The ABCs of Behavior Analysis

An Introduction to Learning and Behavior

A. Charles Catania

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This book started as a brief outline tentatively entitled *A Primer of Behavior Analysis*. One of its antecedents was George Reynolds’ *Primer of Operant Conditioning*, published by Scott, Foresman in 1968. That book ran to 130 text pages plus supporting material and brought together the basic concepts of the field later to be known as behavior analysis. In those days primer was pronounced to rhyme with trimmer, befitting a book that’s supposed to be short; nowadays it’s sometimes pronounced like rhymer.

My earlier book, *Learning*, had grown longer over successive editions and had become more a graduate than an undergraduate text. I’d often thought about a brief version that could function as George Reynolds’ book once did. But we know much more now than we did then, so I’m happy to have ended up with a bit more than 300 text pages plus supporting material. Of course it could have been much shorter, but that would have made it impersonal and far more abstract. I hope readers will find I’ve struck a reasonable balance among concise presentations of basic concepts, discussions of relevance, concrete examples and illustrations of applications.

I can’t date when I first drafted the outline, but I stopped worrying about pronunciation when length made it obvious the *Primer* title was inappropriate. The main title, *The ABCs of Behavior Analysis*, captures the basics while also highlighting the three-term contingency: Antecedents–Behavior–Consequences. The subtitle, *An Introduction to Behavior and Learning*, provides a reminder of the linkage between behavior and learning. The essence of learning is creating new behavior, and that encompasses much of what we behavior analysts do.

Three features seemed especially important as the manuscript evolved. First, it had to represent behavior analysis as a discipline in its own right rather than as a component of psychology: psychology has become an umbrella designation for a variety of approaches only some of which are compatible with behavior analysis, and behavior analysis encompasses many topics treated by psychology as separate domains. Second, selection by consequences had to be its organizing principle: in both its methods and underlying assumptions, behavior analysis has more in common with biology than with most varieties of psychology and cognitive science. Third, it could not be limited to the basic nonverbal processes: it would assume no one unfamiliar with at least the rudiments of the science of verbal behavior could truly be counted as a behavior analyst.

These three prerequisites made the new work inevitably parallel in many ways the organization of my earlier *Learning*. Anyone comparing the respective tables...
A behavior taxonomy is a vocabulary for organizing the various procedures and phenomena of behavior. Please don’t expect explanations of behavior based on formal laws. Instead, think of a systematic classification of behavior based on its origins: given any example of behavior, where did it come from? The taxonomy won’t be exhaustive, because we can’t anticipate everything we’ll run into. Behavior analysis remains work in progress, but we can at least aim for a descriptive system that organizes the phenomena we’ve begun to know while not excluding those we’ve yet to study.

We study the relation between environmental events and the organism’s behavior by changing the environment and observing how this affects what the organism does. In the analysis of behavior, procedures or operations are what the experimenter or the environment does or arranges, and outcomes or processes are the resulting changes in behavior. A convenient analogy comes from medicine, where the surgical operation, a procedure, is what the physician does to the patient, and the processes that follow, such as changes in circulation, respiration and so on, are the outcomes. I’ll usually favor procedure over operation and outcome over process, but within each pair the terms are usually interchangeable.

If you’re familiar with the standard sections of experimental papers you’ll recognize this distinction as paralleling the difference between the Method section, which describes the procedures and other details of an experiment, and the Results section, which describes the obtained data. We can also interpret changes in behavior once we’ve observed them; interpretation corresponds most closely to what happens in the Discussion section.

Behavior of course occurs in natural settings as well as artificial ones arranged by an experimenter. We startle in response to an unexpected loud noise whether produced by accident on the street or deliberately in a lab. For that reason, these terms are applied both to artificial procedures and their outcomes and to natural sequences of events. For example, Chesapeake, our cat, has learned he often gets fed after going to his feeding dish in the kitchen. It hardly matters whether I deliberately trained his behavior or it came about as a matter of course during routine feedings. Either way, being fed was a frequent consequence of going there. It’s convenient to call such circumstances procedures or operations whether or not I arranged them explicitly.

The simplest procedure is to observe behavior: just watch. We discover what an organism can do. But we have no control over events when we simply observe, so we may not be able to draw conclusions about the causes of behavior. To learn more we must intervene, and the simplest intervention is to present stimuli. A more complicated intervention is to arrange the environment so the organism’s behavior can change it or, in other words, so behavior has consequences. Once behavior has consequences it may occur more or less often, when we may sometimes call the respective outcomes reinforcement and punishment.

We haven’t exhausted the possibilities. We can arrange things so stimuli signal the presentation of other stimuli or so stimuli signal the opportunity to produce consequences. We
Selection shaped the bodies of organisms based on how those bodies behaved. Among vertebrates, selection operated on muscular and skeletal and neural structures allowing them to eat and mate and get around via walking, running, swimming, flying, climbing, tunneling, slithering, and so on (arthropods and cephalopods and organisms in other phyla do these things too, but in other ways). Sensory systems were advantageous because without them behavior would have been inappropriate to the settings in which organisms found themselves. As their touch and taste evolved, they could respond differentially to things they contacted. With smell and vision and hearing they could respond to more distant stimuli. I could have started here with sensory systems, because discriminative stimuli come before responses in the three-term contingency. But in the evolution of behavior, responding had to be there first or there’d be no behavior to participate in a three-term contingency, so that’s where we’ll go next after some general points.

THE EVOLUTION OF MOTOR AND SENSORY SYSTEMS

What can we say about the evolution of behavior and learning? Behavior leaves only indirect evidence in the fossil record (nests can hint at ancient ways of raising young; footprints can reveal some details of walking or running). It’s at least safe to assume that response systems evolved before sensory ones. An organism that can’t do anything about what it sees gains no advantage by seeing. Some organisms remained immobile but others began to twitch and squirm. Some were passively moved by ocean currents but others anchored themselves to a site. Still others developed cilia and flagella. The organisms from which we are descended developed ways to get from one place to another.

The most primitive patterns of movement were probably driven primarily by eliciting stimuli. Bright light elicits random movement in an insect larva. In what’s called a kinesis (plural: kineses), it moves until by chance it reaches darkness; then it stops (Fraenkel & Gunn, 1961; Loeb, 1918/1973). We find few larvae in the light but many in the dark, such as under the rotting bark of a fallen tree limb. Their behavior wasn’t directed toward dark places. They got there by chance and congregated there because that’s where they stopped. Directional control by stimuli probably came later. A kinesis differs from a taxis (plural: taxes), orientation directed toward or away from some stimulus. Examples include movements toward light (positive phototaxis) and upward movement, away from gravity, as in climbing a tree (negative geotaxis). Directed movements are sometimes also called tropisms, but that term is more often applied to plant behavior, as when flowering plants turn toward light (phototropism).
Each example involves a fixed pattern of responding to events. First there was movement; then came movement in relation to stimuli. Such patterns were especially advantageous in stable environments. For example, given a sharp stimulus to its paw, a dog flexes its leg, drawing its paw up toward its body. For an animal that walks on the ground, this response is advantageous: if the dog steps on a thorn, its flexion pulls its paw away from the thorn. The sloth, however, hangs from trees and its comparable reflex involves an extension rather than flexion of its limb. If the sharp stimulus is a thorn, the hanging sloth pulling its limb toward its body instead of extending it only drives the thorn deeper (B. L. Hart, 1973).

Not all environments are stable. A major evolutionary step was when patterns of behavior became modifiable or, in other words, when some organisms became able to learn. Learning may at first have been selected within restricted domains. For example, upon leaving its nest the digger wasp flies in ever-widening circles. Its later return to the nest is based on landmarks such as the rocks or plants it flew over before its departure (Tinbergen, 1972). Its capacity to learn landmarks, very specific to finding its nest, is part of its phylogenetic heritage.

The selection of the capacity to learn no doubt occurred in different ways in different species at different times. Things about environments that ordinarily remain constant over a lifetime need to be learned only once. Things about changeable environments need to be learned and then discarded and then learned again. In our own lives, the names of people we know don’t change very often, whereas the items on our shopping lists usually change from one shopping trip to the next. We should expect some kinds of learning to be hard to reverse while others are transient and easily modified.

The survival of a newborn foal may depend on how well and quickly it learns about the features distinguishing its parent mare from others. In a stable environment, such learning may be effectively permanent. The time of life during which learning occurs may also be limited. As the foal grows and becomes more independent, it will learn about things that change from day to day, such as the passage of predators or the places where food or water are found. The capacity to learn and remember likely follows a developmental course. Those looking for learning mechanisms in the nervous system must recognize that evolutionary contingencies may have selected different kinds of learning: some producing fairly permanent changes and others easily reversed; some restricted to relatively narrow situations and others broadly general; and some operating at different times in life than others.

**MOTOR SYSTEMS**

In vertebrates, motor systems range from those involved with eating and drinking and mating to those of locomotion. Depending on the medium, organisms get around by moving fins or legs or wings or other appendages. What we humans do artificially with rotary devices such as wheels or propellers or the screws that move vessels through water most organisms accomplish by back and forth motions, in walking or running or flying or swimming (Gray, 1953). This behavior is sophisticated: robotics is getting better at designing machines that walk successfully on irregular surfaces, but novel environments continue to present challenges.

Walking demands complex muscle coordination along with maintenance of balance. In knee flexions, for example, one muscle relaxes as the opposing muscle contracts. Much of this coordination is built in. When hatchling chicks are deprived of flapping and flight experience by wing restraint or other means and their wing coordination is tested later, flapping is synchronous from the start (Provine, 1984). Many aspects of flight coordination are “prewired” at the level of the spinal cord. Nevertheless, the environment still matters. However the bird does it, current environments determine when it flies and where it goes.

A study of leg movements in infancy recorded the timing and topography with which 3-month-old infants kicked at a mobile (Thelen & Fisher, 1983). The visual consequences of kicking varied: some infants saw the mobile move...
when they kicked and others didn’t. These con-
sequences affected the rate and vigor of kicking
but not the coordination of its flexion and exten-
sion phases. In other words, some features of the
kicks were modifiable but others weren’t. Simi-
larly, contingencies affect the direction in which
you walk but not the detailed coordination of
your muscles and joints as you do so.

Sometimes we recognize people at a distance
simply based on their walks. Many aspects of
coordination operate independently of the envi-
ronment (Gallistel, 1980; Gray, 1953), when they
may be called motor programs. A horse trainer
doesn’t have to shape the details of stepping or
the order of leg movements as a horse speeds
up from walk to trot to canter to gallop. A show
horse might be taught special steps, like the rack,
but even in these cases the new topography mod-
ulates existing patterns.

Motor systems can differ in other ways. For
example, avian flight can occur in two modes:
energic flapping that gets birds off the ground
and up to air speed, and sustained flight with
wings outstretched as airfoils, with movement
mostly restricted to the ends of the wings where
the feathers provide forward thrust. The feath-
ers are functionally like back-and-forth propel-
ler blades and work by flipping their orientation
as the wings move up and down. The breast
muscles driving the energetic takeoff, low in
myoglobin, fatigue rapidly; the postural muscles
of sustained flight are richer in myoglobin and
less subject to fatigue.

Getting around is only one of many motor
functions. Our human hands are special, and we
share opposable thumbs with just a few other
species (F. R. Wilson, 1998). Grasping opens
vast opportunities for interacting with envi-
rionments: working with tools, writing, playing
musical instruments and wielding weapons,
to mention just a few. Some are clearly more
benign than others. I can’t possibly provide an
exhaustive list of motor systems, but one other
that demands mention is our vocal apparatus.
Different anatomical changes came together
to make human talk possible. These included
enhanced articulation following from changes
in the control of lips and tongue and vocal
cords, and the shift to bipedal locomotion that
freed the lungs and rib cage from the constraints
on control of breathing produced by walking on
all fours (Provine, 2004)

These examples emphasize muscle move-
ments, but not all behavior involves muscles.
Even beyond tearing and salivating and other
glandular effects, we needn’t move to interact
with our environments. When viewing art I can
look from one part of a painting to another, but
when listening to music I don’t have to turn
my head to shift my attention from one musical
instrument to another. Eye movements differ
from shifts in listening, but they have in com-
mon that each is modifiable by its interaction
with the environment.

SENSORY SYSTEMS

A pigeon is more likely than a bat to respond
to visual stimuli, whereas a bat is more likely
than a pigeon to respond to auditory stimuli.
If an organism’s sensory capacities aren’t taken
into account, experiments can yield misleading
results. For example, the sound frequencies at
which sensitivity is maximal are much higher
for rat ears than for human ears. The experi-
menter who uses auditory stimuli easily heard
by rats may be unable to tell whether the stim-
uli are on or off, but the one who uses auditory
stimuli easily heard by humans may be giving
the rat sounds hard for it to hear and may incor-
rectly conclude the rat learns slowly and with
difficulty. With squirrel monkeys and colors as
visual stimuli, it helps to know some subspecies
are color-blind whereas others aren’t, so an easy
color discrimination for one may be impossible
for the other. Early studies of maze learning
must be interpreted with caution because rats
have keen olfactory sensitivity. If a maze isn’t
thoroughly cleaned between subjects, a rat’s
performance may depend on odor trails left by
other rats instead of what it learns on its own
runs through the maze. Issues like these become
even more crucial when a child’s behavior prob-
lems interpreted as products of contingencies
turn out to depend instead on a sensory deficit
such as hearing loss or uncorrected vision. These are all examples of sensing stimuli at a distance: hearing and vision and smell. But let’s begin with a contact sense, touch.

**Touch: Breast Self-Examination and Signal Detection**

With our fingers we can sense heat and cold and pressure and pain. Touch is of special interest because much of what we feel depends not on passive contact but on moving our fingertips over our touched environment. Our touch receptors are densely packed there and are exceedingly sensitive to subtle differences. There is passive touch sensitivity, but we need the moving finger to detect the details of forms and textures. We can’t just sit there; we must do something. This matters not only in feeling things around us but also in feeling parts of our own body. One example is breast self-examination (BSE), where the response is palpation of different breast areas and possible consequences are finding potentially malignant nodes or lumps.

Breast self-examination has been studied extensively as a teachable discriminative skill (Pennypacker & Iwata, 1990). Early studies emphasized the detectability of the lump as a function of various properties such as its size or its depth within simulated tissue (Bloom et al., 1982). As the work progressed, methods of palpation and search patterns emerged as significant concerns. For example, the movement needed to detect something in the simulated breast tissue depended on how close to the surface the target was and the search pattern had to be fine enough not to bypass the target, which could be anywhere in the tissue. Perhaps not surprisingly, circular finger movements horizontal to the surface were more effective than pokes. Methods of palpation and patterns of search were refined based on how well targets were detected.

Recommendations from the American Cancer Society at the time advocated a spiral pattern of search, but analyses of area covered and detection success demonstrated the superiority of a grid pattern. Based on data like those presented in Figure 4–1, the grid search pattern was eventually adopted as the primary recommendation of the American Cancer Society. It’s unfortunate that it hasn’t remained so, because it has undoubtedly saved lives. Despite the data, all three search patterns are equally recommended. But any BSE at all is better than none. It’s also worth noting that men too are at risk of breast cancer, though at a lower rate than women; their tumors are typically detected at later stages of their cancers, perhaps because they’re rarely informed about the value of doing their own examinations.

Effective breast self-examination depends on patterns of search and palpation. It illustrates how behavior analysts can extend research with nonhuman organisms to areas of significant human concern (Pennypacker began his career with pigeon research); it reminds us that despite our privileged access to our own bodies we need to be taught much of what we know about ourselves; and it also treats stimulus processes as behavior rather than as passive outcomes of exposure to stimuli. It’s obvious we can feel things only when we touch them, but we also hear things when we listen to them and see things when we look at them. In any modality, shifting attention from one thing to another is behavior. It’s too easy to focus mainly on the stimuli rather than the behavior. As this example illustrates, sensing is something we do.

A stimulus may be below *threshold* or too weak to be detected. Two stimuli may be so close together they can’t be told apart, i.e., their separation may not exceed their *difference threshold*. But a threshold isn’t some absolute value. It varies from moment to moment and is best regarded as a distribution: the probability of detection as a function of stimulus value. The mathematics of these probability distributions provides the basis for *signal detection* theory (D. M. Green & Swets, 1966; Swets, Dawes, & Monahan, 2000). A breast lump qualifies as a stimulus, so signal detection can be applied to it.

A signal-detection analysis assumes an observer responds or doesn’t respond to a signal. Responding to the signal is a *hit* and responding if it wasn’t presented is a *false alarm*; not respond-
The possible outcomes for breast self-examination are summarized in Table 4–1. If a lump is there and I say it is, that’s a hit; if I don’t detect it, that’s a miss. If it isn’t there and I say it is, that’s a false alarm; if it isn’t there and I say it isn’t, that’s a correct rejection.

A hit is obviously better than a miss if there is a lump; if not, a correct rejection is obviously better than a false alarm. Once we know the proportions of hits and of false alarms we can use them to calculate two statistics. One, $d'$ ($d$-prime), is an index of discrimination; it depends on hits and correct rejections relative to total responses. It grows larger with increases in hits and cor-

Figure 4–1  Percent tissue examined in pretest breast self-examination (left) and after training with one of three search patterns illustrated by the sketches. Percentages of areas palpated relative to pretest data show strip or grid search (right) was superior to the concentric or radial methods for either cone or total area searches. (Adapted from Figures 13.10 and 13.11 in Pennypacker and Iwata, 1990).
Behavior Without Learning

Table 4–1 Signal-Detection Contingencies in Breast Self-examination

<table>
<thead>
<tr>
<th>“Yes, a lump”</th>
<th>A lump is there</th>
<th>No lump is there</th>
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<tr>
<td>“Yes”</td>
<td>Hit (Correct Positive)</td>
<td>False Alarm (False Positive)</td>
</tr>
<tr>
<td>“No”</td>
<td>Miss (False Negative)</td>
<td>Correct Rejection (Correct Negative)</td>
</tr>
</tbody>
</table>

rect rejections and smaller with increases in misses and false alarms. A second statistic, bias, is an index of whether one type of response is more likely than the other. Both misses and false alarms can be costly, though in different ways, and the relative costs will bias judgments in one direction or the other. Misses may seem inherently more important than false alarms, but consider what it might be like if someone free of cancer was mistakenly told a biopsy had tested positive. Signal-detection analyses help clarify such issues and have applications across a broad range of sensory systems and diagnostic situations.

Behavior analysts work with children, and even beyond egregious cases like this example they should be able to spot sensory issues. Do a child’s behavior problems arise not from contingencies but from hearing loss missed in school screenings? A quick informal check is to see whether you get different responses depending on whether the child sees you while you’re talking. Problems can also follow from visual deficits. The more you know about sensory systems, the better the job you’re likely to do in dealing with such cases.

Our auditory system consists of (i) the outer ear, through which sound reaches the eardrum, (ii) the middle ear, where a series of three small bones transmits the vibrations of the eardrum to the round window of (iii) the inner ear, or cochlea, consisting of a spiral tube divided by the basilar membrane. The vibrations of the round window become movement along the basilar membrane, which is displaced more at its wide end by low frequencies and more at its narrow end by high frequencies. These waves on the basilar membrane in turn activate hair cells that stimulate the firing of cells in the auditory nerves (von Békésy, 1960). The outer hair cells, so named because they run along the basilar membrane on the outside of the cochlear spiral, are responsible for the transduction of low-intensity sounds; the inner hair cells kick in at higher intensities (but getting into the details of this complex system would take us too far afield).

The dual system of outer and inner hair cells is responsible for a phenomenon called recruitment. Some hearing issues, especially with aging, are caused by loss of outer hair cell function. People with that problem don’t hear quiet sounds, but once the sound level gets high enough it sounds just as loud as it would have before the
hearing loss. I encountered the phenomenon with my mother-in-law. When she finally heard a question asked repeated at successively louder levels, she complained we were shouting at her. The solution was straightforward: it was best to be where she could see you when you talked, instead of standing behind her or to the side. Those working with geriatric populations need to understand recruitment.

Vision: Blood on the Walls, Dust Storms and Haloes

It can be useful to know about the visual system. Some years ago I heaved a heavy bag with a shoulder strap from my shoulder to set it down and saw a stream of blood running up the far wall. I moved my head and the blood moved with it. I covered my left and then my right eye and saw the blood only with the right. I concluded something was happening in that eye. As a graduate student I had spent some time studying vision, so when I experienced this strange vision I was well prepared to interpret it (Catania, 2007).

The retina is the photosensitive lining at the back of the eyeball. It includes not only the light-sensitive visual receptors, rods and cones, but also blood supply and other structures. Light entering the eye passes through some of these structures to reach the rods and cones. Like hearing, human vision involves a dual system. The cones, concentrated in the macula or central retina, serve color vision and the sharp acuity of the fovea. The rods, distributed in the periphery; are much more sensitive than the cones in that they respond to much dimmer levels of light, but they’re not much good for detail and color vision. The foveal cones aren’t sensitive enough to work in dim light but the peripheral rods are, which is why colors fade out in dim light and why you can sometimes see things at night only by looking slightly away from them. There’s good reason to be wary when an eye-witness who saw a jacket only at some distance at night claims that it was red.

When light enters the eye, passing through the lens on its way to the retina, opacities along the way block the light, creating retinal shad-
than fifteen years later. It was most likely caused by another retinal detachment. Near the back of the eyeball, somewhat removed from the fovea in the direction of the nose, is the optic disk, where neural processes from the rods and cones come together to leave the eyeball as the beginning of the optic nerve. The optic disk is a blind spot, with neither rods nor cones. You can locate it in your visual field by closing one eye while looking straight ahead and moving your fingertip along the horizontal on the side of your open eye until you find a place where it disappears. A small ring at the boundary between the optic disk and the rest of the retina sometimes breaks away. Mine seems to have settled down around my fovea for a while.

Symptoms like mine were improbable, especially in combination. They’re sufficiently few and far between that an ophthalmologist might encounter them less than once a decade. I’d seen blood on the walls, dust storms and haloes. What if I hadn’t known enough about vision to interpret them and had lived when no knowledgeable others were around to consult? Similar visions must have appeared to many people throughout history. What stories they must have told! It’s a good bet some have come down to us. But I know enough to be skeptical about claims they should be taken as messages or signs of the paranormal.

My interpretation of these phenomena depended on getting the direction right. We see things because light enters our eyes, traveling either directly from light sources or as reflected from objects, not the other way around. The early Greek philosophers debated whether sight depended on light from objects reaching the eye or on emanations from the eye making contact with objects. The confusion is less likely in hearing, though the echolocation of bats involves both directions: the bat’s generate high-frequency sounds and then locate their prey based on the echoes. With either vision or hearing, those who get the direction wrong won’t be able to understand how the sensory system works.

Sound varies in intensity (loudness) and wavelength (pitch). At each location in a visual array, light also varies in intensity (brightness) and wavelength (color). Different retinal receptors are sensitive to different wavelengths, corresponding to red, blue, and yellow/green classes. The spectral range we see arises from different mixes of these three classes. Those with deficiencies in their receptors may be color-blind. Most color-blindness is in men, but my mother was color-blind. She didn’t see differences in colors at the violet end of the spectrum, so browns and purples looked alike to her. She sometimes wore unusual outfits. I’ve had trouble with colors at that end too, though I’m not color-blind. I finally realized my problem: I’d picked up some of her color confusions because I’d learned my color names from her. The point is that some sensory problems arise not from physiological sources but rather from behavioral ones.

I encountered different color problems later. As we age, our lenses get cataracts, which means they gradually get yellow and cloudy. I needed cataract surgery to correct the loss of focus. After my first eye was done, I looked at the sky first with one eye and then the other. I saw a bright blue sky with the new lens, but to the eye with the old one it was a smoggy day. The yellowing lens had been blocking blue light, which I saw vividly with the new clear one. The yellowing had come on gradually over years, so I hadn’t noticed my losses in the blue region of the spectrum. Now I can again tell navy blue from black.

Not only have eyes evolved many times in many species. We now know that the same gene is the source of all eyes across the entire animal kingdom, from worms and flies and squid and crabs and fish to mammals like us (Carroll, 2006); all of these eyes descended from a common ancestor that produced the first photosensitive cells. In vertebrates, eyes typically come in pairs, but with different arrangements. They’re usually back-to-back in likely prey, mainly herbivores, facing out to each side as in deer and cows and robins; they face forward in likely predators, mainly carnivores and omnivores, thereby enabling depth perception via binocular vision as in lions and wolves and eagles and humans. Figure 4–2 illustrates the back-to-back arrangement as it occurs in pigeons.
Each eye has a central fovea; these foveae receive light coming from either side of the pigeon’s head. Their eyes also have a sensitive region at the rear of the eyeball, receiving light from the front, in some birds this region is a second fovea. The three areas of acute vision, one in front and the two on either side, are sometimes called the visual trident (Catania, 1964). Except at the back of the head, their vision extends almost all the way around, but it isn’t panoramic. Acuity falls off with distance from the foveae or sensitive regions, just as in the human eye.

Not only is their vision acute in these three directions. In the front they’re near-sighted but to the sides they’re far-sighted: a good arrangement given they eat food close to them, in front of the beak, but must look out for predators who can appear in the distance from different directions. I learned about these features of pigeon vision the hard way, when I undertook an experiment on their vision (Catania, 1965). Their optic nerves cross over so each connects to the opposite hemisphere of the pigeon brain.

The question was whether visual discriminations learned with one eye transferred over to the other. I had trouble teaching discriminations in which the stimuli appeared on either side of the pigeon’s head as it pecked a key in front of it. It took a while to recognize that the stimuli were too close. With vision stimuli placed to the pigeon’s sides, things go easier if they are farther away.

Another complication in studying interocular transfer of learning is that the pigeon’s two eyes are separated only by a thin septum of bone. If in a dim room you shine a light into one eye, the other will glow red from the light passing through the septum. We can worry about things that go in one ear and out the other in humans, but in pigeons visual stimuli can literally go in one eye and out the other. Interocular transfer might occur simply because some of the light to one eye directly stimulates the other one.

Proprioception and Biofeedback

Let’s skip over smell and taste and close with one more system, proprioception. Stimulation at the level of our own muscles and joints is essential to balance and locomotion and other interactions with the world. When I was an undergraduate, I served as a subject for Ralph Hefferline, a former gestalt psychotherapist who had switched to studying small-scale muscle movements as a precursor of what later became known as biofeedback (Hefferline, 1958; Hefferline & Perera, 1963). Biofeedback provides meter readings or other visible correlates of your own muscle movements or other physiological processes, helping you to see what you may otherwise have been unaware you were doing.

Equipment in those days was sensitive to ambient currents from nearby wiring, so Hefferline’s subjects sat inside an electrically shielded cage. I watched a meter that showed the activity of my masseter muscle: the harder I clenched my teeth, the more the needle moved. My task was to relax my jaw to get the needle down as low as I could. I’d had some problem with bruxism (jaw-clenching); after brief sessions of this relaxation training, my bruxism eased up. The
biofeedback procedure had taught me to discriminate properties of my own behavior to which I’d previously been indifferent. Much is shaped by natural contingencies, but here again, as with breast self-examination, we see that sometimes we need help in learning things even about our own bodies.

Sensory Gradients and Inhibitory Interactions

Whether in the skin, the ear or the eye, individual receptors respond to stimulation. As their activities trigger the firing of sensory nerve cells the input from single activated points is transformed to patterned interactions, so that more centrally in the nervous system cells fire based on whether the stimulus includes some configuration, such as a moving edge (Hubel & Wiesel, 2005). The beginnings of the patternning occur because the activity passed on by each receptor isn’t just excited by stimulation; it’s also inhibited by the activity of neighboring cells. These inhibitory interactions are common across different sensory systems (Ratliff, 1965; von Békésy, 1967). They’re especially relevant to us because similar interactions occur within behavior systems, as when responding is reinforced in the presence of stimuli within only part of a spatial stimulus array and differences in responding are enhanced at the boundary between the two parts (Catania & Gill, 1964).

Figure 4–3 illustrates how inhibition works in the context of interactions among the rates of firing of receptors in the visual system, shown across a series of graphs. The top section of each graph depicts an array of ten photoreceptors with a light level for each ranging from zero to nine. In 1a, for example, the third and seventh cells (C and G) are lit at a level of 8 and the rest at a level of 0. The graph below displays the activity of each cell as a rate of firing on an arbitrary scale. In 1a, C and G show substantial activity and the other cells remain inactive. In 1b through 1d, the light level is held constant at 8 for cell C but the light is moved closer, to cell F (1b), to

![Figure 4–3](image-url)
cell E (1c) and finally to the adjacent cell D (1d). The closer together the lit cells, the lower their rates of firing; the firing of each cell reduces the rate of firing of the other. This mutual reduction is called reciprocal inhibition (Hartline & Ratliff, 1957).

Graphs 2a through 2c show effects of lighting groups of two, four or six adjacent cells. With two cells, each is equally active. With four or six, the end cells are more active than the ones in the middle; cell activity on the end is inhibited only by neighbors on one side, whereas in the middle it’s inhibited by neighbors on both sides (Ratliff & Hartline, 1959). The enhanced activity difference between unlit and lit cells at the boundary is a contrast effect. All these differences are created solely by inhibition, which reduces the firing of a cell relative to what it would have done if lit all by itself.

