauses are now required (mode shifts to 7.5 seconds) (Pigeons aren't very good at timing long pauses.)



Automatic shaping

- "Automatic shaping" is the change in behavior brought on by a progressive program of reinforcement contingencies that is not arranged by other people.

- E.g., learning to:
  - Juggle oranges
  - Whistle
  - Draw pictures
  - Compose a song
  - Paint a landscape
  - Invent an airplane
- We don't need to be told when we have made an improvement. We can see it.

- The concept of “automatic shaping” is an extension of the more familiar concept of “automatic reinforcement.”

Automatic reinforcement defined

- Vaughan & Michael (1982) report that Skinner used the term nearly 100 times in his major conceptual work, but never as a technical term:

- “Skinner uses it in the ordinary sense of not requiring the mediation of another person.”

- “It is used merely to emphasize the relevance of reinforcement in cases where it might easily be overlooked. That is, it counteracts any tendency to restrict the concept of reinforcement to those occasions upon which it has been deliberately arranged by a person or group.” (p. 218)

The term is controversial:

- It suggests a special kind of reinforcer
- It is sometimes used as a cover for ignorance.
- It can be used in a circular way:
  - Why did he do X? It was automatically reinforced.
  - How do you know? The behavior occurred in strength.
  - But it may be real for all that.

Case I: Reinforcement physically caused by the behavior itself, without mediation by another organism

- Examples

- You reach for a pen, and you get the pen.
- You type “p-e-n” and “pen” appears on the PowerPoint screen.
- You close the window and the draft goes away.

- These cases are uncontroversial and trivial, but not entirely without interest

Automatic reinforcement (in this sense) comes

- Immediately
- (Social reinforcement is usually slightly delayed)

- Without overtones
- (Social reinforcement must share the stage with myriad other dimensions of the social exchange that can modulate or interfere with the reinforcing function.)
-

Case 2: The behavior has some salient stimulus property that is itself a reinforcer.

- We sing songs we like.
- We swing, seesaw, and slide on playground structures.
- We scratch an itch.
- We drum with our fingers.
- We dance.

Case 2: May be invoked to explain self-stimulatory and self-injurious behavior.

- Examples:
  - LG twiddles bits of string in front of his eyes for hours at a time:
    -
  - BR & SD make loud, repetitive vocalizations that serve no apparent function.
    - Proprioceptive or auditory stimulation?
    - Do they serve like the yogi's mantra to interrupt covert behavior or to induce a meditative state?

- Problem: Utter circularity; very speculative; serves only to allay curiosity; but, again, may nevertheless be correct

Possibility of testing?

- LG: String twiddling
  - In this case, the proposal that the twiddling of string is a reinforcer has been crudely tested: He will work to get access to a thread that he can then twiddle in front of his eyes. He'll pull threads out of his sock or tee-shirt, shred tissue, etc. Unclear why.

- BR & SD: Repetitive vocalizations
  - Might be tested by taping the vocalizations. Will they turn them on?
  - Amplify the vocalizations and play through headphones; will they vocalize more softly? (They can get the same auditory effect with smaller effort and less disruption to people around them.)
  - Delayed auditory feedback?: Changing the stimulus arrangement might disrupt the behavior. Ethics uncertain.

Case 3: Automatic reinforcement by achieving "conformity" with the practices of the social (or verbal) community.

- Under some conditions, emitting a response that has stimulus properties that evoke certain kinds of discriminative responses will be reinforcing by virtue of its conformity.
  - E.g., game of "Simon Says …"
  - Underlies generalized imitation
  - Lies at the heart of examples of "automatic shaping"
    - E.g., learning to blow on a blade of grass to make it whistle.
    -

Automatic Shaping: The Hidden Engine of Language Acquisition

- Reinforcement does not need to be mediated by other people. There are at least three ways in which the child's own behavior might be automatically reinforced.

- Verbal responses are distinctive in that they stimulate the speaker in the same way that they stimulate the listener. People with normal hearing can hear themselves talk.

- What they hear may be reinforcing.

Types of automatic reinforcers

- Unconditioned stimuli (innate)
- Conditioned stimuli (learned)
- Reinforcement by detecting when our behavior matches that of a model.