Another effect, not shown, is that the initial firing produced by lighting a cell is typically substantially higher than its later firing under continued light (Hartline, Wagner, & Ratliff, 1956). This may be a result of inhibitory effects on the cell from its own activity. More important, these interactions enhance differential responding to temporal boundaries as well as spatial ones. Effects like these of are great generality across a range of species, from the visual systems of horseshoe crabs, flies, and fish to those of people, and from the visual system to hearing and touch and other senses (von Békésy, 1967). Behavior, too, is a biological system, so we should expect behavioral units to interact in corresponding ways, and they do.

Graph 3 shows the pattern of activity when the five left cells are equally lit at a level of 8 and the five right ones at a level of 3.
Presenting a stimulus is a basic way to change behavior. If I’m standing and talking, for example, a sudden loud noise will probably shut me up and produce the change in my posture called a *startle reaction*. This reliable relation between a stimulus and the behavior it produces has been called a *reflex*. The vocabulary began with René Descartes, a seventeenth-century French philosopher. He was familiar with hydraulic devices constructed to amuse visitors in the royal gardens of France. Stepping on a concealed trigger released a flow of water that made statues move. Descartes saw a similarity between such devices and behavior. According to Descartes, stimuli were comparable to the garden visitors who, entering into one of the grottoes containing many fountains, themselves cause, without knowing it, the movements which they witness. For in entering they necessarily tread on certain tiles or plates, which are so disposed that if they approach a bathing Diana, they cause her to hide in the rosebushes, and if they try to follow her, they cause a Neptune to come forward to meet them threatening them with his trident. (Descartes, translated in Fearing, 1930, pp. 20–21)

Just as a step on a concealed plate triggered the movement of a statue, a stimulus triggers a response. For Descartes, the pipes and water in those statuary systems played roles similar to nerves and animal spirits in living organisms.

Descartes’ concept of the reflex captured the fact that behavior is sometimes caused by environmental events, as when I quickly pull my hand back upon touching an open flame. Eventually physiologists turned their attention to the mechanism of such behavioral relations and explored the components of the reflex arc, the path from the original sensory impact of the stimulus through the central nervous system and then back to the muscular or glandular system within which the response occurred. Analyses became more and more sophisticated (Sherrington, 1906), and eventually the conditioned-reflex concepts of Pavlov (1927) and the related behaviorism of Watson (1919) treated the reflex as the basic unit of behavior.

**THE REFLEX: ELICITATION**

The startle reaction and the withdrawal of a hand from a flame are just two examples. We can add the knee jerk produced by a tap on the patellar tendon; salivation caused by food in the mouth; the postural adjustments triggered by an abrupt loss of support. They have the common feature that some stimulus reliably produces some response. In such circumstances, we say the stimulus *elicits* the response, or the response is *elicited* by the stimulus; the stimulus is an *eliciting* stimulus, and the response is an *elicited* response. But we never use *elicited* the other way around, to refer to the effect of a response on the occurrence of a stimulus.
Once that distinction had been made, qualifications were added. In particular, some argued that instrumental or operant behavior consisted of skeletal responses, such as movements of the limbs, whereas reflex or respondent behavior consisted of autonomic responses, such as glandular secretions. This was also seen as paralleling the traditional distinction between voluntary and involuntary action. Such distinctions have since been seriously questioned.

For example, the crouching posture elicited by a sudden loud noise in the startle reflex is a motor response best described as involuntary. But swallowing seems voluntary and yet also involves a reflex relation. It’s elicited by stimulation of the back of the throat, which is why you can’t swallow if your mouth is dry and you have nothing in it to pass back to that area to stimulate it. On the other hand, driving certainly seems both voluntary and operant. Yet an experienced driver sitting in the passenger seat of a car may involuntarily press hard on the floor even though there is no brake pedal there when something suddenly looms up ahead on the road. We have here all of the possibilities: whether behavior is operant or respondent, we can identify examples that seem either voluntary or involuntary. In other words, the everyday distinction between voluntary and involuntary actions has nothing to do with our distinction between operant and respondent behavior. Instead, the most important determinant of whether we call our behavior voluntary or involuntary may be whether we can identify the source of our actions.

Skeletal responses can be elicited and autonomic responses can be emitted. It’s important to maintain the distinction between elicited and emitted responding. But the same response may be sometimes elicited and sometimes emitted; we can’t classify responding effectively into these two categories based on physiological criteria such as the difference between skeletal and autonomic responses. Some other types of unlearned behavior don’t fall easily into such classification, such as those with the characteristics of oscillators, as in circadian rhythms, or of servomechanisms, as in the compensating adjustments of keeping balance (Gallistel, 1980). Human behavior with sometimes ambiguous antecedents includes laughter, yawning, tickle and the shedding of tears (Provine, 2012).

Successive Elicitations: Habituation

A complication with stimulus presentations is that two different presentations of the same stimulus may have different effects. I may startle much more to the first lightning flash in a thunderstorm than to later flashes. Furthermore, the effects of stimuli may depend on how quickly they follow each other. If I’m peeling onions, the tears elicited by the present onion may depend on whether I began working on it right after finishing the last one or just after taking a long break from peeling. And in another effect, called summation, a stimulus below threshold in eliciting a response if presented once may become an effective elicitor if presented repeatedly. A single whiff of pollen might not be enough to make me sneeze, but several whiffs might do it, even if the pollen in each whiff is about the same. In other words, elicited responding often depends on the number of stimulations and their separation in time.

Habituation. The startle reaction is produced by an unexpected event such as a lightning flash or a sudden loud noise. Even without other events to signal it, a repeated loud noise usually produces successively smaller startle reactions, until eventually there is no startle at all. Many stimuli elicit responses called orienting or observing responses; for example, a dog pricks up its ears in response to a novel sound or begins sniffing in response to an unusual odor. As these stimuli recur, the dog’s responding decreases; it occurs with smaller magnitude and longer latency, perhaps even vanishing completely. This reduction in responding with repeated stimuli is called habituation. Habituation occurs with responses ranging from distress calls of birds when a predator passes overhead to contractions in earthworms exposed to light.

Habituation is central to studies of whether preverbal children can distinguish features of
spoken language such as the basic speech sounds or phonemes of the languages of their caregivers (Eimas & Miller, 1992; Ramus, 2002). With nonnutritive sucking as a response, the infant is given a pacifier connected to a device that records the pressure exerted while sucking. If the infant hears a voice speaking a consonant, say b, the infant will typically stop or slow its sucking briefly. If b is repeated, it has less and less effect. In other words, the response to b habituates.

Now the voice says p instead of b. The phonemes b and p differ in that the former is voiced (the vocal cords vibrate) whereas the latter isn’t. Given an infant several weeks old raised by English-speaking caregivers, the first p will ordinarily produce a pause in sucking, even though the response to b has habituated (this might be called dishabituation). The different responses to b and p tell us the infant can distinguish between the two consonants even though not yet able to produce them.

Not so, however, if the infant has been raised by caregivers who speak a language in which the b and p distinction is unimportant. Consider a child raised in an Arabic household, where a single voiced consonant somewhat like the English b has no corresponding voiceless p. Once this infant’s pause in sucking has habituated to the sound b, changing to p makes no difference. There is no evidence the infant distinguishes between them. This research uses habituation to teach us that infants learn about the sound features of the languages they hear around them long before they become skilled in producing those features.

Potentiation. Stimuli sometimes have the opposite effect. For example, electric shocks elicit squealing in rats; if several shocks are delivered, later ones produce more responding than earlier ones (Badia, Suter, & Lewis, 1966). This is called potentiation, which is most likely to occur with stimuli regarded as aversive. For example, as an undergraduate I was a subject in class demonstrations involving electric shock (they might not have passed contemporary institutional human-subject review boards). One involved holding my hand against an electrode as shocks were delivered. The first shock just tingled, but each successive one felt stronger so it became progressively more difficult not to pull my hand away even though shock level stayed constant. My response to the shock had potentiated.

Time Since the Last Eliciting Stimulus. If the stimulus is absent for a while after habituation or potentiation, response probability returns to earlier values. For example, my startle to loud noise may diminish or even disappear after several noises in succession, but after hours of silence I’m likely to startle again to the next noise. Habituation and potentiation aren’t permanent; responding returns to earlier levels as time passes.

Patterning of Behavior in Time

Presenting a stimulus may determine the responding that occurs over an extended time. For example, if we give a rat food it eats but once it finishes it typically drinks if water is available. This relation between eating and drinking is so strong that by repeatedly delivering food in small amounts we can make the rat drink several times its ordinary daily water ration. This increase is called polydipsia, an example of adjunctive behavior, behavior in which one response reliably accompanies some other response (Falk, 1977; Wetherington, 1982).

Polydipsia follows at least in part from the rat’s normal feeding and drinking pattern. With food and water freely available, the rat ordinarily takes a few large meals daily, drinking after each one. If we force it to take many meals by delivering food in small portions every few minutes, the rat still drinks after each meal but doesn’t reduce each drink enough to compensate for the more frequent drinking.

Respondent procedures called temporal conditioning can also impose temporal structure on behavior. When a stimulus is presented at regular intervals, responding may become patterned within these intervals, with those most closely related to the behavior occasioned by the stimulus become more likely as time passes within the interval. For example, when food is presented to a pigeon by operating a feeder at regular inter-
vals, responses such as preening and pacing and turning occurred early, but pecks directed toward the feeder or the floor and orientation toward the feeder became more likely as next feeder time approached (Staddon & Simmelhag, 1971). The early responding, interim behavior, varied from one pigeon to another and at different times for a given pigeon, but the pecking and feeder-related behavior was consistent across pigeons. The later behavior had something in common with the responses produced by the stimulus presentations. Repeated stimuli not only elicit responses but at other times may produce behavior related to the elicited responding.

FROM ELICITED TO EMITTED BEHAVIOR

One problem in tackling this topic is the very word response. It implicitly suggests a response to something. As a derivative of response without the implication of responding to something, I’m sorely tempted to introduce the term sponse (cf. Provine, 1988), but it would be presumptuous of me to do so because the term has little precedent in the literature of behavior and learning. Nevertheless, if the distinction between elicited and emitted responding sometimes seems too esoteric, it might be helpful to try a translation in which elicited responding becomes responding while emitted responding becomes sponding.

The Role of Exercise

“Practice makes perfect” is a familiar saying about the role of repetition in behavior. Before consequences were appreciated the mere repetition of responding, without regard to its consequences, was believed sufficient to maintain behavior. Early accounts treated effects of response repetition, described as basic to learning in laws of exercise or practice. The laws were usually ambiguous on whether it mattered if the repeated response were elicited or emitted. As the study of learning turned to reinforcement and signaling functions of stimuli, a possible role for exercise or practice became neglected.

The Russian physiologist, Ivan Sechenov, was an early advocate of repetition, arguing that reflex integrity is “maintained by the frequent repetition of the reflex” (Sechenov, 1863/1965, pp.28–29) and, further, that the response may become independent of the effects of eliciting stimuli. In infants, for example, sucking is elicited by stimuli; later these stimuli no longer elicit the response, but through adulthood individuals remain able to produce the response even in their absence (W. G. Hall & Oppenheim, 1987; Schoenfeld, 1966).

Not all responses begin with elicitation. Some of the earliest in an organism’s lifetime occur spontaneously, in the absence of identifiable eliciting stimuli. For example, inside its egg the embryo chick makes uncoordinated movements of its limbs. These may prevent the developing bones from becoming fixed in their sockets and may modify the form of growing bones and connective tissue. Later in development eliciting effects appear, perhaps simply as the embryo’s sensory apparatus matures. The progression from spontaneous to elicited responding may be summarized by saying of the embryos that “they ‘act’ before they ‘react’” (Provine, 1976, p. 210). Stimuli become more important later, as when the chick’s rotating movements in pecking its way out of its shell during hatching are affected by whether the chick continues to encounter intact portions of the shell.

Stimulus Presentations in Imprinting

When a duckling hatches, the first moving thing it ordinarily sees is its mother. Even on its first day outside the egg the duckling will probably stay close to her. But if the mother is gone and the duckling first sees something else in motion, such as a human, the duckling will behave toward this stimulus as it otherwise would have toward its mother. Such stimuli are said to be imprinted or, in a figurative sense, stamped into the duckling (Lorenz, 1937).

Imprinting has been demonstrated with stimuli ranging from real and model birds to
electric trains; some work better than others. Imprinting usually develops within a critical period of one or a few days, so it may not occur at all if it doesn’t during this time. A complication is that fear of novel stimuli develops toward the end of the critical period (Hoffman, 1996). As the birds get older, they move away from novel stimuli and make distress calls. Thus, older birds don’t ordinarily stay near novel stimuli long enough for imprinting, which would happen otherwise.

In any case, the duckling begins behaving in significant ways to a stimulus, whether mother duck, human or some arbitrary moving object, if the stimulus is introduced under appropriate conditions and at appropriate times. The typical response is following the imprinted stimulus as it moves, and it’s sometimes said the duckling’s following is elicited by the imprinted stimulus. But here the term elicitation is misleading. If the imprinted stimulus is the mother duck, the duckling follows her, but how does the imprinted stimulus produce following?

When the duckling walks toward the mother, it finds itself closer; when it walks from her, it finds itself farther away. In other words, changing the distance from its mother is a natural consequence of the duckling’s walking. If closeness to the mother is important to it, it’s no surprise it walks toward her rather than away from her. It follows that if we change the duckling’s world so the mother’s closeness requires a response other than walking, the walking should be replaced by that response, as in an experiment by Peterson (1960).

A dark compartment on one side of a window contained a moving imprinted stimulus. On the other side the duckling could make a response that lit up the dark side. The duckling did so even when the response was incompatible with following: pecking at a disk on the wall or standing still on a platform near the window. The critical property of the imprinted stimulus wasn’t that it could elicit following, but rather that it had become important to the duckling. Depending on the consequences, therefore, it could reinforce varied responses: following, pecking, standing still. In natural environments, the duckling’s following ordinarily keeps it close to the imprinted stimulus (usually its mother), but in a laboratory ducklings can learn other responses if they instead have the important consequence of keeping the imprinted stimulus close.

In imprinting, the initial presentations of the to-be-imprinted stimulus don’t change response probabilities. Rather, the presentations are establishing operations; they change the significance of the stimulus. The imprinted stimulus acquires its significance simply by being presented under appropriate circumstances. Imprinted stimuli don’t elicit following. They begin as stimuli toward which the duckling is relatively indifferent and end as stimuli that can serve as reinforcers and shape the duckling’s behavior. The point should have been obvious to early researchers on imprinting. In natural environments, swimming replaces walking when the duckling follows its mother into a body of water. If walking had been mere elicited behavior, it shouldn’t have done so.

Mixing up eliciting and establishing effects can have profound clinical implications. For example, interpreting a hospitalized child’s problem behavior as elicited behavior when instead it arises from reinforcement contingencies might prevent appropriate treatment options from being considered. Misdiagnosis can go either way. For example, if problem behavior is produced by eliciting stimuli, perhaps for neurological reasons, interpreting it as shaped by reinforcement contingencies might similarly lead to ineffective treatment. It can get even more tricky. In multiple causation, eliciting stimuli and reinforcement contingencies may operate at the same time, so identifying the role of one shouldn’t rule out assessments of the other.
Chapter 7
Reinforcers as Opportunities for Behavior

The reward of a thing well done is to have done it.
— Ralph Waldo Emerson

We identify reinforcers by their effects. Without making a stimulus a consequence of responding we can’t say if it will serve as a reinforcer. But even familiar reinforcers like food vary in effect depending on deprivation. Food as a consequence of lever presses might not do much to the rat’s pressing if it’s already had plenty to eat. Reinforcers are inevitably oversimplified if we treat them merely as stimuli. A fundamental property of a reinforcing situation is the responding for which it sets an occasion. When we study motivation or drive we’re concerned with what makes consequences more or less effective as reinforcers or as punishers. In the taxonomy of establishing operations, deprivation and satiation are important ways to change the effectiveness of stimuli as reinforcers or punishers, but not the only ones.

Reinforcers are sometimes distinguished based on the types of operations that established them. For example, a conditional reinforcer is one that has become effective by virtue of its relation to some other reinforcer; the light that comes on when a pigeon feeder is operated will eventually become a conditioned reinforcer because of its relation to food. The establishing operation here is arranging the relation between the stimuli: setting up the feeder so food deliveries are accompanied by the light. In human behavior, money often works as a conditional reinforcer, and because it’s related to so many other possible reinforcers (all the things we’ve bought with it), it’s sometimes called a generalized conditional reinforcer. A reinforcer that doesn’t depend on a relation to other reinforcers is called an unconditional reinforcer.

Many events regarded as unconditioned reinforcers, such as food, water and sexual contact, have obvious biological significance. But reinforcers aren’t limited to such events. For example, sensory stimuli such as flashing lights can powerfully reinforce the behavior of some children on the autism spectrum (Ferrari & Harris, 1981), and when intellectually challenged children are briefly deprived of music or social praise, these events may become more effective reinforcers of other behavior, such as operating a switch; conversely, when they are satiated with music or social praise, the effectiveness of these events as reinforcers decreases (Vollmer & Iwata, 1991).

THE RELATIVITY OF REINFORCEMENT

Reinforcers exist in great variety. Some are consumed. Others aren’t. Some appear effective on the organism’s first experience with them. Others acquire their reinforcing properties during the organism’s lifetime. No common physical properties allow us to identify reinforcers independently of their effects on behavior. For example, it is difficult for us to say what it is about teacher attention that reinforces student behavior, but we do know that when a teacher moves to a first-grader’s desk with perhaps a pat on the shoulder or an encouraging comment contingent on the student’s reading, the student’s study behavior often increases and behavior such as dawdling decreases (R. V. Hall, Lund, & Jackson, 1968). We also know that changes in student behavior can
duration or intensity of stimulation. These light and dark adaptations depend on the depletion and recovery of photosensitive pigments during periods of light and dark and can be studied by examining single cells. But the firing of each photoreceptor will also inhibit and be inhibited by the firing of neighboring cells. These interactions will determine patterns of firings that can be studied only by examining the activity of cells in the context of the activity of the cells that surround them.

If the effects of reinforcers on responses are a variety of stimulation, then that stimulation might produce more or less resistance to change, but the specific rate of responding produced by the contingencies will depend not only on the reinforcers delivered but also by the interactions of this response with other responses for which reinforcers have been arranged, or, in other words, by the context in which the responding occurs. Thus, just as visual adaptations depend on the direct stimulation of receptors whereas patterns of firing of visual receptor cells depend on interactions among them, so also resistance to change depends on direct effects of reinforcers whereas response rates and probabilities depend on interactions among reinforced response classes.

Another metaphor for the effects of reinforcers on behavior is that reinforcers build up a reserve of potential responding, with subsequent response rate proportional to the size of the reserve and with the emission of responses depleting it. Skinner (1938) called his the reflex reserve but later dropped the idea because it couldn’t easily deal with effects of schedules of reinforcement, in which not every response is reinforced. It may be, however, that he dropped it prematurely (Catania, 2005d; Killeen, 1988).

Activation and Coupling

Are there other ways to analyze what happens in reinforcement? A survey of the many quantitative treatments of reinforcement and behavior is beyond the scope of this chapter, but some provide useful hints about how to proceed (e.g., Killeen, 1992; Killeen & Bizo, 1998; Nevin, 1992, 2015; Nevin & Grace, 2000). Reinforcers produce multiple effects. Converging evidence suggests that reinforcement outcomes are the product of two different effects: general activation or arousal, as for example when a rat that had not been eating is now able to eat again; and a more specific effect of the response-reinforcer contingency, a coupling between response and reinforcer (e.g., Killeen, 1994; Killeen & Sitomer, 2003). As a rough approximation, we can say that the total activation of responding over its reinforcement history determines its resistance to change, whereas its rate is determined by its context, including such current variables as the reinforcement of other response classes (cf. Nevin, McLean, & Grace, 2001). To this point our analyses have mainly shown how basic processes can enter into complex behavior, as in attributing imprinting to acquired reinforcers rather than to elicited behavior. But decomposing reinforcement into activation and coupling shows that even the basic processes themselves can be subject to analysis.
The consequences of many responses remain reasonably constant throughout life. For example, we usually touch the objects we reach for and we usually get from one floor to another when we climb a flight of stairs. But for other responses, consequences change. Responses reinforced during childhood may no longer be reinforced in adulthood. Educational systems may arrange consequences such as praise or grades for solving arithmetic problems or answering factual questions, but sooner or later these artificial consequences are discontinued, with the hope that more natural consequences will maintain the responses when the student moves on to other settings. When a response is reinforced, its probability increases. But the increase isn’t permanent. Responding decreases to its earlier levels when reinforcement is discontinued.

The discontinuation of reinforcement is called extinction; when this reduces responding to its earlier level the responding is said to be extinguished. This mainly demonstrates that the effects of reinforcement are temporary. Responding is maintained while reinforcement continues but not after it stops. If extinction didn’t occur, the effects of reinforcement would be permanent. Any responding engendered by reinforcement would last through a lifetime. Clearly that can’t be generally so. For example, if you wear a watch you probably often turn your wrist to look at it; the consequence of looking is seeing the time. But if you stop wearing the watch for some reason, you’ll eventually stop looking; seeing a bare wrist isn’t an effective reinforcer. The decrease in responding during extinction isn’t a special process requiring a separate treatment; it’s one of the properties of reinforcement.

EXTINCTION VERSUS INHIBITION

Extinction was long assumed to actively suppress responding. It was said to have inhibitory effects, in contrast to assumed excitatory effects of reinforcement. This treatment went back to a language applied to data from Pavlov’s conditioning experiments. Skinner’s operant language depended in part on escaping from the implications of those early usages (Skinner, 1938, pp. 96–102). Once those usages were carried over to the language of consequences, they were kept because they seemed consistent with other effects often accompanying extinction. Thus, textbooks tended to devote separate chapters to reinforcement and extinction rather than treating them as two sides of a single phenomenon.

One such effect was spontaneous recovery. In extinction, responding decreases over time. But response rate at the start of one extinction session is usually higher than it was at the end of the last one. Responding was said to have recovered spontaneously from inhibition built up by the end of the last session; this inhibition was assumed to increase within sessions, actively
suppressing responding, and to dissipate between sessions. Such phenomena were taken to mean that responding reduced by extinction was somehow “there all the time but inhibited” (Reid, 1958). The trouble was that when a response was said to be inhibited in extinction, there was no way to measure what was doing the inhibiting.

It isn’t necessary to assume that extinction requires active suppression. For example, the effects of handling may make the start of a session different from later times. If so, effects of extinction late in one session might not transfer to the start of the next session. On these grounds, Kendall (1965) reasoned that the usual pattern of response rates in extinction sessions could be reversed under the right conditions. The key pecks of three pigeons were first reinforced in 1-hr sessions. Repeated 1-min sessions of extinction followed. The first long extinction session came only after responding had reliably decreased to zero in the brief sessions. Within a few minutes, each pigeon began to respond. Until this session, responding had never extinguished at times later than 1 min into a session; responding occurred at these later times when the opportunity was finally available. In a sense, Kendall had demonstrated spontaneous recovery within a session rather than at its start.

Another example of recovery of extinguished responding is called regression or resurgence (Epstein & Skinner, 1980; F. S. Keller & Schoenfeld, 1950, pp. 81–82). Suppose a rat’s chain pulls are extinguished and then lever presses are reinforced. If the lever presses are later extinguished the previously extinguished chain pulls are likely to reappear. By analogy to clinical terminology, the phenomenon suggests regression from current behavior (lever presses) to older behavior that was once effective (chain pulls). It is of considerable practical significance. For example, the training of show dogs sometimes requires during a show the withholding of reinforcers that had been available during training. This must be done carefully to prevent regression to behavior that had been common before but would now spoil the dog’s performance.

**SIDE EFFECTS OF EXTINCTION**

Discontinuing reinforcement has not one but two effects: (i) the contingency between responses and reinforcers ends, so (ii) reinforcers are no longer delivered. In this context, the term *contingency* simply describes the consequences of responding; here it is the effect of a response on stimulus probability. For example, in a contingency in which a rat receives food if and only if it presses a lever, a lever press raises the probability of food from zero to 1.0, but in a contingency in which lever presses do nothing, the probability of food is independent of lever presses. (Strictly, a response-stimulus contingency is virtually always part of a three-term contingency, but we needn’t address that issue here.)

If an extinction procedure terminates both a contingency and reinforcer deliveries, how much of what happens depends on the end of the contingency and how much on the end of food deliveries? In extinction, the rat’s responses no longer do anything, but the rat is also no longer eating. Taking away reinforcers will affect more than just the reinforced response. If food is suddenly taken away from a food-deprived rat that has been eating, for example, the rat becomes more active and perhaps urinates or defecates. If you looked at it, you’d say this was an angry rat. If food was produced by lever presses, the rat might bite the lever. If other organisms are in the chamber, the rat might attack them (Azrin, Hutchinson, & Hake, 1966). And the opportunity to engage in such aggressive responses could even reinforce other responses (Azrin, Hutchinson, & McLaughlin, 1965).

These effects, though observed in extinction, aren’t results of terminating the reinforcement contingency. They occur not only during extinction but also when response-independent or free food deliveries stop. We call them side effects because they are indirect products of the change in contingencies. Whether after free food or food produced by responses, a rat that has been eating can no longer do so. In extinction, these side effects get superimposed on decreases in the previously reinforced responding because
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the termination of reinforcers is necessarily part of extinction.

These effects, such as the aggressive responding generated by terminating reinforcer deliveries, could have been observed in situations that removed reinforcers but didn’t involve response consequences. The implications for applications of reinforcement and extinction procedures are significant. For example, those who work with children sometimes use free or response-independent reinforcers rather than extinction to avoid the side effects of terminating reinforcer deliveries (e.g., Hart, B. M. et al., 1968).

Extinction was long regarded as the most appropriate way to get rid of problem behavior, but that view has fallen from favor as the side effects of extinction were increasingly recognized. You can see the difference even across my own writings on learning. While I was writing an earlier book (Catania, 1992), my colleague Eliot Shimoff urged me to use more human examples, arguing that it would be helpful to include not just anecdotes and hypothetical cases but also actual human data presented in figures. I agreed it was a good idea and began searching out candidate data sets, first in the Journal of the Experimental Analysis of Behavior and then in the journal where it might be assumed they’d be more likely to appear, the Journal of Applied Behavior Analysis. Here and there I found cases of the extinction of human responding, but typically embedded in complex data presentations. A clear description of the procedure and outcome seemed to require a distracting detailed elaboration and even those examples were rare, which is why you won’t find any human extinction data in this book either.

At the time I was heavily involved in a new Masters track in Applied Behavior Analysis in my department, a joint effort with the behavioral programs at the Kennedy-Krieger Institute in Baltimore (Catania, DeLeon, & Cataldo, 2001). My colleagues there were much involved in work with self-injurious and other serious problem behavior in children, so I consulted them about their use of extinction. What I learned was that their procedures had evolved to minimize the use of extinction, with its attendant side effects, in favor of alternatives that didn’t produce such effects.

Dealing with problem behavior presented by children with severe developmental issues is hard enough. Why deal also with aggressive behavior or other emotional side effects of extinction, especially when other techniques are available (Lalli, Casey, & Kates, 1997; Lerman, Iwata, & Wallace, 1999; R. H. Thompson et al., 2003)? The reason I hadn’t been able to find appropriate extinction data in the applied literature was that extinction was not a preferred procedure, so few data were collected and presented. What, then, are the alternatives to extinction?

EXTINCTION VERSUS FREE REINFORCEMENT

Of the two essential components of extinction, terminating a contingency and terminating the delivery of reinforcers, the latter is primarily responsible for most of the unwelcome side effects of extinction. A contingency can be terminated without terminating the delivery of reinforcers by arranging the free or noncontingent delivery of reinforcers (noncontingent reinforcement is sometimes abbreviated NCR). Figure 8–1 illustrates differences between contingent reinforcement, extinction, and free reinforcement or NCR. Baseline conditions, left of the dashed vertical line, show contingent reinforcement (top), extinction (middle) and free or noncontingent reinforcers (bottom). For convenience, the baseline reinforcement conditions on the left are shown as identical, and this hypothetical case assumes a rich intermittent schedule in which reinforcers are delivered after a small but variable number of responses; on average every third or fourth response produces a reinforcer.

The three frames show contingent reinforcement (reinforcers produced by responses) up to the vertical dashed line, followed on the right by continuation of contingent reinforcement (top), extinction (middle) and free or noncontingent reinforcers (bottom). For convenience, the baseline reinforcement conditions on the left are shown as identical, and this hypothetical case assumes a rich intermittent schedule in which reinforcers are delivered after a small but variable number of responses; on average every third or fourth response produces a reinforcer.

When contingent reinforcement continues (top), reinforcers follow closely after the

CHANGE Hart, B. M. et al., TO B. M. Hart et al.,
Figure 8–1 Hypothetical responding maintained by intermittent reinforcement (left) followed by one of three conditions (right): continued reinforcement (top), extinction (middle), or free reinforcement (bottom). With the response-reinforcer contingency discontinued (middle and bottom), responding decreases. The emoticons represent different side effects: the organism is happy as long as it continues to eat whether food is response-contingent or not, but it is unhappy if the food stops.
responses that produce them. The timing of the free reinforcers at bottom are matched or yoked to those in the top frame, which means the rats in the top and bottom procedures receive the same amounts of food distributed identically over time. The difference is that when free reinforcers are delivered (bottom), they can occur at varying times after responses. On the far right the bottom frame shows some substantial delays between a response and a subsequent reinforcer. With extinction (middle), of course, no reinforcers are delivered.

When contingent reinforcement continues (top), response rate remains roughly constant. When the response-reinforcer contingency is discontinued, during either extinction (middle) or free reinforcement (bottom), response rate decreases. Now consider the emoticons. In all the conditions save one, food is delivered, either contingent on responding or freely, so the food-deprived rats who had been eating continue to eat; food is absent only in extinction, and only in that case do the rats who had been eating no longer do so. Discontinuing food has the behavioral effects described earlier and often referred to as emotional.

The contingency between responses and reinforcers is terminated in both extinction and free reinforcement in the figure, and in both cases responding decreases. In other words, responding decreases once the response-reinforcer contingency is broken, whether or not reinforcers are delivered. But only extinction produces emotional behavior. In other words, the discontinuation of reinforcers is what produces this side effect; the response-reinforcer contingency has nothing to do with it.

For convenience, the response decrements in the middle and bottom right frames were shown as equal, but in practice responding usually declines somewhat more slowly with free reinforcers than with extinction, especially on the first as opposed to later exposures to these procedures. Why the slower decline with free reinforcers than with extinction? First a rat’s lever presses are reinforced with food; then, when presses no longer produce food, food deliveries continue independently of behavior. As lever pressing continues, some are still followed closely by food. Lever pressing declines slowly because these frequent accidental successions of responses and reinforcers counteract the effects of terminating the reinforcement contingency. Eventually lever pressing drops out, but extinction would probably have been quicker. For this reason, arranging a transition from a reinforcement contingency to response-independent reinforcer deliveries has sometimes been regarded as a poor way to examine the effects of terminating reinforcement contingencies (Boakes, 1973).

Again, there are practical implications. Free reinforcers aren’t the only option. Suppose an institutionalized boy with developmental problems often engages in self-injurious behavior such as head-banging or eye-poking. Suppose further we discover his self-injurious behavior is in large part maintained by staff attention as a reinforcer. Extinction is not well-advised because of the harm he might do to himself if we ignore the behavior. Giving him attention independently of the self-injurious behavior is one possibility, but that might reduce the behavior only slowly. An alternative procedure is to use attention to reinforce an alternative response, and especially one incompatible with the self-injurious behavior (Repp & Deitz, 1974). The self-injurious behavior will inevitably decrease as the alternative response increases. Such procedures, sometimes called differential reinforcement of other behavior, have been widely applied to problem behavior (e.g., Skiba, Pettigrew, & Alden, 1971, on thumbsucking).

Reinforcers are important, after all. If attention has contributed to increases in the self-injurious behavior of a child with developmental issues, that tells us how important attention is to the child, who will be better served if we shape alternative and more functional ways of commanding attention than if we simply remove attention (Carr, Severtson, & Lepper, 2009; Goh, Iwata, & DeLeon, 2000; Hagopian et al., 2000).

Unfortunately, generations of students given cursory accounts of behavioral methods in introductory textbooks seem to have taken away as the primary message that you should
never reinforce behavior you want to get rid of; instead, you should just ignore it. But if attention as a reinforcer is implicated in the development of self-injurious behavior, then it must be very important and taking attention away may not be the solution. Reinforcement isn’t everything, but extinction isn’t anything. If the reinforcers are already there, they shouldn’t be wasted; they should instead be used constructively.

We all shape each other’s behavior. The more we know about how reinforcement works the more likely it is we’ll use it productively and avoid its pitfalls, such as coercive practices that can follow if control over reinforcers remains one-sided. Free reinforcers coupled with the shaping of other behavior are a better alternative than extinction. Though it might seem more complicated to arrange these contingencies, the absence of the emotional side effects typically more than makes up for the difference.

Even better, of course, is not getting to the point of being tempted to impose extinction. One way to reduce a child’s bad behavior is to reinforce good behavior, and that’s one reason why “Catch them being good” is such an effective slogan for both parents and teachers. Yet how many still take away from an introductory psychology course the message that what parents should do to get rid of a child’s problem behavior is to ignore it? Left unresolved are the inevitable subsequent issues, such as what parents should do when other problem behavior emerges that is maintained by the same reinforcer. We shouldn’t teach parents to ignore the behavior of their children; we should teach them how to use reinforcers productively. You need more than a superficial understanding of reinforcement to do it right.

We’ve made the case that free reinforcement is typically preferable to extinction in applied settings. Given it involves terminating only the response-reinforcer contingency and doesn’t produce some of the side effects of extinction, perhaps the time has come to argue it’s not merely another way to study the effects of terminating contingencies but is the preferable way to do so.

The Vocabulary of Free Reinforcement

Though both terms are common in the literature, I’ll usually refer to the delivery of reinforcers independently of behavior as free reinforcement rather than noncontingent reinforcement. To speak of noncontingent reinforcers may seem a non sequitur or perhaps even an oxymoron, because reinforcers are defined by the effects on responding of contingencies between responses and their consequences and no such contingencies operate when reinforcers are delivered independently. The terminology isn’t ambiguous if used to refer only to the response-independent delivery of stimuli known to be effective as reinforcers and not to the effects of that procedure, but in that case it wouldn’t parallel other common usages (e.g., extinction as terminating reinforcers or as the resulting decrease in responding). This issue is finessed to some extent by free reinforcement, though free reinforcers might be preferable.

Extinction and Superstition

Given the advantages of free reinforcement, why has extinction remained the primary way to study the effects of terminating contingencies for so long? One factor is that disconnecting the lever from the feeder is easier than disconnecting the lever and at the same time substituting a device that operates the feeder periodically. But the answer may more likely lie in properties of behavior than in a mere change in apparatus.

In the phenomenon called superstition (Skinner, 1948), food is repeatedly presented to a food-deprived pigeon at short intervals (e.g., every 10 or 15 seconds); this is, again, free reinforcement. Responses that occur just before food deliveries are likely to be repeated and therefore to be followed closely by still more food deliveries. The effect of the accidental succession of responses and reinforcers is usually obvious. The bird happens to be executing some response as the hopper appears; as a result it tends to repeat
this response. If the interval before the next presentation is not so great that extinction takes place... [this] strengthens the response still further.... The bird behaves as if there were a causal relation between its behavior and the presentation of food, although such a relation is lacking. (Skinner, 1948, pp. 168–171)

The topography or form of each pigeon’s responding changed gradually as the procedure continued, as accidental relations developed between responding and food deliveries. Skinner called such changes topographical drift. A pigeon responded temporarily as if its responses were producing food as a consequence, but no specific one stayed consistently in place as superstitious behavior. Over long periods of time, variations on pecking often dominate as the behavior just preceding food deliveries (Staddon & Simmelhag, 1971). If behavior persists for long periods in the absence of a reinforcement contingency it is often more appropriate to look for other sources of the behavior than to attribute it to superstition arising from adventitious correlations of responses and reinforcers.

Drift itself demonstrates that the effects of accidental correlations between responses and reinforcers are transient. The evidence that free reinforcers don’t ordinarily maintain behavior is substantial (Catania, 2005c). Nevertheless, worries about creating and maintaining superstitious patterns have persisted. Superstitious responding was seen as a ubiquitous problem because such accidental sequences can occur whether reinforcers are independent of responses or are their consequences. But superstition, in its behavioral sense, is no longer regarded as the enduring phenomenon it was once thought to be. Organisms contact only the temporal relations between responses and reinforcers and not the contingencies that generated them. Nevertheless, ordinarily they are exquisitely sensitive to the differences between events produced by their behavior and those that by coincidence follow the behavior. We humans are sometimes an exception, but that’s because human superstitions involve much more than coincidence (cf. Skinner, 1987). They’re typically intricately interwoven with verbal behavior as well as natural contingencies. For that reason we won’t here consider these verbal varieties of human superstition.
Chapter 9
Consequences of Responding: Punishment

In nature there are neither rewards nor punishments; there are consequences.
— Robert Green Ingersoll (1881)

In reinforcement, the consequences of responses make responding more likely. In punishment, the consequences of responses make responding less likely. Paralleling the vocabulary of reinforcement, a punisher is a type of stimulus, but punishment is neither stimulus nor response. The term punishment names a relation between behavior and environment. The relation includes at least three components: (i) responses must have consequences; (ii) their probability must decrease: they must become less probable than when not having those consequences; (iii) the decrease must occur because they have those consequences and not for some other reason. For example, if we knew only that responding decreased, we couldn’t say that it must have been punished; maybe it was previously reinforced responding that has been extinguished. It wouldn’t even be enough to know that the response was now producing some stimulus it hadn’t produced before. We’d still have to know whether responding decreased because that stimulus was its consequence.

A stimulus that reinforces responding when responses produce it may serve the opposite function when those responses remove it: its removal may punish the responding. Inversely, a stimulus that punishes responding when responses produce it may reinforce responding when those responses remove it. For example, money may reinforce, as when a child is paid for completing a chore, but its removal may punish, as when the child’s allowance is canceled because of a misdeed. Similarly, a painful burn may punish, as when I learn not to touch a pan just taken from a hot oven, but its removal or prevention may reinforce, as when I learn to treat a burn with medication or put on kitchen gloves while handling things around a stove. Except for positive reinforcement, reinforcement by presenting a stimulus, these relations are often grouped together as instances of aversive control, which includes both punishment and negative reinforcement, i.e., reinforcement by removal or prevention of aversive stimuli.

Biological parallels are relevant. The gradual disappearance of legs in the ancestors of whales was a phylogenetic variety of extinction; that disappearance is analogous to the disappearance of unreinforced responding in the extinction of operant behavior. Whether in phylogeny or ontogeny, use it or lose it applies (Carroll, 2006). But in either realm, extinction is not the only possible cause of a population decrease. Decreases can be the result of environments that actively reduce a population, as when in phylogeny a mutation causing a distinctive marking makes an organism more likely to be spotted by predators, or as when in ontogeny some responses but not others cause painful burns or other tissue damage. Punishment in ontogenic selection is an analog of the effects of harmful variations in phylogenetic selection.

THE VOCABULARY OF PUNISHMENT

As a procedure, punishment is arranging a response consequence that makes the respond-
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ing less likely. The stimulus arranged as a consequence is called a punisher. For example, if a rat’s lever presses produce electric shock and this procedure reduces lever pressing, the lever press is said to be punished and the shock is said to be a punisher. The response that changes must be the one that produces the punishing consequence. It doesn’t qualify as punishment if a rat’s jumping produces shock and only its lever pressing decreases.

Like reinforcement, the term punishment applies to both procedures and outcomes. Thus, saying a response was punished may mean either that the response produced a punisher or that responding decreased because it produced a punisher. As with reinforcement, our preferred usage will be to restrict the term punishment to the vocabulary of procedures or operations and to describe the outcome directly as a change in responding. As with reinforcement, however, the outcome usage has so much precedent that we can’t avoid it.

The vocabulary of punishment also parallels that of reinforcement in its object: we say that responses are punished, not organisms. If a rat’s lever pressing produces shock and lever pressing decreases, it’s appropriate to say the rat was shocked and the lever press was punished; it goes against colloquial usage, but it is not appropriate to say that the rat was punished. As with reinforcement, this grammatical distinction encourages us to be precise when we describe behavior. One reason it differs so dramatically from everyday usage is that the everyday concern is too often with retribution rather than with changing behavior.

A child misbehaves. A parent calls the child and administers a spanking when the child comes. It may be convenient to say that the parent punished the child, but this usage makes it far too easy to omit the responses that might be affected. The immediate consequence of the child’s misbehaving was that the parent called; the spanking occurred after the child obeyed the call. Although the child might misbehave less in the future because of the spanking, the spanking will probably also make the child less likely to come when called. By the way, this doesn’t mean that a parent intent on spanking should go to the child instead; reinforcing responses incompatible with the misbehavior and other better alternatives don’t require spanking at all.

The point isn’t just grammatical. We’re more likely to see what’s happening if we state the punished response explicitly (spanking punished the child’s approach) than if we settle for a less precise description (spanking punished the child). In endorsing the grammar of reinforcing responses and punishing responses, we needn’t prejudge how these operations affect behavior. They’ll often affect other responses besides those for which they’re arranged (e.g., a spanking may also elicit crying). A vocabulary that states the consequences of behavior helps us to describe such effects without ambiguity.

**COMPARING REINFORCEMENT AND PUNISHMENT**

The effect of punishment is essentially the opposite of that of reinforcement. The relation between the two is illustrated in Figure 9–1, which shows hypothetical reinforcement and punishment data. The top graph shows a rat’s lever pressing during food reinforcement and then during extinction. We could as easily substitute scenarios involving the effects of reinforcing help with household chores or of punishing errors in school work. Coming up with plausible everyday human alternatives is a useful exercise. In any case, during baseline, when lever pressing has no consequences, responding occurs infrequently. When reinforcement begins, responding increases over the first few sessions, after which it remains at a fairly stable level. In extinction, responding gradually returns to its former low baseline level.

The bottom graph shows the rat’s lever pressing during and after punishment of lever presses with electric shock. Because punishment reduces responding, some responding must exist to begin with or we couldn’t observe a decrease. In this example, responding is already maintained by food reinforcement, which continues throughout all sessions; the
Effects of punishment are assessed by superimposing it on this baseline. The baseline shows the responding maintained before lever pressing is punished. When punishment begins, lever pressing decreases to a maintained low level. In recovery, punishment is discontinued and responding gradually returns to its higher baseline level.

Reinforcement and punishment are symmetrical: the former increases responding whereas the latter decreases it; in both cases the effects continue as long as the procedures are maintained and disappear after they end. Nevertheless, the effectiveness of punishment has long been controversial. Punishment was part of Thorndike’s early versions of his Law of Effect, when he argued that behavior could be stamped out by annoyers as well as stamped in by satisfiers. Statements of Thorndike’s law that included the punishment component were called the strong Law of Effect. Later, Thorndike withdrew the punishment component. The version that remained, including only the stamping in of behavior, was called the weak Law of Effect. Thorndike based his conclusion on experiments on human verbal learning in which saying “right” to the learner enhanced responding whereas saying “wrong” had less effect than saying nothing. Thorndike accepted the finding as evidence against the effectiveness of punishment.

Thorndike’s conclusion had so much impact that even data showing punished responding recovered after it was discontinued were inter-
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Prejudices against recognizing punishment were at times so strong that effective procedures were even given a different name, passive avoidance. For example, consider a rat on a platform above an electrified grid set up so the rat is shocked when it steps down to the grid; once shocked, the rat is less likely to step down again later. Stepping down is here punished by shock, but some would say instead that by holding back from stepping down the rat passively avoids the punisher. This usage allowed effective punishment to be discussed as passive avoidance while other procedures that didn’t reduce responding were used to defend the claim that punishment was ineffective.

The issue remains. A study of the behavior of teen drivers after car collisions showed that g-force events, a measure correlated with risky driving, decreased during the first month or so after a collision but recovered to earlier levels after about three months (O’Brien et al., 2017). In other words, the contingency between risky driving and collisions produced temporary punishment effects, just as we might have predicted. But the report of the study made no reference to what we know about punishment and instead mainly attributed the temporary effects to personality variables such as maturity. My guess,
however, is that similar temporary effects would have occurred with adult drivers.

The direct effects of punishers were examined in a historical context in which punishment was typically regarded either as ineffective or, when effective, as the indirect product of other processes (Azrin, 1956; Azrin & Holz, 1966). For example, Skinner (1953) argued that behavior leading up to a punished response generated aversive proprioceptive stimuli that ceased when the individual turned to doing something else. According to this interpretation, the punished response only indirectly became less likely, because switching to something else avoided those aversive cues. Responding was said to decrease not because it was suppressed by the punisher but because everything else was reinforced by avoidance of the aversive stimulus.

The argument that punishment is reducible to avoidance is curious, because punishment is a robust phenomenon in which the abrupt introduction of a strong punisher typically reduces responding very quickly, whereas it is usually difficult and time-consuming to establish avoidance, though it’s robust once in place. Why invoke hypothetical behavior presumed to arise from relations that are difficult to establish to explain behavior that is easy to establish?

Evolutionary considerations add to the argument for the direct effects of punishers. If the phylogenetic origins of reinforcement are rooted in the effects of consequences it would be strange indeed if operant behavior evolved in only one direction, so consequences could increase behavior but couldn’t reduce it. Even if punishment worked that way, however, so we learned not to stick our hands into fires only because we avoided the aversive stimuli occasioned by approaching one, it would make little practical difference. For those who have to make decisions about whether or when to use punishers, punishment contingencies will work pretty much the same way whichever position one assumes. Nevertheless, we’re treating punishment here as a behavioral process in its own right, not as a derivative of something else.

THE RELATIVITY OF PUNISHMENT

In experiments on punishment, punishers are usually chosen for their reliable effect on a variety of responses, because such stimuli reveal the effects of punishment most clearly. One such punisher is electric shock, which can be measured accurately and can be presented at effective levels that don’t damage tissue. Such stimuli, however, are only extreme instances of punishers. For example, some children with developmental problems chronically engage in head banging, hand biting and other self-injurious behavior. A brief squirt in the face with water mist from the sort of spray bottle used to moisten indoor plants is at worst a minor annoyance. When applied contingent on such behavior, however, it is an effective punisher (Dorsey et al., 1980). As such it is relatively innocuous, especially when compared with the serious damage these children can do to themselves. Unfortunately, some who oppose any use of punishment find even this application unacceptable.

Punishment is inevitable because it is arranged by many natural contingencies. A child who teases a barking dog may get bitten and one who plays with fire may get burned. Furthermore, even stimuli that ordinarily serve as reinforcers can become punishers. For example, food that is reinforcing at the beginning of a holiday feast may become aversive by the time the meal has ended. On the other hand, events that superficially seem aversive, such as falling from a height, may be reinforcing under certain circumstances (consider sky diving and ski jumping). Like reinforcers, punishers can’t be defined in absolute terms or based on common physical properties. Rather, they must be assessed by examining the relation between punished responses and the responses occasioned by the punishers.

The Premack principle of reinforcement states that opportunities to engage in more probable responses will reinforce less probable ones. That analysis can be extended to punishment...
(Premack, 1971). In an apparatus that controls a rat’s opportunities to run in a running wheel or drink from a drinking tube, depriving the rat of opportunities to run while giving it free access to water makes running more probable than drinking, and depriving it of water while giving it opportunities to run makes drinking more probable than running.

Rotation of the wheel can be made a consequence of drinking: whenever the rat drinks the wheel begins to turn and the rat is forced to run. When running is more probable than drinking, this procedure increases drinking and it is appropriate to say drinking is reinforced by running. But when running is less probable than drinking, this procedure has an opposite effect: now drinking decreases when running is its consequence and it is appropriate to say drinking is punished by running. If their relative probabilities can be reversed, as in this example, any response can be either reinforced or punished by any other response.

**SIDE EFFECTS OF PUNISHMENT**

As with reinforcers, punishers can have effects independent of their contingent relation to responses. If an organism is shocked or burned or pinched, some of its responses may have little to do with whether these events were brought on by the organism’s own behavior. Difficulties arise in analyzing punishment because such effects must be distinguished from those that depend on the relation between responses and their consequences. As with reinforcement and extinction, once again we must deal with side effects.

Some effects of shock may be primarily physiological, as when successive shocks systematically reduce a rat’s skin resistance. The effectiveness of later shocks may then vary with the rat’s resistance. Other effects are primarily behavioral, as when the apparatus fails to prevent responses by which the rat can reduce its contact with the shock source. For example, fur is an insulator and rats have sometimes minimized punishing effects of shock by pressing the lever while lying on their furry backs (Azrin & Holz, 1966). In either case, such side effects must be taken into account.

**Eliciting Effects of Punishers**

Another difficulty is that punishers are likely to have some effects that occur whether or not they’re produced by responses. Whether or not it was response-produced, shock is likely to elicit a rat’s jumping. As with reinforcement, the punishment effect must depend on the relation between responses and punishers (contingency), not simply on the delivery of punishers.

Response-produced or response-independent shocks were superimposed on rats’ lever pressing maintained by food reinforcement (Camp, Raymond, & Church, 1967). Measured against a no-shock control group as a baseline, shock reduced responding in both groups, but response-produced shock suppressed responding much more than response-independent shock. This difference makes it appropriate to call response-produced shock a punisher. Just as we must distinguish between effects of reinforcer deliveries and effects of the response-reinforcer contingency, we must also distinguish between effects of punisher deliveries and effects of the response-punisher contingency.

If at five-minute intervals a monkey’s lever presses deliver shock to its own tail, the monkey increases its rate of pressing within each interval, slowing down only after the shock is delivered; if the shocks at five minutes are discontinued, the monkey stops pressing (Morse & Kelleher, 1977). Shocks depend completely on the monkey’s behavior. It would receive no shocks if it didn’t press the lever. Why doesn’t it just stop? The paradox is that the same shock that maintains lever pressing when produced by pressing according to this five-minute contingency suppresses lever pressing when produced instead by every press; the same shock can also be used to initiate and maintain escape or avoidance behavior (J. E. Barrett & Stanley, 1980). So how do we decide whether the language of punishment is appropriate? If every lever press produces shock, we call the shock a
punisher because it reduces responding. Should we call the shock a reinforcer because it generates responding? It wouldn’t help to call the monkey a masochist. Masochism is just a name we apply when a stimulus we think should be a punisher serves as a reinforcer; it doesn’t explain anything. Other research suggests the eliciting effects of shock were strong enough to override the punishing effects, so that the monkey’s pressing occurred in spite of and not because of the punishment contingency (Pitts & Malagodi, 1991). If so, the case is analogous to that of the parent who tries to stop a child from crying by punishing the crying and has trouble because the punisher elicits the very response that the parent is trying to suppress. We may not like these contingencies, but if we ignore them that doesn’t mean they’ll go away. As long as human behavior includes such problems as self-injury, our concern with such phenomena is justified.

Discriminative Effects of Punishers

Another side effect of punishment comes about because punishers can acquire discriminative properties, as when a response is reinforced only when it is also punished. An experiment designed to make response-produced shock signal the availability of food arranged two alternating conditions (Holz & Azrin, 1961). In one, a pigeon’s key pecks had no consequences; in the other, every peck produced shock and some pecks also produced food reinforcers. A low rate of pecking was maintained when pecks produced no shock, because then they never produced food either; but pecking increased once pecks began to produce shock, because only then did they sometimes also produce food. With no shocks, the rate of pecking was low. When responses began to produce shock, the rate increased.

Again we can ask whether the shocks should be called punishers. In fact, responding that produced shock increased relative to responding that did not, so we should conclude that shock was a reinforcer. The main difference between the shock and other more familiar reinforcers is that here the shock acquired its power to reinforce through its relation to food; it loses its power if that relation ends. Perhaps these procedures are relevant to human behavior. For example, a battered child might provoke a parent to the point of a beating because the beatings are often followed by more attention from the then-remorseful parent than ever follows less traumatic parent-child interactions. In this example, the beating is analogous to the shock in the pigeon example and the parent’s attention is analogous to the food. A parent’s attention can sometimes be so potent a reinforcer that it overrides the effects of consequences that would otherwise serve as punishers. Thus, a behavioral analysis may be relevant to human problems such as child abuse.

NEGATIVE PUNISHMENT: TIMEOUT

Responses can be punished by the termination of events. For example, removing food contingent on a food-deprived rat’s lever presses is likely to reduce the rate of pressing. The problem is that it might be hard to demonstrate negative punishment. If the rat is food-deprived and food is available, it will probably eat rather than press, so we’ll have few opportunities to punish lever pressing by removing food. For this reason, studies of negative punishment usually opportunities to work for reinforcers rather than the reinforcers themselves.

Suppose a monkey has two levers available and presses on one of them produce food whenever a light is on. We can expect some presses on the other lever, but we can punish them by making each one initiate a time during which the light turns off and presses on the first lever won’t produce food. Such periods are called timeout or, more fully, punishment by timeout from positive reinforcement (Ferster, 1958). Timeout originated in experiments with pigeons and rats and monkeys and was common in the laboratories in which I worked as a graduate student and early in my career, but those origins are unfamiliar so no doubt it’s now best known
As with any form of punishment, the main function of timeout is to reduce behavior, but it’s too often applied without attention to alternative behavior that might be reinforced (Winett & Winkler, 1972). Some who use timeout without understanding its behavioral basis apply it counterproductively. For example, some years ago I conducted research with preschoolers in a local daycare center and occasionally had opportunities to observe how the staff managed the behavior of the children in their care. Timeout was one of their procedures. By then, isolated timeout rooms were already a thing of the past; instead the staff used designated timeout areas. A child who disturbed other children in a playgroup might be sent to sit for five minutes on a timeout carpet near the play area, in view of the other children. I watched as one boy in timeout sat quietly for about four minutes and then began to cry and act up. The staff person nevertheless rigidly adhered to the five minutes of timeout and let him return to the playgroup at the very time when his disruptive behavior was most dramatically increasing. It would have been better to “catch the child being good” and to have allowed his return at the end of three or four minutes. Unfortunately I couldn’t intervene: I had academic credentials but no applied behavior analysis credentials, and in any case a condition of my research arrangements was that I not intrude on staff practices. But it is good to know that timeout procedures have been falling out of favor and are gradually being replaced by other practices based on reinforcement rather than punishment.

THE ETHICS OF PUNISHMENT

Every day animal shelters put down unadopted dogs and cats and other pets that exceed their capacities. Sometimes behavior makes the difference between life and death. If an owner delivers to a shelter a dog that barks excessively or damages furniture, the dog is far less likely to be placed with a new owner than one that doesn’t present these problems (e.g., Wilkes, 1994). Is it unethical to use punishment if it might eliminate such behavior so that instead of being put down the dog can successfully live in a human home?

Punishment can modify human behavior, so questions inevitably arise about the ethics of its application. But punishment can’t be eliminated from natural environments (Perone, 2003). Without punishment, a child who has been cut while playing with sharp objects or scratched when teasing the cat would remain undeterred from doing so again later on. Artificial punishment contingencies, however, are constrained by practical considerations. Because responding usually recovers after punishment is discontinued, punishment must include plans for environments in which the relevant contingencies may be absent, just as reinforcement must include plans for what will maintain the behavior when reinforcement ends. It may do little long-term good to eliminate a child’s self-injurious behavior with punishment in a hospital setting if the punishment contingency does not exist when the child returns home.

The behavioral properties of punishment have implications consistent with ethical arguments against aversive control. For example, a parent who arranges frequent aversive consequences for a child’s behavior may acquire aversive properties. To the extent the child learns to escape from or avoid the parent’s company, contingencies other than those available to the parent will increasingly influence the child’s behavior. But if punishment seems the only effective technique for reducing the self-mutilating behavior of a brain-damaged child, punishment might be a lesser evil than the permanent damage the child might self-inflict. Self-injurious children have been known to disfigure and even blind themselves.

One of the ethical standards for interventions in applied behavior analysis is to impose the least restrictive treatment. This means a treatment that empowers a child by shaping the child’s communication skills will always be preferable to one that calls for restraints or other environmental...
restrictions (Bailey & Burch, 2005; Goldiamond, 1974). Assessments and applications of reinforce-
ment and extinction and punishment contingencies have become increasingly sophisticated (e.g.,
Fisher & Bouxsein, 2011; Lerman & Toole, 2011; Vollmer & Athens, 2011). We may look forward
to the day when parents and other caregivers as well as behavior analysts share this level of
understanding of basic contingencies.

Unfortunately, if we look at the behavior of those who deliver reinforcers or punishers, we see that effects of reinforcement often show up only long after the reinforcer is delivered (the effect of reinforcing a child’s diligent school-
work each day might not be obvious until several days have gone by), whereas the effects of punishment often show up right away (one effect of slapping or scolding a child who is teasing a sibling stops the teasing stops immediately). Thus, delivering a punisher is much more likely to produce immediate consequences than delivering a reinforcer. That means people usually more readily learn techniques of aversive control than techniques of reinforcement, but it doesn’t mean the aversive techniques are better.