Unconditioned Reinforcement

- Prosody: Karen Blixen
- Alliteration
- Rhyme

- Implications: Early word play. Babbling. “Gets the behavior out.”

Poetry often exploits apparent unconditioned reinforcers: prosody, alliteration, & rhyme

Ah, distinctly I remember it was in the bleak December;

And each separate dying ember wrought its ghost upon the floor,

Eagerly I wished the morrow;— vainly I had sought to borrow

From my books surcease of sorrow— sorrow for the lost Lenore—

For the rare and radiant maiden whom the angels name Lenore—

Nameless *here* for evermore.

Conditioned Reinforcement I

- DeCasper experiments with newborn infants:
  - Prosody of mother's voice shown to be a reinforcer, i.e., apparently conditioned in the womb.
  - Sound of native language shown to be reinforcer for newborns.

Conditioned Reinforcement II

- Speech sounds paired with unconditioned reinforcers can become conditioned reinforcers.

- Examples:
  - Sundberg, et al.:
    - Subjects: Kids with very low rates of vocalization
    - Procedure: They paired speech sounds with unconditioned reinforcers
    - Results: Kids started to vocalize those speech sounds
    - Interpretation: They found the sound reinforcing and could make it themselves

First reference to the concept in behavior analysis

- "In verbal behavior, for example, we may give a sound reinforcing value through conditioning of Type S [classical conditioning]. Any sound produced by a child which resembles it is automatically reinforced." -Skinner, 1937

Implications

- Automatic shaping of response form: Close approximations of target are automatically reinforced.
- May shape babbling toward practices of infant's particular verbal community.

- However, a discrimination is likely to be quickly set up: Our own behavior is unaccompanied by unconditioned reinforcement.

- As we'll see, such effects are often transient and weak in the lab.

Automatic Reinforcement by “Achieving Parity” With Practices of Verbal Community

- Children become discriminating listeners before they become articulate speakers.
- When they speak, they can hear themselves.
- If the stimulus products of their speech evokes discriminative behavior in themselves, they have “matched.”
- Matching is a reinforcer.
- Metaphor of the xylophone.

Automatic reinforcement by matching: A demonstration experiment

- Keys on a computer were programmed to play tones, but not arranged like the keys on a piano: Even in a pianist, the performance must be shaped.

- Result:

JKHGFL;HGGFDSRNGFDYDFGHJKLHGFDLKFHDHFFFHFFHLKKHFDFHHHHFFHFD

How it develops

- When you don’t know what to do, the surest way to a happy result is to do what others do.
- Children are ignorant.
- Achieving parity is automatically reinforcing.

What it is not

- It is not the stimulus properties of the utterance that is reinforcing but the fact that one has matched.

- E.g. we can learn exotic insults which have been hurled at us.

Implications

- Automatic reinforcement is ideally poised to effect the automatic shaping of verbal behavior, for it is immediate and reliable.
- There are countless such contingencies, for they occur every time we speak. We need not wait for the clumsy machinery of social reinforcement to swing into action.

Summary: Automatic reinforcement

- Unconditioned
- Conditioned
  - by pairings
  - Womb effects
- Parity: “Recognizing that we have matched”

- These processes may explain the acquisition of grammatical behavior in the absence of explicit parental instruction.

Experimental evidence: The acquisition of a grammatical constructions through modeling

A demonstration of the ‘book-eater’ experiment

- 3-yr-old girls (N = 2)
- Procedure:
  - “Reinforce” standard usage*
  - Model non-standard usage
  - *Recall Brown & Hanlon study showing paucity of explicit reinforcement in parent-child interactions.

- This monster eats mud. He's a mud-eater. This one eats wood. He's a —

  WOOD-EATER
- *Right. He's a wood-eater; he eats wood. Now this one eats mice. He's a—

  MICE-EATER
- *Right. He's a mice-eater, because he eats mice. Now this one eats chipmunks. He must be a —

  CHIPMUNK-EATER
- *Right. He's a chipmunks-eater, because he eats chipmunks. This one eats marbles. He's a—

  MARBLE-EATER

- *Right. He's a marbles-eater. This one eats chickens. He's a—

  CHICKEN-EATER

- *Yes. That's right. He's a chickens-eater. Now this one eats worms. What's he?