Some argue against any kind of modification of behavior, whether involving aversive stimuli or positive reinforcers. But those who make such arguments should recognize that our behavior is being modified all the time, both by natural contingencies and by the artificial ones created by those around us. Politicians and businesses and educators and religious groups and governments arrange all sorts of contingencies affecting our behavior in many ways. Denying that the contingencies exist doesn’t make them go away. Ignorance rarely provides good grounds for ethical judgments, so the counterargument is that our best defense against the misuse of behavioral techniques is to learn as much as we can about how they work.
Chapter 13
Motivating Variables and Reinforcer Classes

We say that an animal is hungry if, when we give it food, it eats.
— B. F. Skinner

Tasting unsalted soup doesn’t make it more likely salt will be passed when you ask for it; arriving in front of a locked door doesn’t make it more likely you’ll find the key in your pocket. But you’ll be more likely to ask for the salt or to reach into your pocket. In each case something neutral (the salt or the key) has become reinforcing.

The semester after my class on discrimination with Schoenfeld, I took his next course in the Experimental Psychology sequence. It was called Motivation. This too was a laboratory course, but this time the experiments were with rats rather than humans. One involved arranging schedules of what were then called conditioned reinforcers. Courses with this title now would probably cover the topic by providing a systematic survey of motivational systems—hunger, thirst, sex, social drives, and so on—concentrating on physiological mechanisms and perhaps speculating on the evolutionary or social precursors that might have created them. The fields are so broad the coverage could hardly be exhaustive.

We considered the meaning of hunger in the context of discussions of a hypothetical caveman who caught and caged a small animal and then began to observe its eating habits. The word hunger seemed so much a term for a private felt state that buying the argument for how the term must have evolved from observations of behavior came slowly (Catania, 1997b). Counterintuitive as it may seem, the point was the term couldn’t have acquired any function in everyday language except to the extent it was based on observations of the likelihood of eating as a function of time since the last meal and other publicly observable variables.

Food is part of our environment. To deal with how we behave with respect to it we should look there instead of searching inside for drives, feelings, hunger pangs or other inner causes. No one looks inside us to decide whether we’re hungry. We think we know better than anyone else what’s inside, but we often judge our own hunger by our behavior: I didn’t realize I was so hungry, we say, while scarfing down a meal. Certainly we’re different when hungry than when well-fed, and it’s worthwhile to find out how we’re different. But, like the probability of eating, hunger can’t be pulled out of an organism and stuck under a microscope. Sure, physiological systems and processes affect the probability of eating, but they’re not what hunger is.

Here’s a Skinner quotation: “In our everyday use of the word…we ordinarily attribute hunger to an animal only because it eats or because it exhibits behavior that we have frequently observed to be followed by eating” (Skinner, 1932, p. 22). He goes on to say, “the use of the word depends on the conditioning of the experimenter.” Skinner identifies the problem as one of verbal behavior, anticipating critical arguments about the origins of our language of private events.

ASSESSING REINFORCERS

The topic of motivational or establishing operations is about those events that make stimuli more or less effective as reinforcers or punishers. We’ve devoted lots of attention to reinforcers so far, and that’s as it should be. To get to know other people, one of the most important things
you can look for is the reinforcers maintaining their behavior. Some are obvious, as when we notice what people spend lots of time doing: are they mostly involved in reading or music or athletics or social events or politics? The questionnaires on values sometimes used to advise people about the careers for which they may be best suited often ask directly or indirectly how they like to spend their time.

When I was close to officially becoming a major in psychology I discussed my options with Schoenfeld. One question he asked was whether I wanted to go into the field because I thought I could use it to solve my own problems. I was puzzled by the question, though I knew that then, as now, clinical psychology was attractive to many students. I probably said something about being fascinated by the quantitative data I’d seen in his experimental classes and in Keller’s introductory course. I think he was probing whether the reinforcers maintaining my academic behavior were fundamentally about finding out how behavior works. Given where things went from there he must have approved of my answer.

In my own interactions with students after I began teaching, I often took Schoenfeld’s lead and probed potential majors about why they wanted to enter the field. In giving students advice it made a difference to learn whether they mostly wanted to help others or learn about behavior or make money or have a chance to meet well-known scholars such as Skinner. Some were single-minded about one or another but more often it was a mix. An inventory of the reinforcers maintaining someone’s behavior provides a personality test of sorts. Your judgments of other people can change dramatically if you believe they’re doing things based on friendship or love and then discover they’re instead doing it for other reasons: e.g., to make money, advance professionally, get even with someone, achieve a position of power, or escape from aversive responsibilities. Reinforcers can be diagnostic.

Reinforcers are also changeable. Behavioral pediatrics deals with both the common and the unusual behavior problems of children (Francisco & Piazza, 2011). Sometimes such problems require interventions and sometimes they take care of themselves. For example, a parent might be seriously concerned about a child’s persistent thumb-sucking when suddenly it drops out. This might happen because new social reinforcers emerge as the child gets older: at some point the social consequences of thumb-sucking become more important than the oral sensory ones.

Identifying reinforcers is crucial to the applications of behavior analysis. Descriptive analysis is a method for assessing and comparing reinforcers (Vollmer, Borrero, & Wright, 2001). For example, one reinforcer may be masked by another that is more potent, so its effectiveness must be assessed not only when the more potent reinforcer is available but also when it isn’t (Francisco, Borrero, & Sy, 2008). A major component of behavioral economics is assessing the relative potency of different reinforcers based on the behavior they maintain; a measure called value summarizes that potency.

Negative reinforcement mustn’t be overlooked (Flanagan, Goldiamond, & Azrin, 1958). For example, aggressive or fearful behavior in dogs and other pets is often interpreted as elicited or emotional behavior, but it may be better viewed as operant behavior reinforced by keeping aversive events at a distance. A growling dog is less likely to be approached than a placid one. A fearful cat is more likely to run and hide when strangers visit than one that’s more relaxed.

Contingencies like these have been exploited to shape calmer behavior in pets whose behavior includes aggression and other topographies usually interpreted as emotional (Rentfro, 2010, Nov/Dec; Rosales-Ruiz, 2011). With an aggressive dog, for example, another dog is gradually brought closer until aggressive behavior begins. The intruder dog is withdrawn only when the target dog reduces its aggressive behavior. Soon the intruder dog is again brought closer and the procedure is repeated. Gradually the intruder is brought closer still as the criterion reduction in aggression becomes stricter. The aggressive dog becomes a friendly one. These dramatic changes in behavior can be shaped in a few days
or even hours and can be maintained by similar contingencies. The distancing that shapes these changes in behavior involves negative reinforcement: the intruder’s approach is aversive, and using the intruder’s retreat to reinforce calm behavior creates behavior more acceptable to all concerned, not just the pet owners.

Evolutionary contingencies made some reinforcers significant: e.g., food, water, sexual contact, air. Others probably emerged as by-products of those motivational systems. These are sometimes called addictive. Some criteria exist for classifying some reinforcer dependencies as addictions, but the term is often used more broadly. As a long-distance runner, can you get addicted to endorphin highs? Can you become addicted to a person? To a political stance or a religion? To dependence or co-dependence? Aren’t we already addicted to food and drink? What then do we say if food is ingested but then rejected, as in bulimia, or is no longer reinforcing and perhaps even becomes aversive, as in anorexia?

These are all questions about reinforcers. It’s useful to know how they become established, as in the transition from casual to habitual drug use. It’s also useful to identify the components of such reinforcers. For example, cigarettes are a vehicle for nicotine, but nicotine by itself isn’t addictive (Killeen, 2011); people don’t get hooked on nicotine patches. Cigarette manufacturers may have exploited the interaction of nicotine with other products of smoking as a route to addiction. Cigarette smoking is especially relevant to self-control, which involves immediate consequences pitted against opposed later ones, as when the immediate effects of inhaling cigarette smoke are pitted against remote effects such as lung disease or cancer. In abstinence programs, smokers must commit to nonsmoking, and what we know about verbal behavior suggests they’re more likely to be successful if their verbal commitment has been shaped during their own talk about smoking than if it’s grown mainly out of instructions given by others. Where verbal behavior comes from sometimes may be as important as what it says.

**REINFORCER CLASSES AND REINFORCER-SPECIFIC EFFECTS**

In three-term contingencies, the first term, antecedents, includes both motivating or establishing operations and the stimulus classes defining discriminated operants. The second term, behavior, corresponds to the response classes called operants. The events included in the third term, consequences, are also classes of events (Cuvo, 2000). Successive reinforcers arranged in experimental settings may be similar but they’re not identical. Pellets produced by a rat’s lever presses will never be totally uniform. Pieces of grain in a pigeon’s feeder will always differ somewhat in shape and color. A parent’s reinforcing hugs or smiles or positive comments will inevitably vary from one instance to the next.

The self-injurious behavior (SIB) of children with severe developmental issues may be maintained as a higher-order class because it produces attention. By sharing its consequences with other responses like shouting obscenities or throwing things, it may become part of the larger class, attention-getting behavior. Within this class some responses may be more probable than others or may be differently available in different settings (Lalli et al., 1995). For example, a child may be more likely to engage in self-injury if nothing to throw is close at hand, or a child might be more likely to shout obscenities given one audience than given another. Nevertheless, their membership in a common class makes it likely they’ll vary together.

But what if attention from staff members on this child’s hospital unit doesn’t function like the mother’s attention when she visits? If we find one kind of attention can’t substitute for the other, we might best treat attention from these two sources as two separate reinforcer classes. This is important to know, because the behavior shaped by attention from the staff during therapeutic interventions may be incompatible with the behavior shaped by the mother’s attention at home. An effective treatment program must shape the mother’s behavior as well as the child’s or the treatment gains
realized on the unit will be lost soon after the child’s discharge.

Operant classes are created by common consequences. These consequences are the glue holding the classes together. But what does this imply about using a common reinforcer across components of a complex task? In a typical matching study, for example, all correct responses, whether to one comparison stimulus or the other, produce the same reinforcer. If the reinforcers enter into a single functional class along with the stimuli and responses of an arbitrary-matching task, using this procedure may be a mistake. While the contingencies work to separate the different matching classes, such as green pecks given a square sample and red pecks given a circle sample, the common reinforcer class may work instead to keep them together, just as a common reinforcer keeps all forms of lever pressing together in a single operant class.

The problem can be addressed by arranging different outcomes each correlated with a different class of discriminative stimuli and responses. When this is done, acquisition of stimulus-control tasks such as matching-to-sample is typically enhanced (Urcuioli, 1985, 1991, 2005; Urcuioli & DeMarse, 1994). This works with both nonhumans and humans (Dube et al., 1993; Fedorchak & Bolles, 1986). In arbitrary matching by children, they may learn slowly even with correction procedures. If the tasks are modified so responses from the different problem classes each produce a different visual reinforcer, such as different cartoon pictures displayed on a computer screen, the acquisition of accurate arbitrary matching usually proceeds more rapidly than when all responses produce the same reinforcer (e.g., Dube & McIlvane, 1995; Dube et al., 1989; Kastak, Schusterman, & Kastak, 2001; Pilgrim, Jackson, & Galizio, 2000; Urcuioli, 2005). The moral is whenever possible we should arrange different reinforcers rather than a single reinforcer for the shaping and maintenance of different response classes.

This needn’t mean two reinforcer classes must differ qualitatively; it’s probably sufficient for them to be discriminated. For example, if a pigeon’s pecks on one key produce a green light inside its feeder and those on a second key produce a red light, with the lifting of the feeder tray requiring a peck on a left switch inside the feeder given green and on a right switch given red, the two routes of access to the food are likely to function as two different reinforcer classes (Catania, 1969). It’s also important to distinguish between common consequences and common contingencies. Different reinforcement schedules arranged for two different response classes will typically maintain different performances even if both produce the same reinforcer. Here the different contingencies arranged for the two response classes matter most.

**CONDITIONAL OR CONDITIONED REINFORCERS**

Once reinforcers are available they can be used to create new ones. Some reinforcers, called *conditional* or *conditioned*, become effective through their relation to other reinforcers. Some of those, called unconditional or unconditioned, aren’t really endpoints but are instead convenient places to switch from talking about reinforcers to talking about physiology. For example, foods may seem fundamental but many are acquired tastes and can be traced to more basic sources. Chewing and swallowing are followed by digestion and eventually the circulation of nutrients in the bloodstream, but for our purposes it’s usually sufficient to talk about the reinforcing effects of an opportunity to eat.

Conditional reinforcers related to many different source reinforcers, of which money is the prominent example, are *generalized* reinforcers. But verbal behavior may be a more critical determinant of the functions of money than how the money is related to specific other reinforcers; for example, the response most likely to be reinforced by a direct deposit into your bank account is checking your account balance. Just as variable reinforcers may maintain more behavior than fixed ones (Steinman, 1968), conditional
reinforcers based on a broader range of reinforcers are likely to be more potent than those based on a narrower range. In the clicker training of pets (Pryor, 1999, 2009), it’s easy to control the relationship between the clicker and edible treats, but the clicker becomes far more effective if it’s broadly generalized to a variety of other reinforcers, such as playful interactions or access to new environments.

**CONCURRENT-CHAIN SCHEDULES: PREFERENCE**

Widely used procedures for assessing the potency of conditional reinforcers are concurrent-chain schedules (Herrnstein, 1964b). Two schedules operate concurrently, but their respective reinforcers are entries into other schedules. More technically: these schedules include concurrent initial links, and a consequence of initial-link responding is entry into a terminal link, in which another schedule operates. For example, one of two equal initial links might give access to a fixed-ratio (FR) schedule, in which the last of a fixed number of responses is reinforced, while the other might give access to a fixed-interval (FI) schedule, in which the first response after a fixed time since some event is reinforced. More responding in the first initial link than the second would tell us the FR is preferred to the FI; the opposite outcome would tell us the FI is preferred to the FR.

Suppose I’m standing in front of two doors behind each of which is an area where some activity is available and I must knock on one of the doors to gain access to the area behind it. Once I’ve finished the activity in that area I can come around and knock on the doors again. After a while I might find the activities behind the left door are more interesting than those behind the right door, so I end up knocking more often on that door than the other. Knocking on the doors are my initial links and what I do after entering an area is my terminal link. If I knock most often on the left door you’ll know its activities are the ones I prefer.

Figure 13–1 illustrates how this procedure can be arranged on two pigeon keys. The initial-link schedules are typically equal and relatively short variable-interval schedules operating concurrently (e.g., VI 30-s VI 30-s; each schedule arranges a reinforcer for the next response after every thirty seconds on the average). Each terminal link operates separately and the pigeon returns to the initial links after the reinforcer for that terminal link is delivered. In this example, the conditional reinforcers are the green and red terminal link stimuli. In their presence responses produce food, so we can ask how potent each one is in maintaining initial-link responding.

This procedure separates the reinforcing effectiveness of the terminal link from the contingencies maintaining responding in that link. If we looked at concurrent responding maintained by a variable-ratio schedule on the left key and by differential reinforcement of low rate on the right key, we’d see a lot more responding on the left than on the right. But that wouldn’t tell us whether a pigeon prefers the left-key schedule over the right-key one. The same point holds for responding in the terminal links: schedule A might produce a different rate of pecking than schedule B, but this rate difference couldn’t tell us how hard the pigeon might work on the white initial-link keys to get to one or the other terminal link. We judge preferences among situations not by how much behavior they produce but by the relative likelihoods with which an organism enters them.

Concurrent chains have shown that reinforcement rate is a more important determinant of preference than the number of responses per reinforcer (Neuringer & Schneider, 1968) and that variable schedules are preferred to fixed schedules (Herrnstein, 1964a). Studies of preferences among various parameters of reinforcement schedules can be technically complex, because they must control for differences in time or responses per reinforcer in terminal links and for occasional biases toward specific colors or sides.

When two or more responses are available at the same time they’re sometimes called choices
and engaging in one or the other is sometimes called choosing. But is choice something I do just before responding or is it my responding itself? If it’s something I do just before responding, then it too is behavior and I should be able to analyze it. For example, I may look over a menu before placing an order; I may read reviews before going to a movie; I may list alternatives and their pros and cons before making an important decision. But none of these is a choice; they are all preliminaries to a choice, which is simply what I end up doing (cf. Skinner, 1950). In any case, a dominance of one alternate over others in a sequence of choices is typically called a preference, and concurrent-chain procedures are especially well-suited for the analysis of preferences.

Self-Control

We usually speak of self-control when we forgo a relatively immediate consequence in favor of a later larger one. Both the immediate and the deferred consequences may be reinforcing or aversive (Rachlin, 1974; Skinner, 1953). A small reinforcer now may be declined in favor of a large one later, as in skipping a small purchase now and saving up for a larger one later. We might call this self-control or self-restraint. If this kind of behavior under these kinds of contingencies

![Diagram](image-url)
cies characterizes self-control, we should be able to synthesize it in the laboratory.

Concurrent-chain schedules using the procedure in Figure 13–2 provide an example of how to do it (Rachlin & Green, 1972). Initial links consisted of concurrent FR 25 FR 25 schedules: every 25th peck on a key produced its terminal link. With this arrangement, the pigeon could enter one terminal link more often than the other. In terminal-link A, the keys were dark for 7 s and then lit red and green respectively. A peck on red immediately produced two seconds of food; a peck on green produced four seconds of food after a four-second delay. In terminal-link B, the keys also were dark for 7 s seconds; then only the green key lit. As in the other terminal link, a peck on green produced the large reinforcer after a four-second delay.

Confronted with both red and green in A, the pigeon almost invariably pecks red, producing the small immediate reinforcer and not the large delayed one; this has been called impulsiveness. Confronted with only green in B, the pigeon necessarily produces the large delayed reinforcer. But what about the pigeon’s preference for A versus B, in its initial-link responding? The answer depends on 7, the time until the terminal-link keys are lit. When it’s short, say one second, the pigeon usually produces A and then pecks red. When it’s longer, the pigeon is more likely to produce B, in which only green is available. Figure 13–3 shows the relative rate of pecking the left initial-link key (left initial-link pecks divided by total initial-link pecks) as

Figure 13–2 A concurrent-chain procedure for synthesizing some properties of impulsiveness, commitment and self-control. According to FR 25 schedules, pecks on white (W) initial-link keys are followed after 7 s by terminal links. In terminal-link A, red (R) and green (G) keys respectively make an immediate small reinforcer or a delayed large one available. In terminal-link B, the green key alone makes only the delayed large one available. (Adapted from Rachlin & Green, 1972)

Figure 13–3 Relative initial-link pecks producing terminal-link A (left initial-link pecks divided by total initial-link pecks) as a function of 7, the time to the onset of the terminal-link keys. (Adapted from Rachlin & Green, 1972, Table 1)
a function of $T$. As $T$ increased from 0.5 to 16 seconds, the proportion of pecks producing A decreased; the pigeon became more and more likely to enter B and produce the larger reinforcer. Translating to more colloquial terms, when the opportunity to choose was coming up very soon, the pigeon was likely to be impulsive; when it came up later, the pigeon was likely to show self-control.

During initial links, the time to food equals $T$ for the small reinforcer but $T$ plus the delay for the large one. When $T$ is short, this difference is relatively large (e.g., with a $T$ of one second, the respective delays are one and five seconds) and the short delay outweighs the difference in reinforcer magnitudes. When $T$ is long, however, the difference becomes relatively small (e.g., with a $T$ of ten seconds, the respective delays are ten and fourteen seconds) and the difference in reinforcer magnitudes becomes effective. By producing B when $T$ is long, the pigeon commits itself to the large reinforcer even though it wouldn’t do so at the onset of green if red were also present. For this reason, pecks that produce B have been called commitment responses: they guarantee the large delayed reinforcer by making the small immediate one unavailable.

Figure 13–4 illustrates two hypothetical delay-of-reinforcement gradients, one produced by a relative small reinforcer at A and the other by a later large reinforcer at B. If at any time the pigeon’s peck is determined by which gradient has the higher value, then the A gradient is higher as the pigeon approaches time C, it will commit to reinforcer B, showing self-control. At C the gradients cross over so the A gradient is higher; between times C and A it will choose reinforcer A, showing impulsiveness.

With concurrent-chain procedures we can study impulsiveness and commitment with immediate and deferred reinforcers or immediate and delayed aversive stimuli (Deluty, 1978). We can also see whether commitment is modifiable and whether this synthesis of self-control involves variables comparable to those operating in human behavior (Grosch & Neuringer, 1981). We humans are far more likely than pigeons to forego small and currently available reinforcers in favor of large delayed ones, perhaps because human self-control involves verbal behavior. But if more complex processes operate in our self-control, we can only identify them by seeing whether human cases are consistent with analyses based on reinforcer delays. For this reason, these behavior synthases provide an essential reference for analyzing self-control.

Procrastination

Self-control may involve deferring a small immediate reinforcer for a later one, but it may also involve immediate and deferred aversive events. For example, a small reinforcer now may be declined in favor of avoiding a large aversive event later, as when an alcoholic refuses a drink and avoids a later hangover or when a smoker declines a cigarette and avoids later lung disease; a small aversive event now may be accepted in favor of a large reinforcer later, as when strenuous exercise prepares an athlete for a major event later; and a small aversive event now may be accepted in favor of avoiding a large one later, as when a maintenance dental cleaning avoids gum disease or toothache later.
Most situations we’d discuss as examples of procrastination involve deferring a task from now until later, as in playing an online game now rather than preparing for an exam coming up later in the week. Because the task is deferred, one of two assumptions seems reasonable: (i) the task has some aversive elements, or (ii) the task is weakly reinforcing relative to reinforcers available for what can be done right now. While writing this passage, I glanced over at a paperweight on my desk given to me as a gift. Inscribed on it is the saying “The ultimate inspiration is the deadline.” A deadline may reduce procrastination, but it works best as the deadline approaches; completing a major task under time pressure is often more aversive than getting it done earlier at a more leisurely pace. On the other hand, an increase in competing immediate reinforcers will probably enhance procrastination.

What might we do to synthesize procrastination in the laboratory? Suppose we start a pigeon out with forty-second trials in which free food is delivered on the average once every twenty seconds in the presence of either green or red houselights; the pigeon can initiate a green or a red trial by pecking either a green or a red key (Mazur, 1996, 1998). Six seconds into a green trial, the green keylight turns on and the pigeon can get back to the free food condition by pecking five times. Twenty seconds into a red trial, the red keylight turns on and the pigeon can get back to the free food condition by pecking thirty times. We now look at whether the pigeon prefers to initiate green trials or red ones and discover it prefers red, containing the larger later task, over green, containing the smaller earlier task. Pigeons, like people, procrastinate.

Free-Choice Preference

Concurrent-chain schedules can be used to determine whether opportunities for free choice can function as reinforcers. Questions about freedom are questions about whether organisms prefer alternatives. We may believe it’s good to have options, but can we demonstrate such preferences and are they important to pigeons as well as to people? By making two keys available in one terminal link and only a single key in the other, we can ask whether pigeons prefer free choice to forced choice (Catania & Sagvolden, 1980; Sran & Borrero, 2010).

This procedure uses equal VI 30-s schedules operating in initial links; on either initial-link key, pecks produce their terminal links once every thirty seconds, on average. Four keys are lit red or green in both terminal links. In free choice, pecks on any of three green keys are reinforced at the end of a fixed interval (FI 30-s); pecks on red are ineffective. In forced choice, the same FI 30-s schedule operates for pecks on green; pecks on any of the three red keys are ineffective. The FI schedule delivers a reinforcer for the first peck after thirty seconds in either terminal link, so the pigeon earns reinforcers after about the same time and with about the same responding whether doing so on one of three keys in free choice or just one key in forced choice.

In these schedules, pigeons prefer free choice to forced choice. Furthermore, control procedures show the preferences don’t depend on terminal-link differences such as responses per reinforcer or how responses are distributed to keys or colors or locations (Catania, 1975a). Could it be the pigeon has learned that different contingencies exist in free and forced choice? If one key fails during free choice, the other is available as an alternative; if the single key fails during forced choice, no other is available to fall back on. If free-choice preference is learned this way, we should be able to reverse it by making more reinforcers available during forced choice than during free choice. But if we do so, the effects are only temporary; the free-choice preference returns when the reinforcers in the terminal links become equal again. We can’t produce a durable forced-choice preference (Catania, 1980b).

Perhaps the free-choice preference has a phylogenetic basis. For example, food supplies are sometimes lost to competitors or disappear in other ways, so choosing environments with two or more food sources will probably have advantages over choosing environments with only one food source. If such preferences exist even in the behavior of pigeons, they can’t be mere products
of human cultures (cf. Page & Neuringer, 1985, p. 451). They may occur because evolutionary contingencies have selected organisms who prefer free choice to forced choice. If so, we may be able to mask it temporarily, as by punishing responding during free choice but not forced choice, but we won’t be able to eliminate it. This conclusion is based on data from pigeons, but maybe this makes free-choice preference even more fundamental, because it seems to imply that this aspect of our human concept of freedom has biological roots. If so, no political entity can take it away.

MOTIVATING EVENTS IN AVERSIVE CONTROL

The presentation of aversive stimuli makes their removal reinforcing. Even more so than with positive reinforcement, these establishing effects must be distinguished from discriminative, eliciting and other effects of stimuli. When we deal with positive reinforcement, we usually speak of motivating operations such as satiation and deprivation. Food is less likely to reinforce the behavior of a rat that very recently ate than of one that hasn’t eaten for some time. But we must present negative reinforcers to get behavior going. The motivating operation is presentation; we’d call that satiation were the stimulus food instead of shock. Why the motivating event in the case of negative reinforcement is the aversive stimulus itself may not be obvious.

The aversive stimulus is the motivating event because there’s no reason to escape or avoid an aversive stimulus unless it’s either actually or potentially present. It’s tempting to think of the aversive stimulus as signaling a contingency, but contingencies in which responses turn off a shock can’t exist in the absence of shock. This is different from positive reinforcement; when responses produce food, the contingency can be signaled whether or not the rat has been food-deprived.

Here’s an example. Shock is delivered to a rat when a light is either on or off; a lever press removes the shock for a while when the light’s on but not when it’s off (Bersh & Lambert, 1975). Under these circumstances the rat comes to press the lever when the light’s on but not when it’s off. The discriminative stimulus here is the light, because the contingency between lever presses and shock removal is signaled by whether the light is on or off. The shock doesn’t function as a discriminative stimulus because it doesn’t signal the operation of the contingency. It makes shock-free periods reinforcing and its presentation is therefore a motivating operation.

The contingencies operating when the light is off in this example are properly called extinction contingencies. Lever presses remove shock during light but not during dark, but shock absence would be an effective reinforcer during either one given appropriate contingencies. This wouldn’t be so if shock were never present when the light’s off. And even without correlated lights a rat might come to discriminate periods during which its presses turn off shock from those in which they don’t, but that would depend on its sensitivity to relations between its behavior and consequences rather than to the presence of shock per se.

The aversive stimulus is the motivating or establishing event because there’s no reason to escape or avoid an aversive stimulus unless it’s either actually or potentially present. A similar case for shock presentations as motivational can be made for avoidance. It should then be a straightforward exercise to extend the argument to cold or bee stings or loud noise or other aversive stimuli. In each case contingencies are about the consequences of responding whereas motivating events are about whether those consequences are important enough to serve as reinforcers.
Not all classes of responses have consistent consequences. The reinforcement of some responses but not others, intermittent or partial reinforcement, is a general feature of behavior. I don’t always find what I’m looking for when I shop and I don’t always get a satisfactory reply when I ask a question. Suppose I phone a friend. Sometimes I’ll get to talk to my friend, but other times I’ll get no answer or a voicemail greeting or someone else will answer. Games of chance routinely provide intermittent consequences. Continuous or regular reinforcement, the reinforcement of every response within an operant class, is the exception rather than the rule. For this reason, we must examine the effects of schedules of reinforcement, arrangements specifying which responses within an operant class will be reinforced (Ferster & Skinner, 1957).

Three basic schedules are (i) those allowing a response to be reinforced after some number of responses (ratio schedules), (ii) those allowing a response to be reinforced after some elapsed time since some event (interval schedules), and (iii) those allowing a response to be reinforced depending on the rate or timing of prior responses (schedules that differentially reinforce rates or interresponse times). These number, time or rate requirements can be combined to produce more complex schedules. We’ll look at effects of reinforcement schedules as valuable experimental tools and as ubiquitous properties of behavior in their own right.

Let’s return to the telephone. Suppose I call a cousin whose voicemail is inactive and get no answer. My chances of getting an answer later will depend on when and not on how many times I call. My cousin will answer only if I call at a time when my cousin is available; if not it won’t make any difference how many times I try calling. Some varying time will pass depending only my cousin becoming available. I must call at a good time to get an answer. This is an everyday approximation to a variable-interval or VI reinforcement schedule. It schedules a reinforcer for a single response occurring after a specified time has elapsed, and that time varies from one instance to the next; earlier responses do nothing. A VI schedule is designated by the average time to the availability of a reinforcer.

Now I’d like to get something from a vending machine, but the machine won’t accept the change I have. I can start asking those who pass by for change and maybe I’ll get what I need. In this case, whether I get the change doesn’t

Part V: LEARNING WITHOUT WORDS: CONTINGENCIES

Chapter 14
Parameters of Reinforcement: Schedules and Delays

It is a capital mistake to theorize before you have all the evidence. It biases the judgment.
—Sir Arthur Conan Doyle, 1888
with increased reinforcement. The performance is highly resistant to change though its rate remains relatively low, and again illustrates the independence of response strength and response rate (Nevin & Grace, 2000). In DRL and related procedures involving latencies or temporal judgments, with both humans and nonhumans, responding tends to overestimate short time criteria and to underestimate long ones: the longer the time, the more likely it is that responses will be emitted too soon (Catania, 1970).

Other classes of differential-reinforcement schedules set other temporal criteria. For example, the flip side of DRL is the differential reinforcement of high rate or DRH schedule, usually specified by the number of responses required within a time window. For example, an 8-peck/2-second DRH delivers a reinforcer any time the pigeon pecks eight times in less than two seconds. If a pigeon slows down for any reason, pecking fails to meet the rate criterion as often and thus produces fewer reinforcers. This reduces the rate even further, so this vicious circle will probably end in extinction. To restore high rates, the experimenter may have to start over from scratch.

**DELAY OF REINFORCEMENT**

The suggestion that the FI scallop involves a gradient of delayed reinforcement carries the implication that the reinforcer produced by the last of a sequence of responses has effects depending on its relation to all preceding responses and not just the one that produced it. In the early days of schedules, so-called partial reinforcement effects seemed paradoxical: more behavior was generated by reinforcing a fraction of the total responses than by reinforcing all of them. But looking at schedules as the delayed reinforcement of all responses preceding the reinforced response suggests that partial reinforcement works as it does because it allows each reinforcer to act on several responses at a time instead of just the most recent one.

Early responses in sequences ending with a reinforcer contribute less to future responding than later ones, because they’re separated from the reinforcer by longer delays (Dews, 1962). This means we need to know the form of the delay gradient to interpret schedule effects. The delay gradient has entered into mathematical models of operant behavior (e.g., Catania, 2005d; Catania, 2011a; Killeen, 1994), but technical problems complicate its experimental determination. For example, if we arrange delayed reinforcers some fixed time after a response, either we must allow additional responses to occur in the interim, in

![Figure 14–6 Schematic of reinforced response sequences: (i) the last of two responses is reinforced; (ii) the last of eight is reinforced. Reinforcement probabilities are respectively 1/2 and 1/8, but only two responses are followed by the reinforcer in i as opposed to eight responses in ii. Details in text.](image)
which case the time from the last response to the reinforcer will be shorter than the one we scheduled, or we can reset the delay with each response, in which case the timer reset will differentially reinforce pauses at least as long as the delay and that differential reinforcement will be confounded with the delayed effects of the reinforcer (Catania & Keller, 1981). We can’t avoid the problem by presenting a stimulus during the delay, because that substitutes an immediate conditional reinforcer for the delayed one, but we can address it by arranging reinforcers for one response class and studying its delayed effects on others (Bruner et al., 1998; Catania, 1971; Escobar & Bruner, 2007).

Some practical implications may be more important than the technical problems. The effects of delayed reinforcement aren’t restricted to responses in a single operant class. For example, a pigeon’s pecks on one key may be maintained because they’re followed later by reinforced pecks on another key (Catania, 1971). Now consider a task involving correct responses and errors over successive trials (e.g., matching-to-sample). If we reinforce all corrects and repeat any trial with an error until the pigeon gets it right, we guarantee any string of errors will end after some delay with a reinforced correct. Corrects will probably dominate eventually because they’re the ones most closely followed by the reinforcer, but errors may diminish only slowly and even continue at a modest level because they too are reliably followed, after a delay, by a reinforced correct.

The moral of this story is that teachers and clinicians must be alert for sequences in which errors are followed by reinforced corrects, so errors aren’t strengthened along with the reinforced corrects. A reinforcer following a sequence of corrects will do a lot more good than one following a single correct after several errors. Teachers must then judge whether corrects are so infrequent they should be reinforced even though preceded by errors or frequent enough that the reinforcer can wait until the student has made several corrects in a row. When response classes we didn’t intend to reinforce precede behavior we’ve targeted for reinforcement, we may mistakenly conclude the reinforcer isn’t doing its job very well. But if that other behavior is maintained by delayed effects of our reinforcer, it may simply be doing very well a job other than the one we wanted it to do. We should keep behavior we don’t want to reinforce from getting consistently close to reinforcers produced by other responses, and we should again be reminded that shaping is often more art than science.

Delays and the Ratio-Interval Difference

What makes ratio response rates higher than interval rates? Procedures like yoked scheduling rule out reinforcement rate and other input-output alternatives as candidates. The question’s been around a long time (Skinner, 1938). One suggestion was the differential reinforcement of interresponse times or IRTs (Anger, 1956). In VI schedules, the more time that passes without a response, the more likely the interval has ended and the next response will be reinforced; reinforcement probability grows with IRT. In VR sequences, reinforcement probability is independent of IRT; reinforcement probability is constant. The higher reinforcement probability for long than for short IRTs in VI is in effect differential reinforcement of long IRTs, which corresponds to a decrease in response rate. This happens only in VI schedules, so VI rates should generally be lower than VR rates. The IRT argument seems reasonable, but the rapidity with which the VI-VR rate difference emerges works against it. Acquisition of DRL performance usually takes a while whereas the VI-VR difference emerges quickly. Attributing an outcome that develops quickly to a process that occurs more slowly isn’t persuasive.

Delays can provide the answer. The delayed effects of each reinforcer work only back to the preceding reinforcer (Catania, Sagvolden, & Keller, 1988); each reinforcer only affects its own responses. Ratios allow responses to bunch up closer and closer to reinforcers and as they do
so the time between reinforcers shortens, which means delays get shorter still, so responding again increases until it gets to the point where rates can’t get much higher. In intervals, however, getting closer adds more responses but doesn’t shorten time between reinforcers. If responding increases, more responses will occur during that interval but many will be followed by the reinforcer by long delays and therefore contribute weakly to the maintenance of responding.

Think of each reinforcer as generating some potential for responding that’s greater the shorter the delay. If the potentials for each response leading up to the reinforcer are summed and if each emitted response reduces that potential, differences between ratio and interval responding necessarily follow. These relations have been demonstrated in computer simulations (Berg & McDowell, 2011; Catania, 2005d, 2011a) and are consistent with models based on ontogenic selection (McDowell, 2004, 2013).

**REINFORCEMENT SCHEDULES AND CAUSATION**

The effects of reinforcers depend on the responses they follow, but reinforcers can follow responses when either produced by responses or delivered independently of responses. Does responding change the same way when it produces a reinforcer as when it happens by accident to be followed by a reinforcer? Causal relations between responses and reinforcers affect behavior differently than coincidental temporal continguities. Organisms are sensitive to the consequences of their own behavior, and our concept of causation arises at least in part from the distinction between events caused by our behavior and those accidentally correlated with our behavior.

The different effects of response-dependent and free reinforcers depend in a complex way on how correlations among events are integrated over time. We can illustrate the complexity with a human example. If a lobby elevator has no floor indicator, the only consequence of my pressing the elevator button will probably be the arrival of the elevator after a variable delay. But the elevator might also arrive because someone pressed the button earlier and then took the stairs instead, or because someone already in the elevator pressed the button for the lobby floor, or because this elevator always returns to the lobby after calls to other floors. One day the elevator door might open just as I reached out to press the button; on another it might arrive and leave and arrive again, even though I didn’t press the button in the meantime because I was standing there talking with someone. When the elevator arrives, I can never be sure my button press brought it to my floor. Nevertheless, I’ll probably continue to press elevator buttons.

There are several elevators in the buildings I typically visit when I’m on campus. The programs for when the door closes and the elevator starts after someone has pressed a floor button vary from one elevator to another. In one the door closes automatically a few seconds after the press of a floor button and subsequent presses do nothing. The door in another elevator also closes automatically but after a couple of seconds a second press on any floor button closes the door. Still another imposes no delay between a press and door closure. With so many variations I’ve occasionally suggested that students work out the arrangements for one or more elevators as an exercise in analyzing contingencies. Their judgments about causation in these cases, like mine, will depend not on constant conjunctions of events but rather on a sampling of outcomes produced by complex contingencies.

**THE TAXONOMY OF REINFORCEMENT SCHEDULES**

Some parts of the schedule vocabulary are logical but others are admittedly idiosyncratic. For example, the names for FI and VI versus FT and VT schedules are arbitrary; either pair could as easily have been fixed-duration and
variable-duration, presumably abbreviated FD and VD. Though FI, DRL and FT schedules all require passage of time, what responding does is different in each. An FI schedule imposes no conditions on responding during the interval but one response must occur after it ends; a DRL schedule requires time without responding and then the next response is reinforced, while responses emitted too soon start the time over; an FT schedule delivers a reinforcer without regard to responding, so responses don’t anything. These names emerged incidentally as research evolved and are so well established they’d be hard to change.

Most schedule names apply whether schedules are arranged successively without interruption or occur within separate trials. For example, an FI is usually timed from the last reinforcer, but if other events are arranged between successive intervals, timing can begin with the onset of some stimulus, such as a color presented on a pigeon key. Also, the vocabulary of reinforcement schedules can be extended to punishment (Azrin, 1956). The symmetry extends to scheduling effects. For example, superimposing an FI schedule of punishment on maintained responding produces an inverted scallop, a gradually decreasing response rate as the end of the interval approaches, instead of the increasing rate an FI schedule of reinforcement usually produces (Silverman, 1971).

Of several noteworthy attempts to classify reinforcement schedules more systematically (e.g., Schoenfeld, 1970; Schoenfeld & Cole, 1972), none has attained general usage. Appendix III summarizes some major schedules by providing schedule names and standard abbreviations along with brief descriptions of contingencies and notation.

Schedules of reinforcement are powerful determinants of behavior. It’s one thing to describe them and another to watch their effects. It means going “from something read about passively to a practical and powerful activity that influenced large magnitudes of behavior instantly and in orderly ways…. For some, there is a magical sense of playful achievement when a procedure is converted to orderly behavioral control” (Ferster, 1978, p. 348). In an article called “Are Theories of Learning Necessary?” Skinner (1950) contrasted behavioral accounts of learning with theories appealing to dimensions other than behavior. His conclusion wasn’t to reject theories in general but rather only certain types:

Perhaps to do without theories altogether is a tour de force that is too much to expect as a general practice. Theories are fun. But it is possible that the most rapid progress toward an understanding of learning may be made by research that is not designed to test theories…. This does not exclude the possibility of theory in another sense. Beyond the collection of uniform relationships lies the need for a formal representation of the data reduced to a minimal number of terms. A theoretical construction may yield greater generality than any assemblage of facts. (Skinner, 1950, pp. 215–216)
When you’re a Jet and you’re walking toward some gang members down the street, it really matters whether you can discriminate between your own gang and your rivals, the Sharks. The two gangs dress differently and talk differently and act differently, so it’s easy to tell them apart. But discriminating isn’t just easy; it’s inevitable. You couldn’t keep from discriminating if you tried. Continuing down the street is likely to be reinforced if you find yourself among other Jets, but it’ll probably be punished if you end up in the middle of a group of Sharks. This is a straightforward three-term contingency: given the discriminative stimulus Jets, walking down the street is reinforced, but given Sharks it’s punished. So too for Sharks who see either other Sharks or only rival Jets down the street. Under such circumstances, would any member of either gang fail to discriminate based on stimuli correlated with gang membership?

When we discuss discrimination in the technical vocabulary of behavior analysis, we do so in the context of specifying conditions under which organisms come to behave one way in the presence of some stimuli and another in the presence of others. When we discuss it in everyday talk, however, it’s usually in the context of concerns about how people deal with and treat each other. We ask whether some individuals might be discriminated against based on race or ethnicity or gender or sexual orientation, or whether discriminatory practices within certain educational or professional or social or religious institutions might confer advantages or disadvantages on some individuals but not others. Sometimes the term has more favorable implications, as when we say someone has discriminating tastes. All this may seem worlds apart from what makes a pigeon peck a green key but not a red one. Here, however, I’m arguing for a common thread tying all these issues together.

What are my credentials? Well, first, I’m an expert in discrimination. By that I mean I got a grade of A in an undergraduate course, Psychology 3, called Discrimination, and I’ve continued studying and later teaching on that topic ever since. My course, part of an Experimental Psychology sequence, concentrated mainly on vision and hearing and other sensory systems, but its content led directly to the topic of discrimination learning in the field eventually called behavior analysis.

Probably more important, I was fortunate in the diversity represented in the environments in which I’ve lived and worked. I grew up in the Washington Heights area of Manhattan in New York City in an apartment building at the intersection of several ethnic neighborhoods. My classmates in the local elementary school, P.S. 132, though racially homogeneous, included Hispanics, Irish, Scandinavians, Jews, Greeks and Italians, no doubt among a few others. Later, during high school and through my sophomore year in college, I took summer jobs at Harlem Hospital. I was the only white summer employee there, where I worked in the dietary department, the outpatient department, and then as a ward clerk substituting for staff members on vacation. In those days, most doctors and senior staff were
tions from vertical. In this group, changing the line orientation affected its distance from the vertical extinction stimulus but not its distance from the reinforcement stimulus, the absence of a line. This is an inhibitory gradient. This gradient was shallower than the excitatory one, probably because organisms are more likely to attend to stimulus properties correlated with reinforcement than to those correlated with extinction (Dinsmoor, 1995).

Feature-Positive Discriminations

Suppose the alternating stimuli of a reinforcement-extinction discrimination consist of an array of squares with an asterisk substituted for one of the squares or the same array with no asterisk, as in Figure 15–4. The asterisk is the distinctive feature of these stimuli, and a pigeon will acquire this discrimination far more quickly if the asterisk is correlated with reinforcement (feature positive) than if it’s correlated with extinction (feature negative). The pigeon is much more likely to look at the asterisk in the former case than in the latter (Jenkins & Sainsbury, 1970). Human behavior can be similarly captured by such contingencies.

The distinctive stimulus appears in different places in the array over successive trials. As the pigeon masters a feature-positive discrimination,
it begins to look at and peck the distinctive stimulus wherever in the array it’s located. Because it’s correlated with reinforcement, the distinctive stimulus becomes a conditional reinforcer, so looking at it is reinforced. With the feature-negative discrimination, however, the distinctive stimulus is correlated only with extinction, so looking at it isn’t reinforced. If anything, the pigeon looks at the squares without an asterisk, which are correlated with reinforcement during reinforcement trials. A pigeon that fails to look at the asterisk is less likely to learn to discriminate between its presence and its absence and so learns this discrimination more slowly.

Whatever the stimulus, we can always ask about the features to which organisms attend. For example, suppose a pigeon looks only at the upper edge of a key with a vertical line projected on it. If we rotate the line from vertical, its top is gone from the upper edge of the key, which now looks more like it did when no line at all was there. In this case, the line is the stimulus in name only: it’s a nominal stimulus. The functional stimulus is what appears at the upper edge of the

![Figure 15–3](image_url) Excitatory and inhibitory stimulus-control gradients after VI reinforcement of pigeons’ key pecks during one stimulus (SD) and extinction during another (SI). For one group, a vertical line was correlated with reinforcement and its absence with extinction (filled circles); for another, the stimuli were reversed (unfilled circles). Data obtained during nonreinforcement show responding during various line orientations and during absence of the line. (From Honig et al., 1963, Figure 1)
key. We can evaluate such possibilities experimentally, for example by removing parts of the line to see whether its removal produces the same changes in the pigeon’s behavior as rotating it (Touchette, 1969). For a pigeon’s pecks the point may seem trivial, but it can be exceedingly important in application, as when a teacher tries to find out whether a child is attending to the words in a storybook or is faking reading by attending mainly to the pictures.

**FADING: STIMULUS CONTROL BY SUCCESSIVE APPROXIMATIONS**

As usual, our behavior analytic categories have biological parallels. Just as a response may be differentially reinforced during one stimulus but not another, organisms may be selected by evolutionary contingencies in one environ-

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**Figure 15-4** In a feature-positive discrimination, responding is reinforced only if a distinctive stimulus is present (top). In a feature-negative one, responding is reinforced only if it’s absent (bottom). The asterisk is the distinctive stimulus and appears in different places in the block of squares over trials. Feature-positive discriminations are easily learned whereas feature-negative ones are learned with difficulty.
ment but not in others. Fine discriminations can develop with the co-evolution of sensory and motor capacities, as when the sensitivity of a primate mother’s hearing is selected based on her responsiveness to the calls of her offspring while the calls are in turn selected by their distinctiveness from calls by the offspring of other mothers (Rendall, Rodman, & Emond, 1996). Here both phylogenic and ontogenic selection for discriminative capacities may be intimately intertwined.

Just as the response properties defining an operant can be changed gradually by shaping, the stimulus properties defining discriminated operants can be changed by analogous procedures called fading. Training doesn’t have to start with stimuli that are difficult to discriminate. Instead, it can start with stimuli that are easy to discriminate and then move gradually to more difficult ones. For example, it’s usually harder to teach a pigeon to discriminate between vertical and horizontal lines than between red and green. Once a discrimination between red and green exists, however, one between vertical and horizontal can be successively approximated by superimposing vertical on red and horizontal on green and then gradually fading out the colors (Terrace, 1963b). In this section I arranged some crude fading by dropping out variable-interval in favor of its abbreviation, VI, after both had sometimes appeared together.

Creating stimulus control through fading is often effective (Sidman & Stoddard, 1967), but as with shaping no rules exist for how rapidly stimuli should be faded in or out in different situations. For example, if we superimpose vertical on red and horizontal on green and then partially fade out the colors, we might discover after removing the colors completely that the pigeon has learned to discriminate between vertical and horizontal. On the other hand, fading might be unsuccessful; if a pigeon attends only to colors even when they became very faint, discriminated responding might disappear every time we dim them below some minimum level.

Shaping requires some behavior available to be shaped, and fading requires some discriminated responding available to be shifted to a new stimulus dimension. In an experiment on errorless discrimination, for example, a pigeon’s pecks on a red key were shaped with food reinforcers and then pecking during three-minute periods of red was reinforced according to a VI schedule (Terrace, 1963a). Periods of red alternated with another stimulus during which pecks weren’t reinforced. At first, this other stimulus was a dark key lasting five seconds. Its duration was gradually lengthened and it was changed from dark to dim and then to brighter and brighter green, until to a human eye its brightness matched that of the red key. By the end of these conditions, three minutes of red and reinforcement alternated with three minutes of green and extinction. Each pigeon treated this way pecked the extinction key fewer than ten times in the entire course of training; pecking occurred almost without exception on red rather than green. On the other hand, pigeons introduced to this procedure later after initial training or introduced abruptly to green at full duration and intensity pecked the green extinction key hundreds and even thousands of times during equivalent training periods.

The gradual fading in of green was effective in part because turning the red key dark early in training stopped the pigeon’s pecking for a few seconds (any abrupt stimulus change might have had this effect). Pecking wasn’t likely to start again before the brief five-second extinction stimulus ended. Thus, a difference in responding to the two stimuli occurred at the outset. The gradual changes in the duration and intensity of the extinction stimulus built on that difference. After such a history, we might convert the extinction stimulus to reinforcement and the pigeon, never pecking that stimulus, might never discover we had done so. The sense in which such a performance is errorless isn’t obvious. We must be cautious about the language of errors, which implies judgments about the value of responding and may be inappropriate to a behavioral account. But fading isn’t solely of theoretical interest; it has potential applications to education that may give it practical significance.
THE VOCABULARY OF DIFFERENTIAL REINFORCEMENT

Both differentiation and discrimination involve differential reinforcement. The difference is whether differential reinforcement is imposed on properties of responding or on properties of the stimuli during which responding occurs. One implication of the difference is procedural: in studies of differentiation the experimenter must wait for the organism's responses, whereas in studies of discrimination the experimenter controls the order and duration of stimulus presentations. Table 15–1 summarizes the vocabulary of differentiation and discrimination.

Differential reinforcement can be based on simple dimensions of stimuli such as intensity or location. The experimental question is whether responding conforms to the differential consequences, in that more responding occurs during the stimuli correlated with reinforcement than during those correlated with nonreinforcement. The implications are profound. What we've learned from training simple discriminations in pigeons or rats has been used to develop methods for training primates to discriminate among different drugs that have been administered to them (Schuster & Balster, 1977), for studying the sensory capacities of nonverbal organisms (Blough, 1958a), and for teaching young parents to identify their children's illnesses (Delgado & Lutzger, 1988) to mention just a few of a vast number of successful applications.

As illustrated by these applications, differential reinforcement can be arranged for complex properties of stimuli that aren't easily quantified. For example, children learning to read must be able to name the letters of the alphabet. But the properties important for distinguishing among some letters are different from those important in distinguishing among others (e.g., straight line versus curve is important in distinguishing U from V but not V from N), and different distinctions are important for lower case than for uppercase letters (e.g., no pair of uppercase letters has the up-down or left-right reversals that must be mastered to read b, p, d and q). The way in which a child learns to distinguish among letters of the alphabet depends on properties such as curvature (e.g., D versus O) and closure (e.g., F versus P). Properties essential to discriminating among letters are sometimes called critical features (Gibson, 1965).

It isn't enough, however, to enumerate critical features. For some letters, the uppercase and lowercase forms differ more from each other than from other letters (e.g., e, E and F, or h, n and N). Given the multitude of forms, what defines the stimulus class that occasions our saying A or B or C? The problem becomes even more complicated when different contexts are considered. For example, O could be either a letter or zero, and I could be either a letter or a roman numeral. The concepts of X and Y and Z are defined by the stimulus classes to which we respond with corresponding letter names, but such classes are based on behavior, not on common physical properties.

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<th>Table 15–1 The Vocabulary of Differential Reinforcement</th>
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Discriminated operants are classes defined by the stimuli that occasion responding. We often identify such classes in our everyday vocabulary, as when we speak of stopping at a red traffic light or answering a telephone. The red light can vary in brightness and size and the ring can vary in loudness and timbre, but our behavior is reasonably independent of variations along such dimensions, so we speak of these classes rather than specific instances.

**NATURAL CONCEPTS**

It’s often difficult to define discriminative stimuli by physical dimensions. For example, the properties defining the letter A vary according to whether it’s uppercase or lowercase and whether it appears as type or script. The capacity to discriminate among such stimuli exists in nonhumans as well as humans (Morgan et al., 1976). But the difficulty of defining stimuli by measurable physical properties isn’t limited to arbitrary classes created by humans, such as letters and numbers. It’s shared with natural objects and events. On what basis do we generalize between huskies and beagles by calling both dogs while we discriminate between huskies and wolves even though they look more alike than huskies and beagles?

With pictures presented on a screen next to a pigeon’s key and pecks reinforced during some but not others, pigeons have been taught discriminations involving pictures containing natural forms, such as presence versus absence of leaves, or maple-tree leaves versus leaves from other trees (Herrnstein, Loveland, & Cable, 1976). Such discriminations have been called natural concepts, where concepts can be loosely defined as discrimination between classes and generalization within classes (F. S. Keller & Schoenfeld, 1950). Pigeons learned discriminations between pictures with and without trees, or with and without water, or with and without a person. After training with one set of pictures, such as those with and without people, the pigeons discriminated among pictures from those classes they’d never seen before; sometimes the new pictures were more accurately discriminated than those used in training.

Natural concepts are examples of probabilistic stimulus classes, classes in which each member contains some subset of features but no feature is common to all and the number of features in the subset may vary from one class member to another. Such classes, sometimes called fuzzy sets, don’t have well-defined boundaries, though class members may have family resemblances (Rosch, 1973). Defining stimulus classes is a general problem. Appeals to physical measurement don’t resolve it, because the reading of meters or other instruments is also discriminated behavior. Behavior classes depend on the common contingencies that created them and not on their physical properties. Even the behavior of the scientist depends on discriminations learned in the laboratory.

The behavior of moving from one place to another has a privileged place in the study of learning (Olton, 1979). Going to food isn’t the same as producing food while remaining in place. One important difference is that environments change more drastically when we move to a new location than when we introduce a new stimulus into our present one. We humans have substituted other responses for ordinary locomotion: to go places we step on gas pedals, turn steering wheels, press elevator buttons and stand on escalators or moving walkways. Furthermore, movement produces continuous changes in the environment, whereas sequences of other responses may produce no change until the sequence is done. Beyond these differences, does it matter whether an organism moves to a new place or produces new stimuli where it is?

Such questions were implicit in a controversy over place learning versus response learning (Restle, 1957). Suppose the right arm of a T-maze points toward the brighter windowed east wall of a laboratory. The rat might learn right turns or it might learn to run toward the window. We could test these alternatives by turning the T-maze around so the right arm points west and the rat now approaches the choice-point from
the north. If the rat still turns right but now away from the window, it shows response learning. If it turns left but still toward the window, it shows place learning: it moves toward the same place, even though turning in a different direction. Does the rat learn right versus left turns or east versus west turns?

The rat’s performance depends on the stimuli available both inside and outside the maze. The typical rat can discriminate the general direction of lights and other gross features of a room. But if those stimuli are eliminated by placing a roof over the maze, the direction the maze faces in the room becomes irrelevant and the rat can’t show anything but response learning. Whether the rat learns place or response, therefore, depends on how the experimenter sets up the maze. By judiciously choosing conditions, an experimenter can make things turn out either way.

In natural environments, food at a given location isn’t necessarily replenished as in the goal box of a laboratory maze. In foraging, an animal is more likely to move to a new location than to return to one where it has already consumed the available food. Again, the features to which the organism attends can vary with constraints imposed by the experimenter (Collier & Rovee-Collier, 1981; Lea, 1979). For example, when a rat is given daily sessions with food at the ends of each of several alleys and the food isn’t replenished during the session, the rat learns not to repeat visits to alleys where it has already eaten (Olton & Samuelson, 1976). The lessons from these once-controversial issues in spatial learning are: (i) they’ve usually been resolved by looking at procedural details instead of theoretical assumptions; and (ii) incompatible alternatives from which we seem forced to choose usually turn out to be different categories of behavior each of which in its own right belongs in our taxonomy of behavior.

The field of animal cognition is concerned with what organisms know as they interact with their environments. It’s therefore often framed in terms of stimulus structure. For example, if an organism discriminates among stimuli based on some critical feature, an animal cognitivist might say the organism represents the stimuli to itself in terms of that feature. For example, in search for prey, a predator may be said to compare potential targets with a search image. This is a metaphor. Search here involves differential attention, and has much in common with what we do when we search for a jigsaw puzzle piece based on image rather than shape.

Examples of animal cognition include judgments of visual symmetry (Delius & Nowak, 1982), discriminations of numerosness (Davis & Pérusse, 1988), and visual search (Blough, 1989), to mention just a few. As an example, consider a pigeon watching a clock hand projected on the center key of three pigeon keys (Neiworth & Rilling, 1987). The hand starts at vertical and rotates at a constant rate from vertical through 90°; then it disappears. A little later it reappears farther along, at 135° or 180°. The timing of its reappearance is either consistent or inconsistent with it having moved at a constant rate of rotation while invisible. After presentations consistent with a constant rotation rate, left-key pecks are reinforced; after inconsistent ones, right-key pecks are reinforced. Pigeons learned to discriminate trials consistent with a constant rotation rate from those in which the constant rate was violated even though the rotating stimulus was absent some of the time; this discrimination also transferred to new locations of reappearance of the clock hand, so it couldn’t have been based on trial durations or specific clock-hand locations. It therefore demonstrates visual tracking in the absence of the visual stimulus; such tracking is sometimes called imagery. Colloquially, we might say the pigeon knew where the stimulus was even while it was invisible. This is a useful skill, as when an edible insect passes behind an obstruction and the bird waits for it to emerge from the other side.
Chapter 16
Conditional Discrimination and Stimulus Classes

...because species often occupy multiple habitats, a mutation may be favored in some locales and selected against or ignored in others.
S. B. Carroll, 2006

During many years of team-teaching the learning course with my colleague Eliot Shimoff we used pigeon and rat demonstrations in the classroom. One started out with a pigeon pecking red but not green. I arranged the contingencies and the key colors with hand switches, alternating between red and green every ten or fifteen seconds or so. During red I reinforced about one in every four or five pecks on average and during green I didn’t reinforce any. The deal was that Shimoff talked while I concentrated on the apparatus.

But we had a problem. As I worked with the pigeon Shimoff talked about stimulus control. His example was a pigeon conforming to traffic signals, going on red and stopping on green. At one point he said he could name the key color without even looking at the demonstration chamber, which was located somewhat behind him and to the side on the stage area of our classroom. He said all he had to do was listen, so while I had the pigeon pecking on a red key he said the key must be green and when I had it stopping during green he said the key must be red. The class seemed amused.

We soon got into an argument about what we had agreed on for this demonstration and what instructions the teaching assistant had been given. The teaching assistant stood nearby but wouldn’t take sides. The only thing I could do was offer to fix things by teaching the bird to reverse itself and start pecking green instead of red. When Shimoff suggested doing the reversal in the available time would be impossible and the class had been ruined, I said I could complete the reversal in less than ten minutes. He took me up on the offer and started a clock to see how long I’d take.