  A WORMS-EATER

- *Right. He's a worm-eater. But this one eats candles. He's a—

  CANDLES-EATER

- *Right. He's a candle-eater. This one—

  YOU SAY "CANDLE-EATER," BUT I SAY "CANDLES-EATER"

Extension to a more complex example:

- Acquisition of the passive voice
  - Model passive construction
  - “Reinforce” active construction

Active vs. passive

- The active voice:
  - I ran 8 pigeons in Condition 1
- The passive voice
  - Eight pigeons were run in Condition 1.
- Active:
  - The cat is brushing the dog.
- Passive:
  - The dog is being brushed by the cat.

Goal of Experiment

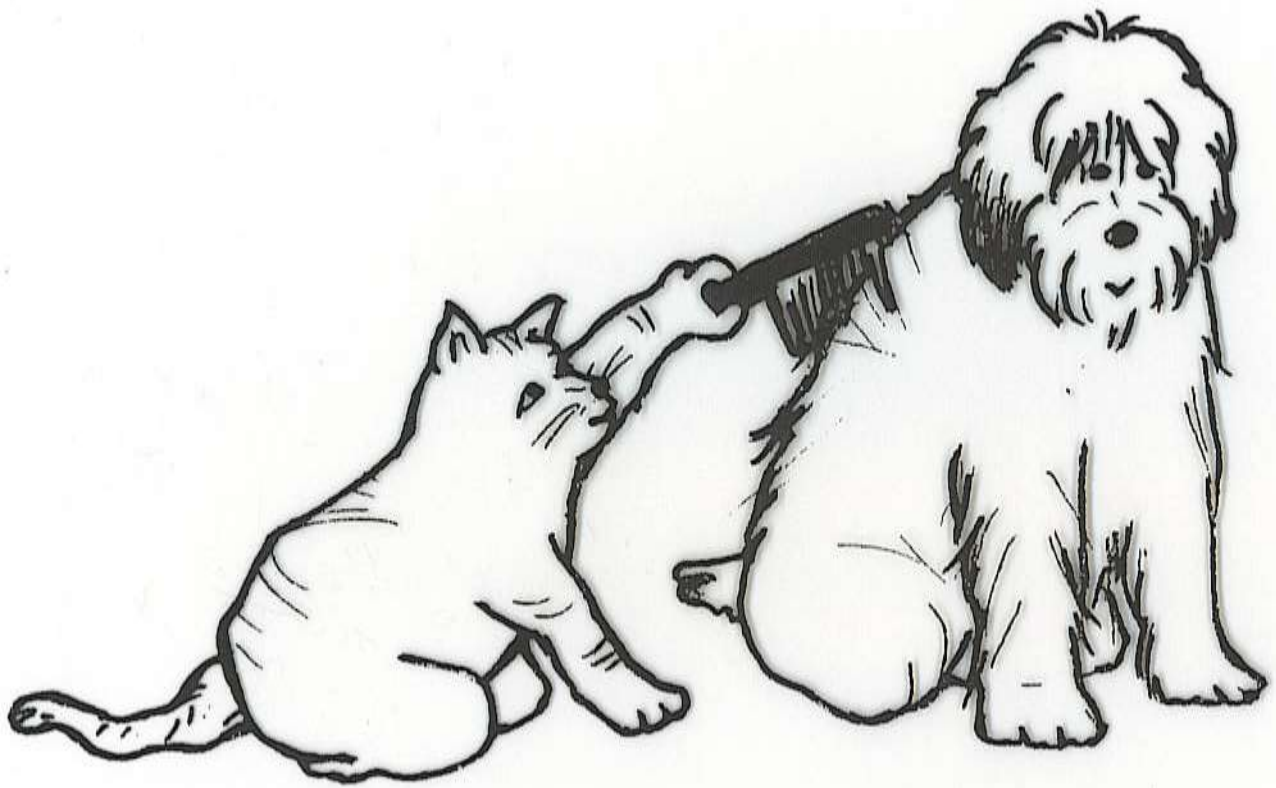
- To replicate the “books-eater” experiment with a more complicated grammatical construction (acquisition of the passive)
- To see if modeling alone is sufficient, in the absence of explicit instruction, and indeed in the face of a “nominal” reinforcer for an alternative construction