It was a setup, of course, though most students claimed after class they hadn’t been fooled by our phony fight. The first thing I did was to stop reinforcing pecks on red, but the bird didn’t slow down much at all while the key remained that color. Next I switched to green, and the pigeon, whose performance had been very well prepared by the teaching assistant, became practically immobile, facing the key but at some distance from it. I operated the feeder and the pigeon quickly came over to eat, so I immediately began shaping key pecks during green. It took just two or three reinforcers to get the bird to move its beak toward the key, and with only three or four more I had it pecking on green. But when I switched the key back to red the bird still pecked. It was now pecking both green and red, so only half the job was done. The bird now went on green, but I had yet to get it to stop on red.

I began reinforcing one of every three or four pecks on green, and after delivering a few reinforcers I switched back over to red, during which I reinforced no further pecks. That meant green was itself becoming more potent as a reinforcer.
while red was becoming less so. In other words, only pecks on green now produced reinforcers, so by virtue of that contingency green was becoming a conditional reinforcer. And if it was a reinforcer, I should be able to use it. The pigeon was still pecking red a lot, but the next step was to change the key from red to green during any slight pause in pecking. I’d use the onset of green to reinforce pauses during red.

Within the first minute or so I caught some good pauses and let the bird produce two or three reinforcers during green before going back to red. As the pauses during red became longer I could now pick up head movements away from the red key and make the onset of green contingent on them. Soon the pigeon was backing away from the key as soon as it turned red and moving toward it and pecking as soon as it turned green. By alternating quickly between green and red I could even get the pigeon to bob its head in front of the key for a few seconds: it moved toward pecking the green key, but I turned the key red before it got there; it backed off and I could turn the key back to green again. Less than ten minutes had elapsed on Shimoff’s clock and he now had a pigeon that went on green and stopped on red. We debriefed the class and were especially pleased if our contrived argument had been convincing enough that some students had really been worrying about us.

But one semester things went strangely. The preparation for our demonstrations began in our lab. Most of our research involved steady-state procedures, so our pigeons were around for a long time (the age of our oldest was twenty when it died of natural causes). One bird had been devoted to the reversal demonstration for several semesters. Ahead of time each semester one of us or a teaching assistant shaped up the performance of pecking red but not green. Then we did the reversal in the classroom. After returning to the lab, we again shaped up pecking red but not green so the bird would be ready the next time around. This time the bird seemed just fine when we checked it out a day or so before our demonstration, but when we got it to the classroom it began to pause on red and peck on green well before Shimoff and I got to our argument. Though we then demonstrated a reversal, it lacked the classroom drama we had planned for.

What had happened? We finally realized our pigeon had been through these procedures so often it had learned a conditional discrimination, where the conditional stimulus was whether it was in the lab or the classroom. In the lab we always reinforced pecks on red but not green; in the classroom, after the first couple of minutes we always reinforced pecks on green but not red. The bird had finally reached the point where it didn’t wait for us before starting its reversal. We solved the problem by doing reversals in the lab as well as in the classroom.

Like contingencies, discriminations may be effective under some conditions but not others. For example, your response to a green traffic light will depend on whether you’re facing it or looking at it from the cross traffic. Such discriminations, in which the role of one stimulus depends on others that provide its context, are called conditional discriminations. We examined attention in an experiment using triangles or circles on red or green as the stimuli. We could have added a lamp above the key and reinforced pecks in the presence of triangles when it was lit and pecks in the presence of red when it wasn’t. Under these circumstances, the pigeon learns to peck triangles but not circles without regard to color when the lamp is on, and to peck red but not green without regard to form when it’s off. In other words, whether the pigeon attends to form or color is conditional on whether the lamp is lit.

We’ve already considered more socially significant conditional discriminations, such as those worth learning on city streets or in academic institutions. Here we’ll examine other ways in which they can function. We’ll consider procedures in which stimulus-control contingencies depend on the contexts within which they’re arranged. These procedures sometimes generate higher-order classes of behavior, in the sense that the classes are defined not by specific stimuli or responses but rather by relations among them. Matching-to-sample, oddity and arbitrary matching provide a context in which to explore conditions under which one stimulus
can become the functional equivalent of another, as when, in varied settings, uppercase A and lowercase a function as the same letter even though they look very different.

Matching and oddity are relational properties of stimuli. We often treat stimuli as if they’re limited to concrete objects or environmental events. But as we learn to respond consistently to objects or events, we also learn to discriminate among abstract or relational features, that are independent of specific objects or events. When it identifies abstract or relational features, the term stimulus can function in this more general way. For example, we might say a chair was placed to the right of a table. The chair and table are concrete objects but being-to-the-right-of isn’t, and yet we discriminate between this relation and being-to-the-left-of.

RELATIONS AS STIMULUS DIMENSIONS

Many conditional discriminations involve arbitrary relations between a conditional discriminative stimulus and the discriminations for which it sets the occasion. Some cases in which those relations aren’t arbitrary are of special interest. For example, whether one stimulus in a stimulus set matches one or more of the others or is an odd one depends on, or is conditional on, the context of other stimuli within which it’s presented. For example, if stimuli A and B are blue and C is yellow, then B is a matching stimulus in relation to A whereas C is an odd stimulus in relation to A plus B.

Matching-to-Sample and Oddity

Figure 16–1 illustrates matching-to-sample as it might be arranged for green (G) and red (R) stimuli in a three-key pigeon chamber (Ferster, 1960; Skinner, 1950). During an intertrial interval, all keys are dark. A trial begins when the center key is lit, presenting the sample. A peck on the center key, sometimes called an observing response, turns on new stimuli and also makes it likely the pigeon has looked at the sample. The side stimuli produced by the center-key peck are called comparisons; one matches the sample and the other doesn’t. A peck on the matching key then produces a reinforcer followed by a new intertrial interval, whereas one on the non-matching key is followed directly by the intertrial interval without a reinforcer.

Both the sample stimulus and the left-right position of the matching comparison change over trials. A common matching-to-sample feature is a correction procedure, which repeats the same samples and comparisons on the next trial if a trial ends with a peck on a nonmatching key. This procedure keeps responding restricted to only one key or color from developing, but it also guarantees errors are sooner or later followed by reinforcers produced by correct responses.

Suppose a pigeon pecks only the comparison on the left. If the matching comparison alternates irregularly between left and right, these pecks will be reinforced on half the trials, and reinforcement on half the trials can maintain left-key pecking indefinitely. With a correction procedure, however, the pigeon must switch to the right key sooner or later, because a trial with a match on the right will repeat itself until a right-key peck occurs and is reinforced. Similarly, if the pigeon always pecks red comparisons, these pecks will be reinforced on half the trials unless a correction procedure forces the pigeon to switch occasionally to green.

Another refinement is to enhance the pigeon’s attention to the sample by modifying the contingencies arranged for sample-key pecks. For example, if to produce the comparisons one sample requires a high rate of pecking and the other requires a low rate, the pigeon’s rates of pecking the two samples can tell us how well it’s discriminating between them. Such procedures sometimes produce faster acquisition of matching but sometimes also reduce attention to the comparisons (Urcuioli, 1985).

In any case, suppose now a pigeon is matching accurately given red (R) and green (G). How should we describe its performance? Has it learned to peck left given the configurations RRG and GGR and right given GRR and RGG? Or has it learned matching in general, the iden-
tity relation? If we added blue or yellow and the pigeon matched with the new sample colors we’d feel better about speaking of generalized matching. But in fact, matching in pigeons doesn’t usually transfer easily to new colors, though the likelihood of transfer depends on the details of training. Even if we saw matching with new colors, what if we failed to get matching with geometric figures? We might just say the pigeon has learned color but not form matching, noting that the human concept of matching seems not so limited by specific stimulus dimensions. Matching-to-sample has sometimes been called identity matching, but we reserve that term for cases in which matching generalizes to novel samples and comparisons, such as matching of forms after training with colors. With a limited stimulus set, what looks like matching based on identity too often turns out to be matching based on specific stimulus configurations.

Matching-to-sample has many variations. If reinforcement is arranged for pecks on the nonmatching rather than the matching comparison, the task becomes an instance of oddity responding, because the odd key is necessarily the odd one of the three keys. This version of oddity requires a minimum of two pecks per trial, one on the sample and the other on the nonmatching comparison. Another version of oddity uses no sample; if all three keys are lit at the same time, the odd key can be any one of them and each trial will require just one peck.

The relations among stimuli can also involve arbitrary matching. For example, we could train the pigeon to peck green given square as a sample and red given circle as a sample. Would the pigeon then peck square given a green sample and circle given a red sample? Probably not. We expect such reversibility when we deal with words and objects, as when a child who’s learned to point to a picture of a car on seeing the word car can also point to the word on seeing the picture. This reversibility, a property of symbolic behavior, isn’t to be taken for granted.

How organisms cope with matching or oddity or related conditional discriminations varies considerably depending on procedural specifics. In some experiments pigeons rarely show generalized matching or generalized oddity; in others they do well (Katz & Wright, 2006). One condition making a big difference is the number of stimuli used in the procedure. The matching-to-sample procedure of Figure 16–1 uses just two stimuli, red and green. Other procedures use large populations of slides, such as travel scenes, so the stimuli used in one match are never repeated in others. A strong case can be made that the two-stimulus procedure is far more difficult than the many-stimulus procedure, in that the contingencies arranged for common stimuli across different trials in the two-stimulus procedure interfere with each other whereas the large populations in procedures with many stimuli minimize such

Figure 16–1 Diagram of a matching-to-sample trial in a three-key pigeon chamber. An intertrial interval of $t_s$ is followed by a sample (green or red) on the center key. A center-key peck turns on the side-key comparisons. One matches the sample; the other doesn’t. A peck on the matching comparison produces food, after which the next intertrial interval starts; a peck on the nonmatching one starts the next intertrial interval without food. The sample and the left-right locations of the comparisons vary from trial to trial.
interference (Sidman, 1987; Wright, 2012; Wright & Roediger, 2003).

Symbolic Behavior: Equivalence Classes

If a pigeon’s pecks are reinforced in the presence of green but not red, we could say the pigeons pecks in the presence of green, but we’d hardly entertain saying the pigeon greens in the presence of pecks. Such a reversal makes no behavioral sense. But this isn’t so in matching. Both the sample stimulus and the comparison response are defined by stimuli presented on the keys. We could therefore ask about a red response to a red stimulus, or the reversibility of a vertical response to a diagonal stimulus, or whether round responses to dim stimuli can be created by training round responses to large stimuli and then large responses to dim stimuli.

These cases illustrate relations called reflexivity, symmetry and transitivity. Reflexive properties are those holding between a term and itself (as in $A = A$); symmetrical properties are those in which the order of terms is reversible (as in $if A = B then B = A$); and transitive properties are those in which the common terms in two ordered pairs determine a third ordered pair (as in $if A = B and B = C then A = C$). Equivalence relations are those having all three properties. The terms entering into them are said to be members of an equivalence class (Sidman, 1994). An equivalence class is rarely considered in isolation. For example, with three-member classes we might identified one as $A_r$, $B_i$ and $C$, and another as $A_r$, $B_i$ and $C_r$, or one as $\alpha$, $\beta$ and $\gamma$ and another as $X$, $Y$ and $Z$.

For other relations, only some of the three properties hold. For example, a magnitude relation such as greater than is neither reflexive nor symmetrical, but it is transitive, because if $G$ is greater than $H$ and $H$ is greater than $I$, then $G$ is greater than $I$. As another example, the relation opposite is symmetrical: if $D$ is the opposite of $E$, then $E$ is the opposite of $D$. But it’s not reflexive: $D$ isn’t the opposite of itself. Nor is it transitive: if $D$ is the opposite of $E$ and $E$ is the opposite of $F$, then $D$ isn’t the opposite of $F$; instead, $D$ is the same as $F$.

Figure 16-2 shows how standard and arbitrary matching can be used to demonstrate reflexivity, symmetry and transitivity, where the first equivalence class consists of red, $\Delta$ and $\Phi$ (light), and the second consists of green, $\circ$ and $\bullet$ (dark). Each procedure includes two samples, shown as Sample A in the middle of the three-key array on the left and as Sample B in that on the right. For convenience, the matching comparison is always shown in the left position of each three-key array, but in practice the side positions of the comparisons vary from trial to trial. As in Figure 16-1, a sample peck produces comparisons, and a peck on the matching comparison produces food whereas one on the non-matching comparison doesn’t.

The top two rows (reflexivity) illustrate standard matching procedures with color and form. The next two (symmetry) illustrate symbolic matching with color samples and form comparisons and then a reversal with form samples and color comparisons. The bottom rows (transitivity) show how the common stimuli in two symbolic matching procedures (color to form and form to intensity) can be combined in a test of transitivity (color to intensity). An alternative test, illustrated in the last row, combines reversal and transitivity (intensity to color); it’s called an equivalence test, and the relations among the stimuli of the equivalence test are sometimes called equivalence relations. The relations of the reversal and equivalence tests were never explicitly taught. If appropriate matching occurs in these tests, the new relations are called emergent, in the sense that they’ve emerged without explicit training; they’re examples of novel behavior produced by the matching contingencies.

When we say a pigeon that pecks in the presence of green can’t green in the presence of pecks, we’re saying the relations between antecedent stimuli and the responses they occasion in a three-term contingency aren’t symmetrical. This means we can’t reduce equivalence classes to classes of discriminative stimuli. Equivalence relations are symmetrical, but the relations among the terms of a three-term contingency aren’t.
Despite its initial support, Darwin’s account of evolution as a product of natural selection soon met difficulties because of what was known about genetics in the nineteenth and early twentieth centuries. It couldn’t work without variations from which to select and it wasn’t clear where those variations could come from. What was the source of the novel variations on which the changes in species over evolutionary time depended? The answer came when data on mutations were added to what was known about genetics. Genetics provided the transmission from one generation to the next and mutations provided the variations. Even now the origins of novelty rather than natural selection itself have been favorite targets of Darwin’s critics (Kirschner & Gerhart, 2005, p. 265).

The ontogenic selection of behavior by its consequences faced similar challenges, especially with regard to the role of reinforcement in the acquisition of language by children. After the publication of Verbal Behavior by Skinner (1957), the linguist Noam Chomsky (1959) wrote a critique of the book in which he argued that Skinner couldn’t account for the child’s capacity to produce grammatical sentences the child could never have encountered before.

When we write a sentence, it’s likely to differ from any others we’ve written. We couldn’t have learned them individually because the number of ways in which words can combine into grammatical sentences is astronomical. This feature of language is called productivity, but language shares this property with nonverbal behavior. We can deal with novelty by identifying features the new sentence shares with earlier ones; novel productions involve new combinations of established syntactic and semantic classes (Esper, 1973). New combinations have also been important in evolution through natural selection (West-Eberhart, 2003).

Because children couldn’t possibly make contact with all possible sentences in the language they were mastering, Chomsky appealed to the poverty of the stimulus (Chomsky, 1959; Crain, 1991). Based their limited samples, how could children learn the difference between grammatical and ungrammatical sentences? Given some ungrammatical forms were so unusual children were hardly ever likely to encounter them, how could they know they shouldn’t use them? Chomsky concluded that children had to start out with some built-in language acquisition device or they’d be unable to learn their native languages.

But a pigeon doesn’t need to see all other wavelengths of a visual stimulus before learning to peck green but not red (Catania, 2003b). Neither does a child need to hear ungrammatical sentences before learning past and present tenses or active and passive voices. The selection of operant classes by their consequences doesn’t depend on extensive sampling of nega-
and fast responding given triangles. During this training, appropriate rates produced food reinforcers. Throughout the training conditions, no rate contingencies were ever arranged for bottom-key pecking. Then the two parts, A and B, were arranged in series, so that successful completion of A produced B, as diagrammed in the figure.

Within about two weeks after A and B were combined, rate differences corresponding to those on the top key emerged on the bottom keys. The differences were smaller than those on the top key but occurred even though differential reinforcement of bottom-key responding depended only on response location and not on response rate. Reinforcement was maintained during all sessions in which the A and B components were combined, but the bottom-key rate differences developed gradually and occurred despite continued reinforcement of roughly equal rates on the bottom keys across all stimuli during the sessions immediately after A and B were combined. Just as voicing persists in the plural -s in human verbal behavior, differential rates persist in the plural responding in the pigeon analog. These are of course small coordinations, but they show how response properties can constrain sequential behavior when different classes are combined.

Coordinations in Parallel

Never before having met a green dog, we’d probably still say something like Look at that green dog if we met one today. This example of adduction comes about through a new combi-
nation of the well-learned words, green and dog, in response to a novel combination of color and species. Such novel combinations are commonplace in human verbal behavior.

One account of productivity is that novel behavior emerges from the novel intersection of two or more properties of behavior, each determined by a different stimulus property (cf. Esper, 1973). This is an instance of multiple causation. We often speak of stimuli setting the occasion for responses. Strictly, however, discriminative stimuli don’t occasion responses; instead, stimulus properties occasion response properties. For example, the introductory example, green dog, involved a new combination of color word and species word, with each part of the verbal response depending on a different property of the nonverbal stimulus (cf. Skinner, 1957). Figure 17–2 illustrates a pigeon panel from experiments designed to provide a nonhuman analog of such relations (Catania & Cerutti, 1986; Catania, Ono, & de Souza, 2000).

The objective was to separately establish control of response location by form (left-right) and by number (top-bottom) and of response rate by color (green-red), and then to combine the separate discriminations. Stimuli were presented on all four keys in 3-s trials, after which a peck on any key ended the trial with food if contingencies had been satisfied or without if not. Stimulus number, singular versus plural, determined whether a peck on the top or bottom row was reinforced. Stimulus form, circle versus plus, determined whether a peck on the left or right column was reinforced. Stimulus color, green versus red, determined whether the peck was reinforced only after a high rate of pecking during the trial or only after a low rate. Differential reinforcement of rates of pecking during green and red gradually established two nonoverlapping classes of responding, high rates during green and low rates during red. By the end of shaping, a peck at the end of a trial including green was reinforced only if at least eight pecks during the trial, and at the end of one including red only if fewer than three pecks were emitted.

Would a pigeon trained to peck rapidly during green and separately trained to peck the upper left key during singular circles then peck rapidly on the upper left key given singular circles on green, a stimulus combination it had never seen before? In fact that didn’t happen. Novel stimuli often disrupt behavior and did so in this case. The newly combined dimensions of the stimulus combinations rapidly acquired control once relevant contingencies were added for them, but that didn’t qualify as adduction because it might not have happened without the added contingencies.

In the next experiment, the adduction test didn’t include extinction. Instead, for pigeons

![Figure 17–2](image-url)
who were experimentally naive prior to training, incomplete contingencies were arranged for some stimulus combinations, so differential reinforcement operated only for some response dimensions: all the former contingencies were in place, except no rate contingencies were arranged during trials with singular-circle-green or plural-plus-red. I’ll call these the adduction stimuli. The question was whether an appropriate novel combination of response properties would emerge for these stimuli in the absence of differential reinforcement.

From the start, location contingencies worked for all keys and peck locations quickly came to conform to them. Rate differentiation proceeded more slowly, with response rate changes for the two adduction stimuli lagging behind those for which rate contingencies operated. Over about a month, however, rates for the adduction stimuli caught up with the rest, though no differential reinforcement operated for those two stimuli and though intermediate rates of pecking had often been reinforced during the adduction stimuli in the early weeks of training (Catania et al., 2000). In other words, rates of pecking during the two stimuli not participating in the rate contingency gradually came to conform to the differential rates maintained during the other stimuli. These patterns of responding were maintained for more than three months of subsequent sessions, though these rates were never differentially reinforced given these stimuli.

If even a pigeon can do this, should we be surprised if a child who’s learned to say one deer running, two sheep walking, one sheep running, two deer walking, two deer running and one sheep running when appropriate circumstances arise? Here too we have multiple causation: singular or plural determines the number, the creature determines the noun, and the fast or slow pace determines the gerund verb.

But why didn’t the novel combination work during extinction? Testing for stimulus control in extinction, as in generalization gradients, has an extensive history in behavior analysis, but that kind of test may have problems. Consider the phylogenic contingencies. After its behavior during its first few encounters with a novel stimulus is unreinforced one organism stops engaging with the stimulus, but another persists in that behavior. The latter may be at a disadvantage relative to the former, because novel stimulus combinations in natural environments aren’t necessarily correlated with corresponding combinations of contingencies. A food with some combination of properties such as color, size and shape may have become well-established as a reinforcer based on its nutritive properties, low toxicity and so on. A new food may share some of these properties and is likely to be sampled when encountered, but if it’s not very nutritive and has delayed toxic effects besides, an organism that persists in consuming it even though its consummatory behavior is no longer effectively reinforced may soon face both ontogenic and phylogenic extinction.

It’s all too easy to make up evolutionary just-so stories, but perhaps phylogenic contingencies like these have selected organisms to be more like the former finicky sort than the latter obstinate one. If so, many procedures for testing novel stimulus arrangements might be fundamentally flawed even if they include a history of intermittent reinforcement prior to extinction. If novel stimulus combinations lead organisms to behave this way given extinction contingencies during tests of transfer or emergence, then novel stimulus combinations will quickly lose control and we may often incorrectly conclude that adduction doesn’t occur. Perhaps we sometimes fail to observe emergence simply because we arranged testing procedures operating against it. The emergence of novel combinations of response rates and locations in this procedure but not in an extinction test is consistent with these speculations.

These experiments don’t explain behavior; they’re demonstrations. To some extent they’re nothing more than thought experiments realized in practice (Catania, 1980a). In fact, when I first became involved in discussing them they hardly seemed worth doing because it seemed obvious they could be made to work. I needed to do them only to show those who found the analogies unconvincing that nonverbal organisms could
indeed produce such behavior. Nevertheless, I learned some things along the way, such as the different effects of extinction versus relaxed contingencies during adduction tests.

**Joint Control**

Now it’s time to ask how adduction works in our own behavior. *Joint control* occurs when common responses to different stimuli mediate judgments of equivalence or other relations, as when a child matches one arbitrary stimulus to another after having been taught to give the same name to each (Lowenkron, 1997). “Joint control is a discrete event, a change in stimulus control that occurs when a response topography evoked by one stimulus (e.g., the sample) and preserved by rehearsal, is emitted under the additional (and thus joint) control of a second stimulus (e.g., the comparison)” (Lowenkron, 1998, p. 332). *Joint control*, by the way, is about two stimuli jointly determining the behavior of a single individual; it shouldn’t be confused with *joint attention*, which involves one individual attending to a stimulus someone else is pointing to or otherwise indicating.

As an instance of joint control, Lowenkron (2004) offers the example of someone trying to find a number in a list, as in checking a set of winning lottery numbers. Say the number is 135476, as read from the lottery ticket. If I were doing this, I’d probably repeat the number to myself as I ran my finger down the list. What else must happen before I can shout *I won!* if I find 135476 in the list? I’m already saying the number to myself but now I’m also saying it as I see it. Together, these two sources of saying the number have come together so they jointly control my saying it. But here’s the critical part of the argument: before I can *say I won!* I must be able to distinguish this instance, in which there is a match, from all the other cases in which the number I’m saying and the number I’m reading don’t match.

In other words, for joint control to work we must discriminate between instances in which we find correspondences and those in which we don’t. These correspondences have sometimes been said to exhibit *parity*, a match between two sources of behavior arising from different sources (Palmer, 1996, 1998), as when babbling children react to having produced sounds resembling those made by their caregivers. But what sort of history could create the discrimination between jointly controlled responding and responding not involving joint control?

Instances in which some response is occasioned by two different events at about the same time are sometimes notable. Skinner (1977) remarked on his reaction to hearing his teacher say a word at the same time he was reading it. Our attention is often captured by unusual events, including coincidences: we notice if someone says something the same time we say or think it; in the cocktail-party phenomenon, we start attending to someone else’s conversation on overhearing our own name in it; in our lottery-ticket example of joint control, we react to the coincidence between the number on our ticket and the winning number on the list.

We’ve learned to look at parents and teachers and others when they’ve called us by name, so attending on hearing our name has had consequences. It’s reasonable to think of attending to our name when we hear it in the context of a new source, as in the cocktail party phenomenon, as a product of that history. This implies that pre-attentive behavior can be reinforced (some might prefer to invoke search images that govern our attention; this is no problem if they work like rehearsing a number to oneself). Aside from the source, how different is this from listening for your name as attendance is taken or searching for it on a list? And if this works for hearing your name, how about hearing a word at the same time you’re reading it?

That too has a history. If a child is shown a letter in class and is asked by the teacher to say it, the child must attend to both the seen and the spoken letter together. An enormous number of occasions for these sorts of combinations of events will arise as the child matures. Maybe the more appropriate question is not why joint control becomes important but instead what happens if a child fails to become responsive to
it? Could this be a component of some developmental deficits? If it’s absent, can it be taught?

Joint control involves discriminative responding to a property of our own behavior. We can no more pin down the stimulus dimensions on which this discrimination is based than we can say what defines redness or time or beauty. We don’t appeal to physics before deciding whether some stimulus class enters into a discriminated operant. Once we’ve seen a few instances, we can usually identify joint control when we see it.

Fluency and Teaching

To some, teaching a child number facts until the child reaches a level of proficiency of 75% or 80% might be acceptable as a passing performance. If you got the child to 85% or 90% or maybe even 95%, you’d probably be pleased. Getting the child to 99% or better would be even nicer. Certainly those are levels we’d like to see if these children someday become professionals in engineering or medicine or other demanding disciplines. But let’s settle for 95%. Even at this level it might be inappropriate to decide your high-performing child is doing well enough. Suppose you start asking questions like How much change will you get from ten dollars if you buy three toys costing two dollars each?, where the arithmetic needed for the answer is well within this child’s competence. If you were asking lots of questions like this and the child hasn’t been taught to translate word questions so they can be dealt with as arithmetic, you might see the child’s performance drop below passable levels. So now you teach the skill to a proficiency level of 95 percent or better and you try the test again. The child still doesn’t come close to 95 percent.

This is a failure of adduction. The two components, translating the word problem and doing the arithmetic, must combine if the child is to answer correctly, but here they mostly don’t. Just putting the two pieces together isn’t good enough to produce adduction. The child must be taught to a level of fluency, the “combination of accuracy and speed that characterizes competent performance” (Binder, 1996, p. 164). The child must answer both accurately and rapidly, and this means continuing to practice beyond the level of high accuracy alone. After all, this is what we expect of fluent language. It matters in other skills too (Poless, Grabavac, & Parsons, 1997). Once the child becomes fluent in arithmetic and translating word problems, adduction typically follows (Binder, 1996; K. R. Johnson & Layng, 1992). Given the question above, the child will quickly reply Four dollars. Fluency training is a powerful educational tool, and students taught this way come to excel in reasoning and putting facts together and the various other skills making up critical thinking; when confronted with the pieces of larger problems, adduction comes easily (Greer & Ross, 2004; Twyman, 1998).

One way of thinking about how this works is to assume the correct answer is given by the product of the probabilities of each part. If the child can do the arithmetic part at a 90% level and the word translation part at an 80% level, the chance of getting both right is 0.9 times 0.8, which equals 0.72. Even with both at 90%, the probability works out as 0.81. That suggests the child starting out at 99% and 99% should end up with an accuracy of about 0.98 on the combined problem. But that doesn’t happen. In cases like these, children do far worse than the combined probabilities suggest they should. Why do we need overtraining for both speed and accuracy?

One possibility is that when two reinforced classes of behavior come together, each has an inhibiting effect on the other. If so, the function of the overtraining for speed and accuracy may bring each class back up to the level it would have reached in the absence of the other. It would also make them stronger, in the sense of being more resistant to change than other classes that hadn’t been learned to a fluency criterion (Nevin, 1992). This is consistent with what we know about accuracy in other settings. For example, correct responses and errors in a matching or oddity problem will ordinarily differ in strength, and introducing reinforcers for other responses will typically reduce the errors more than the correct responses (Catania & Dobson, 1972). Paradoxically, instead of
competing with or degrading the matching or
oddity performance, introducing some other
concurrently reinforced response class makes
the performance more accurate.

Fluency is about the behavior of the stu-
dent rather than the behavior of the teacher. It
therefore has special relevance for educational
practices. Clearly it can’t be managed by teach-
ers working with large classes; for some well-
deﬁned skills, such as mastering basic arithmetic
facts, computers may function as better teachers
than humans. Teaching programs built around
ﬂuency have become increasingly sophisticated
and we’re learning more about how it works
(Binder, 1996). The foundations on which it’s
based have been around for a long time.

This is worth saying more than once, so
expect to see it again: for far too long, educa-
tional systems have focused on what the teacher
does instead of what the student does. What the
student does is what the student learns. The
more time students spend with the material to
be learned, the more they’ll learn, so anything
teachers can do to get them to put in more time
will probably be a good thing. For example, I
thought I might do no favors for my readers by
including chapter outlines, so I almost decided
to omit them completely. They are gone from
the chapter headings, though they do appear in
Appendix I. Try creating your own outline first,
and then see how it compares with what you
ﬁnd there.