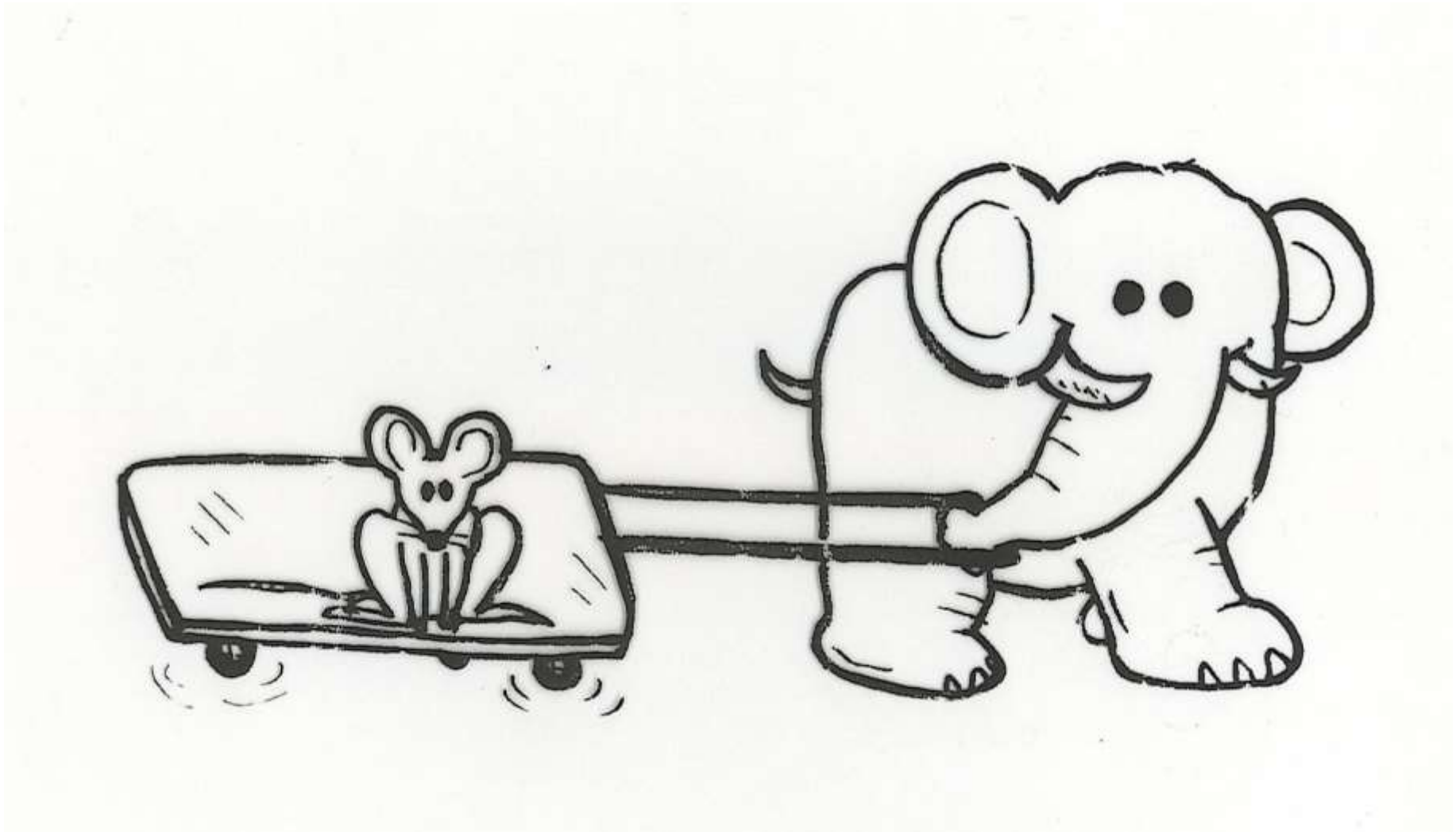
Subjects

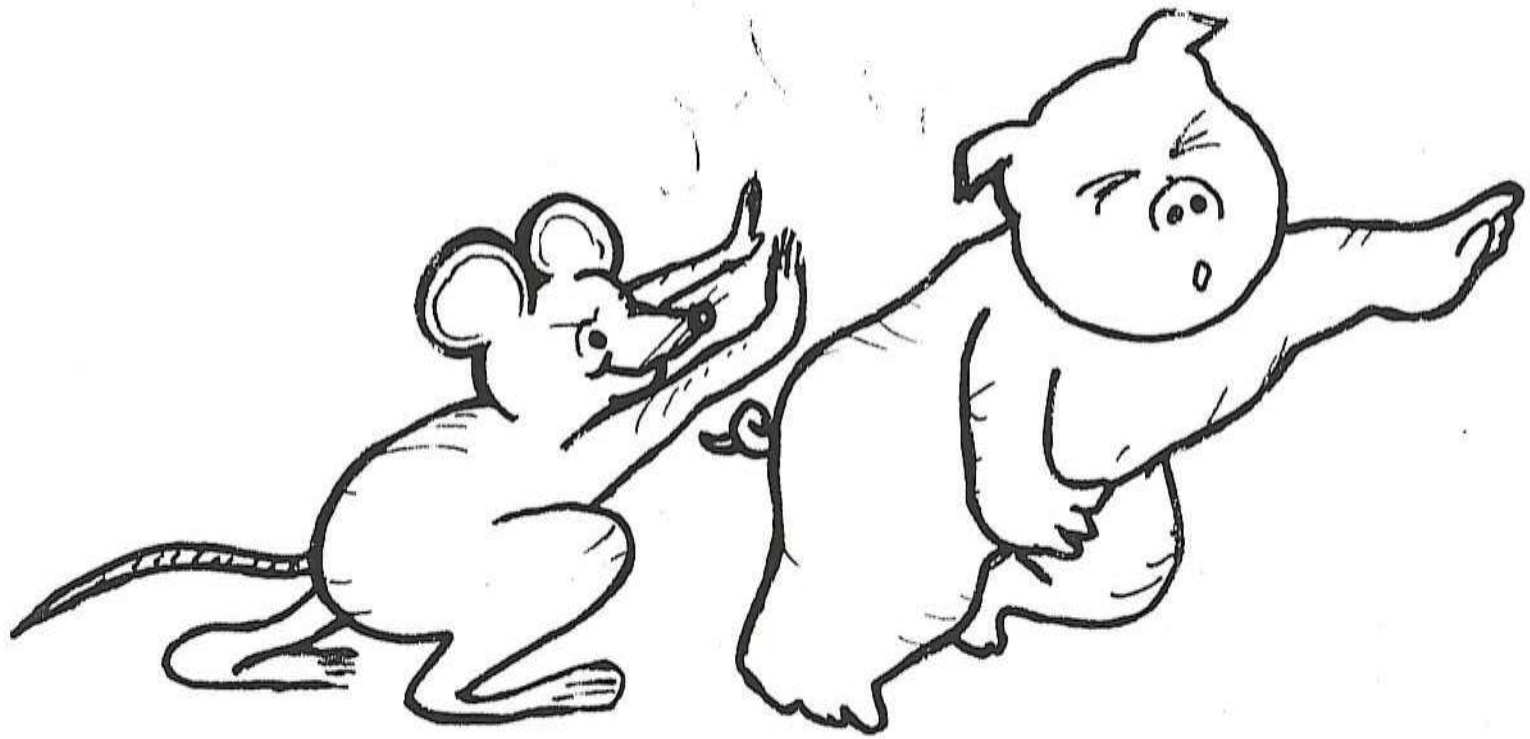
- Subjects were 6 children aged 2.5 to 4.5 years.
    - “Too young to use passive.”
    - No evidence of passive in early trials.
- Two were developmentally delayed but had a verbal repertoire.