I did leave out lists of key words, because it
should be easy enough for readers to generate
their own and to check them out against terms
in the glossary. I’ve been stingy with cross-refer-
ences, too, on the assumption that searching
out related topics by using the index or other
resources is a good thing to do. But I’ll make an
exception here: I hope instructors asked to do the
things students should be doing for themselves
will direct them to the section on teaching in the
chapter on applied behavior analysis.
Chapter 18
Behavior Synthesis

Novelty in an organism’s physiology, anatomy, or behavior arises mostly by the use of conserved processes in new combinations, at different times, and in different places and amounts, than by the invention of new processes.
— Kirschner & Gerhart, 2005

Schedules don’t always operate in isolation. They can alternate, either with correlated stimuli (multiple schedules) or without them (mixed schedules). The consequence of completing one schedule can be the onset of another, either with correlated stimuli (chained schedules) or without them (tandem schedules); in such contexts, one schedule can be the unit of behavior on which another operates (higher-order schedules). Schedules can operate at the same time, either for different responses (concurrent schedules) or for the same response (conjoint schedules), and schedules operating concurrently can each produce other schedules (concurrent-chain schedules). Some notable schedule combinations are summarized in Appendix IV, but these aren’t of interest just for their own sakes. Instead, they bear on general issues, such as discrimination learning (multiple schedules), conditioned or conditional reinforcement (chained and second-order schedules) and choice (concurrent and concurrent-chain schedules).

This probably seems daunting, especially if you’re not a reinforcement-schedules junkie like me and some of my colleagues. But we won’t explore these complex schedules for their own sakes. A proper exploration would take far more than one chapter anyway. Instead, we’ll use a few schedules as examples to show how they can shed light on topics of more general interest. We’ve already seen how we can approach human issues like self-control and procrastination and preference for free choice. Here we’ll enlarge our tool kit and add to our taxonomy.

An experimental analysis takes complex behavior apart. Our taxonomy of behavior provides the behavioral units for our analysis. Once we’ve finished an analysis by teasing the pieces apart, we can validate it by seeing if we can put them back together again. The reversal of an analysis is a synthesis, as when, in chemistry, a compound is synthesized after an analysis determines its elements and its structure. Here we’ll use various schedule combinations to synthesize complex behavior. The success of our syntheses will tell us something about the adequacy of our analyses.

MULTIPLE AND MIXED SCHEDULES: OBSERVING RESPONSES

In multiple schedules, two schedules alternate, each correlated with a different stimulus; we speak of stimulus control when the performance appropriate to each schedule occurs during the corresponding stimulus. For example, with an FI schedule operating for a pigeon’s pecks during green and a VI schedule operating during red, we’d expect to see FI scallops in green alternating with roughly constant VI response rates in red. Reinforcement often alternates with extinc-
tion and the inverse lower activity after stimulus offset in sensory systems.

CHAINED, TANDEM, AND SECOND-ORDER SCHEDULES

Chained schedules have been used extensively to study conditioned or conditional reinforcers, reinforcers that acquire their capacity to reinforce through their relation to other stimuli already effective as reinforcers (Kelleher & Gollub, 1962). For example, a feeder light becomes a reinforcer only through its relation to food in the feeder, and a clicker becomes a reinforcer only through its relation to the reinforcers arranged by a pet owner. Because the opportunity to engage in highly probable responses reinforces less probable responses only if the opportunity is signaled, the conditional reinforcing functions of stimuli have something in common with their discriminative functions.

Extended Chains

Assume we’ve gradually increased the size of an FR schedule for a pigeon’s pecks on a white key to a value of FR 240. In this situation, with only the food produced by pecking, the pigeon easily maintains an adequate daily ration. In fact, a pigeon can eat its daily diet in as little as four or five minutes and each food delivery lasts only four seconds or so, including the time to get from key to food hopper, so the pigeon may be done for the day after just sixty reinforcers. At FR 240, the pigeon must peck 14,400 times per day to earn this much food. It does so with a typical FR performance in which postreinforcement pauses are followed by uninterrupted rapid pecking. Our pigeon will earn enough food daily to keep itself alive and healthy indefinitely. Its life expectancy may be twenty years or more, and with this kind of diet a veterinarian might even judge the bird to be slightly overweight, unless they live at sites where they’re handsomely fed by tourists, pigeons in the wild tend to maintain themselves at 70% or less of free-feeding weights, so maintenance at 80% of free-feeding weight is hardly a starvation diet.

But pigeons can’t count very well, so we might wonder whether the pigeon is at a disadvantage each time it goes through its 240 pecks. Let’s help it estimate how many pecks are left to

Figure 18–3 Reinforced responding showing spatial and temporal analogous to those seen in sensory systems. Successive trials included FI reinforcement (RFT) or extinction (EXT) of a pigeon’s key pecks. In a spatial sequence (left), the top eight lamps in a vertical array of sixteen were correlated with RFT and the bottom eight were correlated with EXT. In a temporal sequence (right), six trials with one top lamp (RFT) alternated with one or three trials with one bottom lamp (EXT). The spatial sequence showed sustained contrast at the boundary between RFT and EXT; the temporal sequence showed transient contrast, with RFT rates highest immediately after EXT and EXT rates lowest immediately after RFT. (Adapted from Catania & Gill, 1964, Figures 2 and 3)
go by changing the key color after every forty pecks. Each ratio starts with a blue key for the first forty pecks; it turns green for the next forty, yellow for the next forty, orange for the next forty, red for the next forty, and purple for the final forty pecks, the last of which produces the reinforcer. The pecks per reinforcer remain the same; only the key colors have changed.

With no distinctive stimuli, the pigeon worked well enough, earning an adequate daily ration. Have we helped by providing the colors? The stimuli have the surprising effect of slowing the pigeon down. The pause at the start of the ratio, when the key is blue, lengthens. When the pigeon finally responds, the pecks that came in rapid succession now occur sporadically. When the key turns green after forty pecks, the pigeon pauses again before starting the next forty. When the key was always white, the pigeon didn’t pause at this point. In green, another forty pecks and the key turns yellow; then another forty and it turns orange. This time the pigeon is less likely to pause. Forty more pecks turn the key red and then forty more purple. The pigeon now quickly completes the last forty pecks and food is delivered. But then the key is blue again and another long pause begins. The reinforcing effects of the stimulus changes in the chained schedules were mostly restricted to the late components, close to the reinforcer.

The added colors didn’t help. This chain will never become a chunk. The pigeon takes much longer to earn each food delivery than it had when the key remained white. In fact, though the pigeon maintains an adequate diet at 240 pecks per food delivery when the key is always white, we’d now be wise to watch carefully so its daily food intake doesn’t decrease so drastically it starves to death. And all we did was add some stimuli (Catania, Yohalem, & Silverman, 1980).

When we added the colors, we broke the 240 pecks down into six distinct units of forty pecks each. We call these chained FR schedules: the separate stimuli correspond to the links of the chain. But the chain breaks the 240-peck sequence up into six FR components instead of holding it together more cohesively. When the key was always white, pecking at the start of the sequence wasn’t very different from pecking at the end, just before the reinforcer. Once the stimuli were added, pecking during the early stimuli became less like pecking later. In blue, for example, pecks never produced food. At best they turned the key green, but pecks never produced food during green either. In chained schedules, a stimulus supports less responding the further it is from the end of the sequence. Even severe food deprivation may not counteract this effect.

These differences occur with various schedules. Our example involved tandem and chained FR schedules, but Figure 18-4 illustrates similar effects with FI components. Comparable effects of chained schedules occur with other organisms besides the pigeon, with different kinds of responses and different schedules, and with different kinds and orderings of stimuli (Kelleher & Gollub, 1962). Because these effects have such generality, we may wonder whether they’re relevant to human behavior. The things that people do, of course, depend on consequences more complex than food deliveries. Nevertheless, so much of what we do involves sequential behavior we might wonder whether we sometimes operate under the strain of too many links in our chains. Did you ever have trouble writing that first page of a paper as its due-date approached? The first page is certainly the beginning of a chain. The ability to formulate and achieve long-range objectives is supposed to be a unique human characteristic. But if adding even a single link to a chain so devastates a pigeon’s behavior, perhaps we should be alert for similar effects in our own behavior.

The constant ordering of the chained stimuli matters. The long pauses decrease markedly if stimulus order changes from one reinforcer to the next (Gollub, 1977). Analogous but inverse effects also hold for schedules of punishment; relative to tandem schedules, chained schedules of punishment reduce responding mostly in the later components of the chain (Silverman, 1971). An implication is that punishment after a deed is done probably has its greatest effect on the behavior that precedes getting caught and only
minimal effects on the much earlier behavior that led up to the misdeed.

Brief Stimuli

Early experiments on conditional reinforcers were conducted during extinction, after a history of consistent pairings with a primary reinforcer (e.g., making tone a conditional reinforcer by following it with food and testing later with tone alone). Although this procedure countered the objection that responding might be maintained directly by the later primary reinforcer rather than by the conditional reinforcer itself, it was also one in which the effectiveness of conditional reinforcers diminished rapidly once the primary reinforcer was removed. Convincing demonstrations of conditional reinforcers came only when reinforcement schedules were applied to their analysis: schedules were arranged not only for the production of conditional reinforcers by responses but also for the contingent relation between conditional and primary reinforcers (Zimmerman, Hanford, & Brown, 1967). For example, a tone may function as a conditional reinforcer even if it’s followed by food only one time in twenty.

In second-order schedules, the completion of one schedule is a behavioral unit reinforced according to another schedule, as when the second-order schedule FR 10 (DRL 5-sec) arranges a reinforcer for every tenth interresponse time longer than five seconds. This arrangement, with a brief stimulus at the completion of each first-order schedule, is one of several types of second-order schedules. Consider a schedule arranged for a pigeon’s pecks in which the peck that completes each 60-second fixed interval produces a brief green light on the key and in which every tenth such interval is followed also by food; the notation for such schedules may include the brief stimulus: FR 10 (FI 60-s: green). Such schedules typically maintain FI scalloping within intervals even though most intervals end without food.

In contrast to chained schedules, second-order schedules with brief stimuli can amplify reinforced responding. For example,
when a chimpanzee’s pushbutton presses were reinforced with food according to an FR 4000 schedule, postreinforcement pauses ranged from many minutes to hours. But when the light accompanying food delivery came on briefly after every 400 responses, responding increased and typical postreinforcement pauses decreased to five minutes or less. The light converted the simple FR 4000 schedule to a second-order schedule, FR 10 (FR 400: light) and amplified the amount of behavior maintained by the food reinforcers (Findley & Brady, 1965). The cumulative records in Figure 18–5 illustrate these effects. The three FR 4000 sequences (unshaded) are each preceded by pauses of half an hour or more; the three FR 400 x 10 sequences with brief stimuli (shaded) include some early pauses, but once they’re under way they’re completed in less than half an hour.

Variables such as the relation between the brief stimuli and primary reinforcers determine the effectiveness of second-order schedules (Gollub, 1977). Both chained schedules and second-order schedules with brief stimuli involve conditional reinforcers, but where chained schedules may attenuate responding, second-order schedules may amplify it. Their opposite effects illustrate how critically schedule effects depend on the detailed relations among stimuli, responses and consequences (Malone, 1990, pp. 294–296; Morse & Kelleher, 1977).

Second-order scheduling can also include other kinds of operants, as when correct responses in matching-to-sample are reinforced according to various schedules. In such contexts, lower levels of accuracy may be correlated with the times at which responding is least likely to be reinforced. For example, errors are more likely early in FR runs or in the early portions of FI scallops than in responding occurring later and therefore closer to reinforcer deliveries (M. C. P. Boren & Gollub, 1972; Thomas, 1979). Classes defined sequentially may also imply higher-order classes. For example, individual pecks are functional units, but within FR performance the entire ratio may function as a unit. The FR performance has a property consistent with higher-order classes: as long as the higher-order class is reinforced, the subclasses within it may also be maintained even though they are no longer reinforced. In other words, the first peck of the fixed ratio does not extinguish, even though by itself it never produces the reinforcer.

**CONCURRENT SCHEDULES: MATCHING AND MAXIMIZING**

Any reinforced response is likely to occur in a context of other behavior maintained by other consequences. The effect on one response of reinforcement schedules operating for other

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**Figure 18-5** Sample chimpanzee cumulative records from FR 4000 during red and a second-order FR 400 x 10 schedule during green. During red the FR 4000 performance was preceded by very long pauses; responding on the second-order schedule mostly began promptly during green. (Adapted from Findley & Brady, 1965, Figure 2).
responses may therefore be of interest. Concurrent schedules are schedules simultaneously arranged for two or more responses. Consider an FR 25 schedule for a pigeon’s pecks on one key and an FR 50 schedule operating concurrently for pecks on a second key. Alone, either schedule maintains responding, but when they operate concurrently, responding is likely to be maintained exclusively on the key with the FR 25 schedule. The outcome isn’t surprising. A reinforcer requires only twenty-five pecks on the first key but fifty on the second.

Now consider concurrent interval schedules, such as VI 30-s reinforcement of pecks on one key and VI 60-s reinforcement of pecks on the other. In this case, the pigeon produces 120 reinforcers per hour by pecking only the first key or sixty per hour by pecking only the second. By pecking both, however, it produces the reinforcers of both schedules, or 180 per hour. In this case, responding is likely to be maintained on both keys. Variables with small effects in single-response schedules often have large effects in concurrent schedules, which are therefore useful for studying effects of reinforcement variables (e.g., reinforcer duration: Catania, 1963a; response force: Chung, 1965). Perhaps the most general feature of behavior revealed by concurrent performances is that increasing the reinforcement of one response reduces the rate of others (Catania et al., 1988; Killeen, 1972; Rachlin & Baum, 1972). This interaction depends on the reinforcers and not on competition between responses for available time (Catania, 1963b). The response rate generated by the total rate of concurrent VI VI reinforcement is independent of how the reinforcers are distributed to the two keys. It follows that the sum of the two rates will be constant, so increasing the reinforcement of one necessarily reduces the rate of the other.

Although pigeons distribute their pecks to both keys with concurrent VI VI schedules, there’s a complication. If pecks on one key are immediately followed by a reinforced peck on the other, the reinforcer may act both responses, so pecks on one key are maintained partly by reinforcers scheduled for the other. For this reason, concurrent VI procedures have often incorporated a changeover delay, which prevents either response from being reinforced immediately after a changeover from the other. With a changeover delay, the pigeon distributes its responses to concurrent VI VI schedules roughly in proportion to the distribution of reinforcers they arrange (Herrnstein, 1961); for example, a pigeon is likely to peck a VI 30-s key (120 reinforcers per hour) about twice as often as a concurrent VI 60-s key (60 reinforcers per hour).

This phenomenon is sufficiently general it’s been proposed as a general law of behavior, the matching law (Davison & McCarthy, 1988; Herrnstein, 1970), which states that relative rates of responding match the relative rates of reinforcement produced by that responding. The law even holds for concurrent ratio schedules, because exclusive responding on one schedule means all the reinforcers will be delivered according to that schedule. Herrnstein’s account has also been applied to responding maintained by a single reinforcement schedule, on the assumption that other events besides the reinforcers arranged by the experimenter may have reinforcing effects even though we can’t identify them. To account for issues of scaling and bias, the law has been extended to the generalized matching law (Baum, 1974; Davison & McCarthy, 1988), but this is not the place for an exposition of the mathematical details of this and other extensions of quantitative analyses.

The matching law and the generalized law of which it’s a special case summarize performances in a variety of schedules, but their status as a convenient description or as a fundamental properties of behavior rests on whether they can be derived from simpler processes (Catania, 1981; Hineline, 2001; Rachlin, 1971). For example, consider how concurrent VI VI schedules operate when arranged for a pigeon’s pecks on two keys. As the pigeon pecks one key, time passes during which the VI schedule for the other key may set up a reinforcer. A time comes when the reinforcement probability for changing over to the other key exceeds that for continuing to peck the same key. If the pigeon emits the response with the higher current reinforcement probability and this probability shifts from one key to the
other as time passes, the pigeon will distribute its responses to both keys in concurrent VI VI schedules (Hinson & Staddon, 1981; Shimp, 1966). This has been called \textit{maximizing}; with several responses available, maximizing means emitting the response with the maximum reinforcement probability. With unequal concurrent ratio schedules, this is always the one with the smaller ratio, but with concurrent VI VI schedules the response with the maximum reinforcement probability changes from moment to moment; concurrent VI VI performance has therefore been called \textit{momentary maximizing}. Thus, momentary maximizing at the molecular level may lead to matching at the molar level. Matching and maximizing may seem contradictory alternatives, but they are measured in different ways (Hineline, 2001).

We can’t speak about matching without some sample of responses and reinforcers from which to estimate relative frequencies, but we can speak about maximizing with a single response, just by noting whether it was the one with the maximum reinforcement probability. To some extent, the issues involve the level of detail at which performances are analyzed. Furthermore, matching and maximizing don’t exhaust the possibilities. For example, other analyses have examined whether concurrent performances can be described as \textit{optimization} (the organism produces the highest possible overall reinforcement rate), \textit{satisficing} (it meets some minimal requirement, such as a given food intake) or \textit{melioration} (it balances performance so as to produce equal reinforcement rates under different conditions); this is not an exhaustive list, and in their quantitative details these and other treatments (Killeen, 1994; Mazur, 1991; Nevin & Grace, 2000) are more than we can handle here.

Whether generalized matching is a fundamental process in some way dictating the details of schedule performances or is a derivative of the moment-to-moment responding generated by reinforcement schedules has long been a source of controversy. Is behavior built from the top down or the bottom up? Those who argue for the former call theirs a molar approach (Baum, 2002), contrasting it with molecular analyses. But this is a false dichotomy, because molecular measures such as distributions of interresponse times, other measures called molar, are derived from behavior sampled over extended periods of time. Biology has gone through similar controversies in its history, but it now appears that the molar biologists were wrong to give up on the microbiologists. “In evolutionary parlance, Evo Devo reveals that macroevolution is the product of microevolution writ large” (Carroll, 2005, p. 291). Why should we expect behavior to be any different?

Natural Foraging

Concurrent-chains have been broadly applied to the synthesis of complex behavior. If the interpretation of complex behavior in a natural habitat suggests it consists of several simpler components, the interpretation can be tested by trying to assemble those components in a laboratory setting. A successful synthesis supports the interpretation; an unsuccessful one may reveal inadequacies in the assumptions about what was going on in the natural setting.

In the field of \textit{behavioral ecology}, this strategy is illustrated by studies of natural foraging (Fantino & Abarca, 1985; Kamil, Yoerg, & Clements, 1988). In their foraging, animals in the wild travel from one food patch to another, staying or moving on to new ones depending on what they find. For example, a bird might fly to a bush in which the eggs of an edible insect have just hatched. As it eats, it gradually depletes its prey, and when it moves on depends on such factors as how much is left, how far it must go to find another bush and what the chances are of finding food there (Wanchison, Tatham, & Hineline, 1988).

Because analyses of natural foraging involve switching among food sources as food availability or other conditions progressively change, as in the last example, progressive schedules have been useful tools (Hackenberg, 1992; Neuman, Ahearn, & Hineline, 2000). In a progressive schedule, some parameter of the schedule varies over successive reinforcers or blocks of reinforcers. By analogy to the cost of switching over from one food source to another, some procedures provide an alternative response allowing
the organism to reset the schedule to its starting value. For example, a progressive FI schedule arranged for a pigeon’s pecks on one key might start with FI 30-s and add 15-s to the FI value with each reinforcer, but completing an FR on a second key might reset the progressive FI back to 30-s. The FI value at which the pigeon resets the progressive schedule will vary with the size of the required ratio, so this schedule can be used to study how the pigeon trades off time (FI) and number (FR).

Some factors within natural ecological settings can be simulated within concurrent chains. For example, varying the schedules that operate in initial links is analogous to varying the time and effort involved in traveling from one bush to another, and varying the schedules in terminal links is analogous to varying the availability or depletion of different food sources at different sites. Concurrent-chain schedules in the laboratory simulating those in natural habitats have revealed some properties of foraging. For example, organisms are less selective in the food they accept if they spend more travel time (more time in initial links) between potential food sources; and if one food is preferred over another, the availability of the preferred food (the schedule operating during the terminal link in which that food is the reinforcer) is a primary determinant of the choice of food patches (as shown by initial-link responding). In other words, natural foraging may be treated as a set of concurrent-chain contingencies, and properties of natural foraging, in turn, may suggest variables important to concurrent-chain performances.

A SCHEDULE TAXONOMY

Reinforcement schedules are tools applicable to a variety of behavioral phenomena relevant to human concerns. Our examples have ranged from causal relations between behavior and environment to self-control and freedom of choice. Yet even so-called simple schedules aren’t simple; the complexity of schedule effects has made schedule analysis highly technical. In surveying multiple, chained, second-order, concurrent and concurrent-chain schedules, we’ve often omitted procedural details. This is perhaps inevitable. Unlike most of our other topics, reinforcement schedules didn’t even exist as a systematic subject matter until relatively recently (Ferster & Skinner, 1957; Skinner, 1956). One concern of this subject matter has been maintaining behavior in the steady state, and yet the change in behavior accompanying any transition from one schedule to another is an instance of learning.

We examined multiple and mixed, chained and tandem and second-order, and concurrent and concurrent-chain schedules, but we haven’t exhausted the possibilities for combining the basic schedules. For example, reinforcers can be arranged for completing either of two schedule requirements (alternative schedules) or both of them (conjunctive schedules). In an alternative FI 30-s FR 50 schedule, either the first response after thirty seconds or the fiftieth response is reinforced, whichever comes first. In a conjunctive FI 100-s FR 20 schedule, a response isn’t reinforced until both one hundred seconds pass and nineteen responses have already been emitted. In a progressive schedule, some parameter of a schedule changes systematically over successive reinforcers or blocks of reinforcers. For example, a ratio might increase by ten responses after every fifth reinforcer (sometimes a second response is available that resets the progression to some starting value according to some schedule). Adjusting schedules vary as a function of some property of performance, as when a ratio varies in proportion to the last postreinforcement pause, or as when shock delivery changes the RS interval of an avoidance schedule. A schedule in which time and number requirements interact is an interlocking schedule. For example, an interlocking FR FI schedule might shorten the interval as a function of number of responses, or lengthen the ratio as a function of time. An example is winding a grandfather clock, in which the reinforcer is the tension of the fully wound spring; until the spring is completely run down, the number of turns required to wind it increases as time passes.

For convenience of reference, the major schedule combinations are summarized in
Appendix IV, which provides definitions, examples and standard abbreviations. The formal designations may make some relations among the schedules more obvious. For example, multiple and mixed schedules both involve the alternation of component schedules, and chained and tandem schedules both involve sequences in which completion of one schedule produces another. In both pairs, the only distinction is whether the component schedules each operate during different stimuli or during a single stimulus. Similarly, the only distinction between concurrent and conjoint schedules is whether the two simultaneous schedules operate for different responses or for a single response.

These schedule combinations are our tools. Once we’ve used schedules to analyze complex behavior we may be able to use these tools to put the parts back together in a synthesis. For example, we can test our interpretation of behavior in a natural habitat by trying to assemble its components in the laboratory. We can’t create a behavior synthesis without making explicit our assumptions about the properties of the behavior we’re trying to synthesize. For that reason, when we attempt synthesis we probably profit more from our failures than our successes. In fact, it may be a general principle of scientific research that we learn the most when our experiments produce data we didn’t expect. After all, what’s the point of doing experiments if we always know exactly how they’re going to turn out?
Historically, respondent conditioning so dominated the field of learning it provided the opening chapters of many learning texts and is still typically treated before operant learning. It's also been variably called classical or Pavlovian conditioning. The language of conditioned reflexes has entered everyday vocabulary, although in its popular usage it's often confused with operant learning. Many still speak indiscriminately about operant conditioning and respondent conditioning; a case for some common underlying processes can be made (Donahoe & Palmer, 1994), but the persistence of that usage runs the risk of confusing properties of environments that interact with behavior in very different ways. For example, some behavior classes can separately be either elicited or shaped, but respondent procedures don't lend themselves to shaping.

Respondent conditioning is stimulus control applied to stimulus presentations rather than to consequential contingencies. In other words, instead of signaling the consequences of responding, the stimulus signals that some other stimulus will be presented. Pavlov's conditioned salivary reflexes are the prototype example: when a bell repeatedly signaled food to a hungry dog, salivation came to be elicited by the signaling stimulus as well as by the food itself. Ironically, Pavlov may never have used a bell in his research; his rare mention of bells occurs only in later work and there probably refers to electrically operated devices. The Russian word used by Pavlov for bell, звонок (zvonok), also has buzzer and doorbell as synonyms; Pavlov didn't use колокол (kolokol), another Russian word for bell that doesn't have these synonyms. Besides, Pavlov was scrupulous about stimulus consistency, and unlike buzzers or doorbells, a handbell with a clapper is likely to vary from one ring to the next. The ubiquitous references to Pavlov's bell may have originated with the common use of the dinner bell and salivation as an example in the writings of John B. Watson and others. I visited Pavlov's apartments in 1993, when St. Petersburg was still called Leningrad. The apartments are now a Pavlov museum, and the only bell was on his desk, presumably for summoning servants or assistants.
Chapter 21
Social Learning

It is because our behavior is important to others that it eventually becomes important to us.
— B. F. Skinner

One variety of selection operates on populations of organisms over successive generations. It appears as *phylogenetic selection*, Darwin’s treatment of evolution as natural selection. Another operates on populations of responses within the lifetime of an organism. The effects of consequences, especially in the shaping effects of reinforcers, involves this variety, *ontogenic selection*. The third variety also operates on behavior but involves more than one organism. The behavior an organism acquires within its lifetime is eventually lost if not passed on to others. Once social learning becomes possible, learned behavior can survive the organism that learned it. It then continues in what others do, perhaps in the behavior not only of descendants but even of contemporaries who aren’t closely related. This variety, *cultural* or *memetic selection*, involves the selection of behavior passed on from one organism to another, as when local languages or ethnic cuisines or religious practices spread within or across cultures.

**KINDS OF SOCIAL CONTINGENCIES**

Learning from others is especially significant in human behavior. A substantial part of what I know I’ve learned from others, and some was explicitly taught, either in the informal context of interactions between my family members and friends or in the formal context of the schools I attended. But the earliest types of social learning must have been much simpler. At what point did organisms begin to learn to do things just by attending to what happened as others did them?

We may think of learning by observation as commonplace. It occurs so often in our human behavior. But it’s not clear how much of it goes on even among nonhuman warm-blooded vertebrates (mammals and birds). Among primates, one example involved sweet potatoes fed to macaque monkeys on a Japanese reserve adjacent to a beach (1959). The potatoes typically became sandy, but one juvenile monkey discovered that rinsing them in the ocean removed the sand. The practice spread to other juveniles of the colony but wasn’t taken up by the adults.

Human cultures offer many examples of the social selection of behavior as behavior is passed on from one individual to another. Some ways of raising children, getting and preparing food, building shelters and dealing with group members and outsiders survive over generations. Some practices spread to other groups who aren’t close genetic relatives of those who began them. In contemporary Western culture, for example, ethnic foods are prepared and eaten by
many who aren’t members of their originating ethnic groups.

Some socially transmitted behavior survives because of its consequences. In early human history, the person who learned from someone else how to make stone tools or fire or garments was probably also more likely to survive long enough to pass the behavior on to someone else than one who couldn’t learn that way. Suppose some patterns of child rearing work so adults are likely to rear their own children the same way their parents reared them; let’s call these self-replicating patterns of child rearing. Whenever a self-replicating pattern happens to be used by some parents, for whatever reason, it will likely appear again in the next generation; other patterns will come and go. Little by little over many generations, the self-replicating patterns will displace the others and become traditional. Once such patterns get going, they’re likely to survive for a very long time, perhaps even in the face of powerful countervailing contingencies such as discriminatory practices.

Darwinian evolution and shaping depend on variable populations on which selection can operate. Similar constraints exist at the level of cultural selection. For example, cultural practices favoring ethnic diversity may survive those that don’t simply because they allow such variability. It was no help to Hitler that some Jews who left Europe because of Nazi policies included scientists like Albert Einstein. At every level of selection, we usually look at how selection operates at the level of the survival of individuals rather than the survival of the group, though the need for that constraint has sometimes been questioned (D. S. Wilson & Sober, 1994).

Learning about Others

In many situations, the discriminative stimuli provided by others are more important than those provided by inanimate objects and events. For example, parental investment in offspring may be wasted if parents can’t discriminate between their own offspring and the offspring of others; potential mates must be distinguished from potential competitors, and among potential mates the receptive must be distinguished from the unreceptive; and so on. In many organisms, such properties are correlated with anatomical features (e.g., colorful plumage in birds); often, behavior is the crucial dimension (e.g., courtship dances in birds).

Releasers and fixed action patterns provide many examples of effects of social stimuli. In some cases, the behavior serving as a social stimulus and the behavior produced by that stimulus are topographically similar, as when one bird’s takeoff triggers the flight of other birds, or as when a few galloping steers set off a stampede. Such cases may superficially look like imitation, but they’re limited to a narrow range of response classes (e.g., contagious yawning; Provine, 2012) and must be distinguished from it.