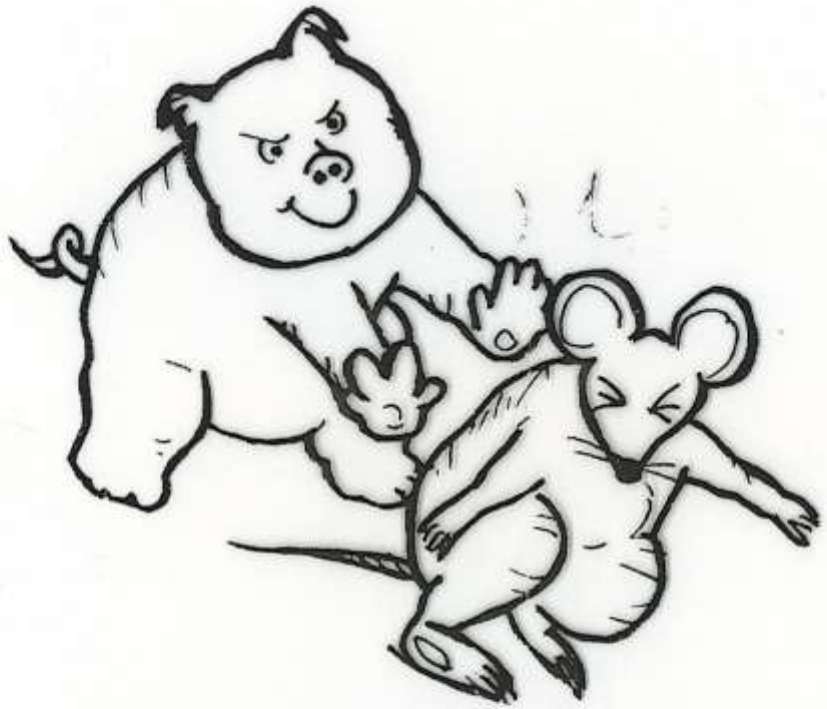
Procedure

- Experimenter and subject took turns describing 20 pairs of pictures.
- There were no instructions.
- The experimenter always described the first picture in each pair in the passive voice.
- If the child used the passive voice, the experimenter said nothing.
- If the child used the active voice, the experimenter said, “That’s right.” (Thus the procedure was biased against finding a modeling effect.)









- Transcript of S1, age 4 yrs 2 months. Responses indented.
- **The . . . the hippopotamus is bringing the seal**.
- *The zebra is being painted by the peacock. (Do that one!)*
- **The zebra is painting the peacock.**
- *The giraffe is being squirted by the cat.*
- **The . . . the . . . the. . . giraffe is squirting the cat.**
- *The lamb is being hugged by the bear.*
- **The lamb is being . . . the lamb is be. . . hugging the bear.**
- *The rabbit is being kicked by the cow.*
- **The rab . . . the rabbit „ . . the cow is getting kicked by the rabbit.**
- *The duck is being hit by the kangaroo.*
- **The duck ... is hitting the kangaroo**.

- *The octopus is being stopped by the dolphin.*
- **That's a seal . . .** [Oh] **. . . That's a dolphin. A dolphin.**
- **The octopus is saying "no" to the dolphin.**
- *The snake is being licked by the dog.*
- **The dog is being licked by the snake.**
- *The lamb is being hugged by the bear.*
- **The lamb is hug...ging . . . by the bear**.
- *The turtle is being ridden by the horse.*
- **The horse has the turtle standing on the horse.**

- *The pig is being pushed by the mouse.*
- **The pig is pushing the mouse.**
- *The mouse is being pulled by the elephant.*
- **The elephant is being pulled by the mouse.**

- **Children covertly echo each exemplar.**
- **The grammatical frame is common to all example.**
- **Intraverbal control of one part of the frame by another is acquired.**
- **The frame itself comes under the control of contextual cues.**
- **Under appropriate motivating conditions, the frame is emitted overtly.**
- **Variables in the frame are supplied by the context.**

Verdict on the role of “matching” as an explanation of grammar

- Modeling is a powerful agent of behavior change in children, even in the acquisition of subtle grammatical distinctions.
- Modeling is effective apart from explicit parental approval.
- Given the huge number of examples of verbal behavior to which children are exposed, it is premature to claim that grammatical verbal behavior cannot be learned by children.

Review of automatic reinforcement in applied studies

- Wright/Ostvik
- Clo
- SIB and self-stimulation
- Prosody

Procedures for boosting baseline verbal behavior rates

Rationale:

Some children vocalize at low rates, making the shaping of vocalizations difficult. If their vocalizations are automatically reinforcing, they should emit them at a higher rate.

Several relevant procedures to address this:

1) The Stimulus-stimulus (S-S) pairing procedure; e.g., Sundberg, et al. 1996
2) The response-contingent S-S procedure; e.g., Lepper & Petursdottir, 2015
3) The discriminative response procedure; e.g., Lepper, Petursdottir & Esch 2103
4) Observational learning, e.g., Greer, et al., 2008

(The latter procedure has not yet been applied to increasing vocalizations, but they could in principle)

The S-S pairing procedure

- The earliest procedure, pioneered by Sundberg in the late 70's based on Skinner, 1957.
- Vocalizations by experimenter were immediately followed by reinforcer (hence Stimulus-Stimulus, or S-S)
- 12 or more studies. Four found no effect
- Four found no effect.
- Effect was inconsistent in most of the others, with some subjects showing no effect.

The response-contingent pairing procedure

- Procedure: Child presses button and then gets S-S pairing. (Lepper, et al.)
- On other trials S-S alone
- Both procedures worked for all 3 children, but the RCP procedure was superior for each child.

The discriminative stimulus procedure

- In Lepper, Petursdottir & Esch:
  - Target vocalization is presented.
  - If subject raises arm then reinforce.
  - Test for vocalizations.
- All children vocalized under this procedure, but no more than in a parallel S-S procedure
- (Others have found advantage for discriminative response procedure when assessing for conditioned reinforcement, but have not targeted vocalizations as a response variable.)

The observational learning procedure

- (No studies have used this procedure for assessing vocalizations, but it has been used to establish neutral stimuli as conditioned reinforcers, so it remains a potentially useful intervention.)
- Procedure: One child sees a second child getting a neutral stimulus as a reinforcer for some behavior.
- Subsequently that stimulus will function as a reinforcer for the observing child.

Theoretical considerations

- Observational procedure is theoretically incoherent
- S-S procedure is flawed: No reason to expect the target vocalization to occur spontaneously. It must be shaped. Or if already in the repertoire, it has to occur at least once before reinforcement can be expected.
- Kids should quickly develop a conditional discrimination: Primary reinforcers don’t follow when they vocalize themselves.
- Unless kids already have an echoic repertoire, but in that case there is no need for the procedure. Simply reinforce echoic behavior.

Methodological considerations

- Why the response-contingent and discrimination procedures might be better than stimulus-stimulus pairing procedure:
  - Response is most likely to occur when motivation is highest
  - The child might be more likely to attend to the vocal stimulus
  - Kids seem to prefer reinforcers that they have to work for than those that are free

- E.g., Esch, et al., got better results with the S-S procedure when they used “enhanced” procedures that made contingencies more salient (spoke in “motherese,” varied ITIs, added prompts, varied trial types).

- Other suggested enhancements:
  - Put reinforcer under glass
  - Present a variety of non-target speech sounds
  - When target sound is presented, immediately remove glass

Verdict on procedures for increasing vocalizations

- The procedures using S-S pairings, response-contingent pairings, or discriminative-stimulus are worth trying for the special case of kids who vocalize at very low rates.
- Using any procedure that enhances the contingency is likely to be most effective.
- If kids vocalize, conventional response forms can be directly shaped.
- If autistic kids don't find matching the behavior of models to be reinforcing, then shaping is presumably the only alternative. Results are likely to be limited.
- For high-functioning kids who find matching reinforcing, the parity procedure is most powerful and can lead to complex verbal behavior.
- In all cases, careful programming is essential.

Automatic reinforcement in other therapeutic domains

- Shaping normative prosody in speech
- Potentially shaping and maintaining maladaptive or ritualistic behavior
  - Self-stimulatory behavior
  - Self-injurious behavior(?)

Conclusion

- Automatic reinforcement plays an important role in the typical course of language acquisition and has been implicated in a variety of other domains as well.
- Reinforcement by “matching” appears to be the most relevant form of automatic reinforcement in typical development.
- When possible, automatic reinforcement should be recruited in applied settings in order to facilitate the automatic shaping of complex response forms.
- If verbal stimuli are not already reinforcing in themselves, various pairing procedures have been shown to help, though results are inconsistent.