Discriminating the behavior of other organisms, whether of one’s own or other species, has selective advantages. If one antelope in a herd limps just a little, a lion that notices the limp may be more likely to make a capture. The antelope that can tell the difference between a lion that hasn’t eaten for a while and another that’s just finished may be more likely to move away in a safe direction. A predator that can distinguish whether it’s been noticed by its prey has a distinct advantage over one that can’t; an advantage also accrues to a prey that can distinguish whether it’s been noticed by its predator. Over an extensive phylogenetic history, attention to the behavior of prey was a dimension on which natural selection operated in the evolution of predators, just as attention to the behavior of predators was a dimension on which natural selection operated in the evolution of prey. Following from such selection, discriminations of social behavior have become so sophisticated they sometimes override other types of discriminations.

Discriminations of the behavior of others are at the heart of the concept of intentionality ( Dennett, 1987): I say I understand someone’s intentions when my discriminations of that person’s past and current behavior allow me to act appropriately toward that person’s future behavior. In fact, if discriminating my own behavior is a special case of discriminating the behavior of
others, it can be argued this topic encompasses all the phenomena considered under the rubric of intentionality. Our judgments of the intentions of others are social judgments (Bem, 1967). It takes no special assumptions about selective contingencies to see they could shape well-prepared capacities for social discriminations both within and across species.

Social discriminations within species have many functions: within dominance hierarchies; in the defense of territory; as isolating mechanisms maintaining the integrity of a group against intrusions from outsiders; in the distribution of limited resources among group members. Within species living as social groups, like most primates, individuals learn what sorts of behavior to expect of those with whom they have extensive contact.

Learning from Others

It’s one thing to learn about other organisms. It’s another to learn something from them. Sometimes the behavior of one organism allows another to act based on stimuli available only to the first, as when a vocal call from one monkey allows another to escape from a predator it hadn’t seen. Warning calls are well-documented in bird behavior. In monkeys, predator calls can vary with kinds of predators, and the response to the call can depend on who the caller is and who the listener is (Seyfarth, Cheney, & Marler, 1980a).

**Observational Learning.** Learning based on observing the behavior of another organism is called *observational or vicarious learning* (Zentall & Levine, 1972). Sometimes what seems to be observational learning involves simpler processes. For example, food preferences in rats are learned in social contexts. When rats come together they sniff and lick each other, so by smell and taste each rat becomes familiar with the food the other has eaten (Galef & Stein, 1985). If the food is novel and the other rat is healthy, the first rat later prefers that novel food over other novel foods, but if the other rat is sick, the first rat avoids that novel food. In other words, this is a socially mediated taste aversion; that’s why it’s hard to get rid of rats by poisoning. One rat has learned about some novel foods from another, in the sense that combinations of foods and social stimuli change the effectiveness of the foods as reinforcers or as aversive stimuli.

Observational learning has been compellingly demonstrated with rhesus monkeys (Mineka et al., 1984). Monkeys in the wild show fear of snakes by screaming and other agitation and by snake avoidance. Even if their parents fear snakes, monkeys reared in the laboratory who’ve had no experience with snakes don’t; for example, if food is on the other side of a container with a snake in it, they’ll reach across the snake for the food. But if laboratory-reared monkeys briefly observe a parent behaving fearfully toward snakes, they too become fearful. Their fear is intense and persistent; it’s still there if tested three months later. What they’ve learned is based solely on observing a parent’s behavior toward a snake. But there’s a phylogenetic component, because such learning is more likely with snakes or snakelike objects than with other types of stimuli. These kinds of learning may play a critical role in the onset and maintenance of post-traumatic stress disorders (PTSD) and other human anxiety disorders (Mineka & Zinbarg, 2006).

Observational learning is a prerequisite for other varieties of learning and social interaction. For example, *joint attention*, in which a child looks where a caregiver is looking or pointing, depends on the child first learning to attend to the caregiver’s looking and pointing (Dube et al., 2004). Observational learning is probably best treated as a higher-order variety of behavior. Different skills must come together appropriately for observational learning to work; in human observational learning it’s also likely there’s a large verbal component.

**Imitation.** The crucial difference between observational learning and imitation is that in imitation the observer’s behavior corresponds to that of the observed organism. Imitation doesn’t imply the imitating organism has learned about contingencies, so not all imitations are advantageous. For example, a coyote seeing another coy-
ote step into a trap would do well not to imitate that behavior; a hatchling bird that hasn’t yet grown its flight feathers would do well not to follow its parents when they fly from its treetop nest.

Following may sometimes be imitative. After food-deprived pigeons learned to eat from an experimenter’s hand, the hand then approached and "pecked" the key, producing food; the pigeons followed the hand and began to peck the key (Neuringer & Neuringer, 1974). This procedure often worked more rapidly than shaping of the key peck. Under natural conditions, young animals may learn to behave like their parents simply by following them to sources of food.

We call responding imitative when one organism duplicates the behavior modeled by another. Some imitations may be limited to duplicating only specific instances explicitly taught, while others may involve correspondences between the behavior of model and observer even in novel instances, when it’s called generalized imitation; in the latter, imitative responding is a class that may be differentially reinforced; in other words, it’s a higher-order class (D. M. Baer, Peterson, & Sherman, 1967). Suppose a child learns to imitate behavior modeled by a puppet: jumping, skipping, clapping, etc. If consequences maintain imitation of all but the clapping, the child will usually continue to imitate clapping along with the others even though this imitation is never reinforced. If imitation of clapping doesn’t extinguish, it’s a member of the generalized class. With generalized imitation, the child will also produce novel imitations if the puppet does something it never modeled before, such as stamping its foot; in fact, responses occasioned by novel stimuli define generalization, as when a pigeon pecks when it first sees yellow or blue after a history of pecking only during green. Because modeling of a new response can produce novel behavior only if a child’s imitation has generalized, it can supplement shaping, as in teaching skills to children with autism or other developmental issues (degli Espinosa, 2011).

Generalized imitation is consistent with what we understand about the contingencies creating higher-order classes, but the correspondences defining it are complicated. For example, if you touch the top of your head when it’s modeled in the game of Simon says, you see but don’t feel the leader’s hand and you feel but don’t see your own hand. Someone else’s seen hand and your own felt hand involve different stimulus dimensions, so how did you learn to imitate?

You can learn such correspondences by behaving in front of a mirror. Humans and some primates can learn these correspondences without explicit training. For example, if a chimpanzee experienced with mirrors has a spot painted on its eyebrow while asleep, it will touch the spot the next time it sees its face in a mirror. Some monkeys pass this test and others don’t, but the differences may depend not on cognitive capacities but on behavior interfering with looking in mirrors (Rajala et al., 2010). For example, species of monkeys differ in gaze aversion, i.e., looking away if another monkey looks at them; thus, when some monkeys look in a mirror and see themselves looking back, they’ll look away before seeing the spots on their eyebrows.

With other organisms, such as pigeons, these correspondences can be taught. First, a pigeon’s pecks at blue cardboard dots pasted on its body were shaped. Next, discriminations among blue dots reflected in a mirror were taught by presenting the dots behind holes in one wall only when the pigeon faced a mirror on the opposite wall; each dot was gone by the time the pigeon turned around, but only pecks at the hole where it had appeared were reinforced. When another blue dot was attached to the pigeon’s breast while it wore a short bib allowing it to see the dot in the mirror but not by looking down, the pigeon pecked down toward the dot on its body even though it saw the dot only in the mirror (Epstein, Lanza, & Skinner, 1981). Did monkeys who failed the mirror test simply lack relevant experience with mirrors?

Social Origins of Language. Another way to learn from other organisms is through verbal behavior: you can be told about contingencies instead of observing them. But verbal behavior can’t have started that way, because descriptions of contingencies require sentences and the ear-
Our talking and listening and reading and writing are all behavior, but everyday usages get in the way when we talk about them. Consider the common term *word*. We seldom bother to distinguish spoken words from written ones. Yet speaking a word isn’t the same as writing it, and speaking and writing usually occur in different circumstances. Even worse, we often speak of *using* words, as if they were things instead of behavior. I don’t say I use a reach when I pick something up, but I might say I use a word when I say something (Skinner, 1957).

We also speak of words as if directed toward events or objects. We say words or sentences refer to, deal with, speak of, call attention to or are about things. The language of reference implicitly includes a direction from verbal behavior to environment. Everyday language doesn’t include words emphasizing the other direction. As with treating vision as light entering the eye instead of as something emanating from the eye and contacting things seen, getting the direction right makes a difference. Has our everyday language prejudiced us about how verbal behavior works? We hardly ever say nouns are uttered in the presence of relevant objects or sentences are occasioned by relevant events. Instead, we say words refer to objects or sentences are about events. These usages are appropriate to the equivalences relating different classes of verbal behavior, but in analyses of the behavior of speakers and listeners or readers and writers they can be misleading.

The language of meaning is another complication. Dictionaries don’t contain meanings of defined words; they just contain other words. We speak metaphorically when we say words contain meanings and that we convey these meanings to others through language. The metaphor of words as containers for meanings has been around for a long time, and yet the stored patterns corresponding to a recorded voice or the patterns of pigment on a page corresponding to a handwritten message have no meaning unless someone listens to the recording or reads the note; the meaning isn’t waiting to be released from the computer or the ink. If language transmits anything, it’s verbal behavior itself; in listening and reading, our own behavior re-creates some features of the behavior of the speakers and the writers constituting our verbal community. We share our verbal behavior; it is, above all, social behavior.

Our first task is classifying verbal behavior. But our taxonomy must be functional, not structural. A grammatical classification of words in a sentence doesn’t tell us how it was produced or what consequences it had for the one who produced it. The same holds for phonological classifications of the sounds in someone’s speech. You can say “I’m thirsty” or “Please pass the water” and get the water either way. They’re members of the same verbal operant class, but linguists will usually put them in different grammatical categories. Functional accounts of verbal behavior examine what verbal responses do. As with

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**Chapter 22**

**Words as Stimuli and Responses**

In an American school if you ask for the salt in good French, you get an A. In France, you get the salt.

— B. F. Skinner

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**Fixes needed on 206, 209, 212(2)**

No pages deleted from this chapter
nonverbal behavior, structural and functional accounts can complement each other. Unfortunately, those of verbal behavior were often pitted against each other as if they were incompatible instead of complementary (Catania, 1972, 1973b; Chomsky, 1959; Skinner, 1957).

**VERBAL BEHAVIOR: NOT A SYNONYM FOR LANGUAGE**

By itself, verbal behavior doesn’t do things. It’s effective through the mediation of other people. The mode isn’t critical; you can tell someone what you want when shopping by asking for it or pointing or in writing, as when you place an order online. But mediation by others characterizes all social behavior, so we must add another proviso. The social contingencies shaping verbal behavior don’t just create and maintain the conditions for speaking. They also create verbal repertoires with a special property: in the ordinary give and take of everyday talk, as speakers become listeners and listeners become speakers, the behavior of the listener reinforces the behavior of the speaker. Some nonhuman behavior may minimally qualify, as when a horse is taught to turn in response to a touch of the reins to its neck; the turns then reinforce the trainer’s behavior. But the horse and trainer differ crucially from a child and an adult parent or teacher. For the latter only, verbal contingencies become reciprocal: the child learns to ask as well as answer and to say thank you as well as you’re welcome. Thus, in some respects all verbal cultures are mutual reinforcement societies (Skinner, 1957, pp. 224–226).

Consider a simple verbal exchange: A says, Hi; B replies, Hi, how are you?; A continues, I’m fine, thanks. And you?; B answers Okay; and so on. The first reply of B is both a consequence of A’s greeting and an occasion for A’s continuation, but so is A’s response with respect to B’s antecedent and consequent verbal behavior. If you have any doubt about whether consequences maintain verbal behavior here, just imagine A’s or B’s verbal behavior if the verbal behavior of the other simply ceased. Verbal behavior involves both listener behavior shaped by its effects on the speaker’s behavior, and speaker behavior shaped by its effects on the listener’s behavior. These reciprocities define verbal behavior. Verbal behavior is shaped and maintained by the practices of a verbal community.

When we define verbal behavior this way, by its function, we distinguish it from language (Skinner, 1957, p. 461). Languages are defined by structure and not function. The definitions, spellings and pronunciations in dictionaries and the rules in grammar books describe standard structures of verbal units in a language. In so doing, they summarize structural properties of the practices of a verbal community. The verbal behavior of speakers occurs in the context of those practices, but the maintaining practices, language, must not be confused with what they maintain, which is verbal behavior.

**CORRESPONDENCES BETWEEN SPOKEN AND WRITTEN CLASSES**

Our verbal communities shape correspondences between things and their names, between words and their definitions, between what we did and what we said we did, between what we promised and what we accomplished, and so on. The conditions maintaining correspondences determine how they work in our verbal behavior. Our first examples will consist of formal verbal relations between spoken and written classes, not because they’re the most fundamental but because they’re familiar and involve well-defined correspondences. They illustrate how to talk about words antecedents and consequences instead of as references and their meanings. In other words, they help us talk about words as behavior.

The term verbal is general and applies to language in any modality; we distinguish it from vocal, which is specific to spoken language. We could extend our account to other modalities, such as the gestural modality of sign language or the tactile modality of Braille, but for convenience we’ll mostly restrict our attention to spo-
ken and written classes of verbal behavior. Also, it’s sometimes worth distinguishing spoken from vocal, because not all voiced sounds qualify as speech. But these technical issues won’t affect our basic story.

Correspondences between verbal stimuli and verbal responses in formal verbal relations are implicit in the colloquial vocabulary: we say words are the same whether they’re heard or spoken, seen or written, or, translating, whether they’re auditory or visual stimuli or responses. An elementary verbal function is the replication of verbal behavior: we repeat what others say or copy what others write. Thus, our cases include the replication of verbal behavior in all four combinations of spoken or written stimuli and spoken or written responses: spoken to spoken (echoic behavior), written to written (transcription), written to spoken (textual behavior), and spoken to written (dictation-taking).

It’s easy to forget most of these relations are arbitrary. A spoken letter has no visual shape and a written letter has no sound. The relations between visual and spoken forms come about only after a very long history. What’s important here is that saying the letter sets the occasion for writing it down. Saying the letter can’t possibly look like the letter, but given an appropriate verbal history it can become a recipe for writing it down.

Echoic Behavior

Imitation of properties of vocal stimuli appears relatively early in an infant’s acquisition of speech. We call this class of verbal relations echoic. When a parent says “mama” and the child repeats “mama,” the child’s response is echoic to the extent (i) it’s occasioned by the parent’s utterance and (ii) the phonemes of the child’s utterance have a one-to-one correspondence to those of the parents. Even though the stimulus and the response have common properties, this verbal relation isn’t simple. Hearing a sound isn’t the same as making the vocal adjustments producing the sound. The stimulus is a complex sound pattern. The response consists of the coordinated articulations of lungs, vocal cords, tongue, lips and so on. These produce sounds but aren’t themselves sounds. How then does the child know what to do to produce the sounds heard as “mama” or “dada” by the parents?

The speech units called phonemes are more easily defined by articulations (positions of the tongue, etc.) than by acoustic properties (Lane, 1965; Liberman, 1982). The interactions of articulation and sound are complex; for example, many English consonants (e.g., p, b, d) can’t be produced unless accompanied by a vowel, and their acoustic properties vary as a function of context (e.g., both the l and k sounds are different in lick and in kill). Echoic behavior isn’t defined by acoustic correspondences; it’s defined by the correspondences of phonetic units.

Voices differ in many respects: an adult voice is deeper than a child’s; a woman’s voice differs from a man’s; people speak with varying regional dialects. If a young boy from a small New England town repeats what a grandmother from Atlanta just said, their utterances will differ acoustically in many ways. But differences in vocal quality and regional dialect are irrelevant to whether the boy’s behavior is echoic; the criterion for echoic behavior is the correspondence of verbal units like phonemes and words. That’s why a parrot’s duplication of human sound patterns doesn’t qualify as echoic: its duplications are acoustic rather than phonetic. For example, if a child’s lisp of an s is reproduced by a parrot, the parrot will make the lisped th sound but a parent would ordinarily use the unlisped s instead. A voice synthesized by a computer often sounds unrealistic because the computer doesn’t produce its approximations to speech the way a human vocal tract does.

Echoic units can vary in size from individual speech sounds to extended phrases or sentences. A variety of verbal phenomena, such as speech errors (Fromkin, 1971), can help us decide what these units are. Echoic relations can appear in poetic rhyming and alliteration (Skinner, 1972; B. H. Smith, 1968). For adult speakers, units of echoic behavior may be whole words or phrases. The echoic production of extended phrases or sentences occurs in dramatics, as when an actor
repeats lines whispered by a prompter, and on ritual occasions, as when a bride and groom repeat a marriage vow spoken by a member of the clergy. Echoic units aren’t defined by size; they’re defined by the correspondences into which they enter.

Echoic behavior doesn’t simply accompany the acquisition of language and then vanish; it persists in mature speakers. For example, I might repeat the name of someone to whom I’ve just been introduced. But whether a speaker has understood what’s been echoed is independent of whether the speaker has echoed successfully. Meaning doesn’t enter into the definition of echoic behavior; we must deal with it in other ways.

Some verbal responses are only partially echoic, as when I say something incorporating just a couple of words from a question I’ve been asked. In his design of a system to tap latent verbal behavior, Skinner (1936) took advantage of partial echoics. To the participants, his verbal sum-mator was supposed to test speech detection in noise. After general instructions, they were asked to “Listen to the phonograph until you find yourself saying something; then say it aloud.” Their stimuli were repeated inflection patterns (e.g., oo-ah-ee, oo-ah-ee, oo-ah-ee) and not words; nonetheless their verbal responses were typically words. The inflection patterns of the words matched those in the stimuli but also reflected whatever verbal behavior was currently strong in the listener’s verbal repertoire for other reasons, so they worked like an auditory analog of the Rorschach inkblots used in personality testing.

The Development of Echoic Behavior. Echoic behavior depends at least in part on the shaping of articulations by their vocal consequences (Risley, 1977; Skinner, 1957, p. 58). Before their own vocalizations begin to be differentiated, infants discriminate among many aspects of the speech of those around them (Eimas et al., 1971); for example, they readily discriminate between sounds of their native language and those from an unfamiliar foreign language but not between sounds from two unfamiliar foreign languages (Mehler et al., 1988). This means they can hear the differences when they make the sounds themselves and some of the sounds may become reinforcers (Friedlander, 1968).

At first their babbling includes undifferentiated sounds, but over time they retain native speech sounds in their spontaneous vocalizations while other kinds gradually disappear. It was once thought early infant sounds included all possible human speech sounds, but instead infants progress from intonations and stress patterns to vowels and then consonants, starting with the easiest ones (Vihman, 1996). Eventually their babbling evolves to self-repetitions (echolalic speech; e.g., “ma-ma-ma-ma-ma”) and then repetitions of the speech of others (echoic speech).

Vocalizations can be reinforced (Poulson, 1984), and the vocalizations of infants are engendered and maintained by what they hear themselves saying; without these auditory consequences (as in cases of hearing impairment), the behavior doesn’t develop. As we know from recordings, our own voices sound different to us than they do to others, because we hear our own voices via bone conduction as well as from sound traveling through the air. This adds to the case that echoic behavior is defined by correspondences of learned phonetic units rather than by the matching of acoustic properties.

Rare individuals may, through accidents of anatomy, hear themselves as others hear them. They have the advantage of knowing how well they’ve imitated other voices. I first heard how different my own voice sounded to me than to others when a high school friend used a hidden tape recorder to record a group conversation. After listening to the tape, one of our group said he didn’t hear much of a difference. He was good at doing vocal impressions. Given he sounded roughly the same to himself as to others, if he talked so he sounded like Humphrey Bogart to himself then he’d sound like Humphrey Bogart to us too. I’ve occasionally asked in class about how people hear their own voices; over the years I’ve encountered fewer than half a dozen who said they heard themselves as others heard them. But each was good at doing impressions.

Perhaps native speech sounds become reinforcing relative to sounds of nonnative lan-
guages simply because they often accompany activities of the infant’s caregivers (DeCasper & Fifer, 1980). An articulation producing something sounding like what mommy says may be reinforced automatically by this correspondence between the infant’s and the parent’s utterances. The differentiation of phonemic structure may then follow from the overlapping contingencies into which different speech sounds enter.

**Categorical Perception of Phonemes.** A child raised exclusively in an English-speaking environment will discriminate between the consonants $b$ and $p$, but one raised exclusively in an Arabic-speaking environment, which doesn’t include separate $b$ and $p$ consonants, won’t. Furthermore, if the $b$ is gradually changed to a $p$ for the English speaker, the switch from calling the sound a $b$ to calling it a $p$ occurs discretely; listeners don’t report an intermediate consonant that’s a cross between them. This type of transition is called categorical perception, in that responses to stimuli varying along some continuum don’t also vary continuously but instead fall into two distinct categories (Harnad, 2003).

Another fact about acquisition of phonemes is that discriminations of speech sounds learned easily at an early age may be hard to learn later (Werker, 1989). For example, the distinction between spoken $r$ and $l$ in English doesn’t exist in Japanese and is much more easily learned by a Japanese child than an adult Japanese speaker. Infants master simple articulations before moving on to more complex ones. If the vocal units differentiated during babbling are different from one language to another, perhaps an adult learning a new language finds it difficult to master the new phonemes in part because the prerequisite simpler articulations were never differentiated.

The environment may be able to sculpt language units in various ways. Developing nervous systems divide into functional regions sometimes called compartments (Irvine & Rauskolb, 2001; Kiecker & Lumsden, 2009). The formation of boundaries may also be significant in the development of behavioral units like phonemes (Kim & Bao, 2008). For example, we know cortical tactile receptor areas in primates include boundaries between the projection areas for different fingers that can be visualized with appropriate stains. Adjacent cells on one finger are likely to be stimulated at the same time, whereas those on a neighboring finger, though projected close by on the cortex, are likely often to be stimulated separately. These differences between correlated and uncorrelated firing may provide the basis for a boundary. Moreover, the number of compartments is determined during development by the number of units at the periphery (e.g., the separate rays in the nose of the star-nosed mole: Catania, K. C., & Kaas, 1997).

This has been an ontogenic account of the natural selection of phonetic units of verbal behavior. The selection is based on correspondences between the language already available in a verbal community and the vocalizations of an infant language learner, so it provides a means for transmitting verbal behavior at the cultural or memetic level, in this case from one generation of speakers to the next. There are ways it can fail: motor disorders may constrain articulation; hearing may be impaired; relevant consequences may be absent, perhaps because of neglect or abuse by caregivers or because neurological deficits have reduced the effectiveness of social stimuli. But once vocal articulations have been shaped and the child can hear their consequences, the minimum conditions for the ontogenic selection of vocal units are in place. In contrast, reinforcement of nonhuman vocalizations is typically limited to rate; it’s difficult to modify topography (K. Hayes & Hayes, 1951; Lane, 1961). A lot may follow from the shaping of speech: “The human species took a crucial step forward when its vocal musculature came under operant control in the production of speech sounds. Indeed, it is possible that all the distinctive achievements of the species can be traced to that one genetic change” (Skinner, 1986, p. 117).

**Transcription**

Verbal stimuli and responses can correspond when both are written. In such cases, the behavior is called transcription. For example, you might
copy a number from a telephone book or an author and title in preparing a bibliography. It doesn’t matter whether you produce the copy by writing it or typing it or dragging and dropping it. Just as we distinguish vocal articulations and the sounds they produce in echoic behavior, we also distinguish the movements involved in producing words from the looks of the words in transcription. Just as echoic behavior depends on correspondences of verbal and not acoustic properties, transcription depends on correspondences of verbal and not visual properties. A handwritten sentence looks different from the printed text from which it was transcribed (the script letters run together but the printed ones don’t). Even so, writing the sentence qualifies as transcription if the script sentence replicates the printed one in spelling, word order and punctuation.

Just as units of echoic behavior can vary from individual phonemes to entire phrases or sentences, units of transcription can vary from individual characters to extended passages, depending on the circumstances in which the behavior occurs. A child learns to copy single letters before learning to copy whole words. In doing so, the child learns correspondences between arbitrary visual forms, such as printed and script \textit{a} in upper- and lowercase. No visual property is exclusively common to all forms of the letter \textit{a}. Consider the different forms of the several following English letters:

<table>
<thead>
<tr>
<th>Aaa</th>
<th>Bb#</th>
<th>Dd\</th>
<th>Ee\</th>
<th>Ff\</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ggg</td>
<td>QqQ</td>
<td>Rr\</td>
<td>Ss\</td>
<td>Tt\</td>
</tr>
</tbody>
</table>

Such differences within the forms of a single letter are sometimes greater than those between different letters, as in the following groups of letters with properties in common:

\textit{hnm} – \textit{ODQ} – \textit{bdpq} – \textit{MNW}

The variations of form explain why transcription differs from copying in the pictorial sense. A skilled Asian calligrapher unfamiliar with the European alphabet in which a text is printed might produce an accurate copy, but the copying would not be verbal. The behavioral units in the two kinds of copying matter. The critical features of the calligrapher’s copying are geometrical properties of letters in the text and marks produced by the calligrapher’s strokes; the critical features of transcription are the verbal units—letters, words and phrases—in the original text and its copy. Visually, the calligrapher’s copy might look more like the original than a handwritten copy by a speaker of the language, but only the latter counts as transcription. An \textit{A} may be transcribed as an \textit{A} or an \textit{a} or an \textit{a}, but a mere picture of an \textit{A} doesn’t qualify.

Except for their respective spoken and written modes, echoic behavior and transcription are formally similar. Children ordinarily acquire echoic behavior early even without specific instruction, but they take some time doing so. They don’t ordinarily acquire transcription unless it’s explicitly taught. Nevertheless, the relative ease with which one or the other is learned provides no grounds for assuming one is simpler than the other.

Pure transcription is probably rare. It occurs only when transcription is unaccompanied by other behavior, such as responding to a text in reading for meaning. For example, if a skilled typist accurately transcribes a letter while not responding verbally to it in other ways, say while listening to a conversation elsewhere in the office, the typist afterwards may be unable to describe what was in the letter. This would be a case of relatively pure transcription: the typist was transcribing \textbf{and doing nothing else}. Responding to the text in other ways, as in reading or understanding it, is doing something more that may combine with the transcription but doesn’t count as part of it. When we’re transcribing, we’re usually doing a lot more besides. As with echoic behavior, meaning isn’t part of our definition of transcription.

Textual Behavior

When a written verbal stimulus sets the occasion for a corresponding spoken verbal response, the
behavior is *textual*. You might say aloud what’s on a menu or read a bedtime story to a child. In textual behavior, the arbitrary correspondence between verbal stimuli and responses is more obvious than in either echoic behavior or transcription, because the stimuli and responses are in different modes. A written word is a visual stimulus; it has no sound. A spoken word is an auditory stimulus; it has no shape. Yet these correspondences are so familiar we rarely notice the arbitrary nature of the relations between verbal shapes and sounds.

As with transcription, textual behavior is usually taught explicitly, and some controversies about teaching it are based on assumptions about the units appropriate to various stages of instruction, such as whether the teaching of reading should begin with individual letters, syllables or whole words (Gleitman & Rozin, 1973).

As with the other formal classes, we must distinguish textual behavior from other kinds of responses to written verbal stimuli. For example, if a sign says STOP, reading the word aloud is textual but stopping isn’t. In the mature reader, textual responses become less important than other kinds of responses to written verbal stimuli. Vocal responses diminish in magnitude, become subvocal and perhaps disappear completely as a child becomes a proficient reader. Reading is behavior but it’s far more than textual behavior; textual responses are at best one part of reading. For example, a father reading a bedtime story aloud to a child might finish a page and suddenly realize he doesn’t know what just happened in the story, even though the child does. His example, without understanding, is a pure case of textual behavior.

The colloquial vocabulary doesn’t distinguish between reading when it’s nothing more than saying the words on a page and reading when it’s the kind we call reading for understanding. Most of us have occasionally found ourselves partway through a page unable to say what was in the last couple of paragraphs. We were at that time presumably engaging in some reduced form of textual behavior and absolutely nothing else (I assume it never happens while you’re reading this book!). Such experiences are evidence for the importance of these distinctions. Reading for understanding includes other behavior along with or instead of vocal or subvocal speech, so it’s more—probably a lot more—than textual behavior.

### Dictation-Taking

Just as a written stimulus can set the occasion for a spoken response, a spoken stimulus can set the occasion for a written one. This is called *dictation-taking*. We’re concerned here with the listener who takes the dictation, not the speaker who dictates. For example, you might take notes at a lecture. The units of dictation-taking are typically entire words or phrases, but individual letters may also serve (e.g., as when children are taught the written alphabet or an unusual name is spelled out for a stenographer). As with transcription, the form can vary: shorthand, script and typing all qualify.

Some of the special properties of dictation-taking follow from the relatively permanent record produced in a written text. In addition, occasions for dictation-taking are limited relative to textual behavior, because, unlike our vocal apparatus, writing implements aren’t parts of our anatomy. Perhaps for this reason, we aren’t much tempted to pursue its covert manifestations; we’re more likely to speak of subvocal reading than of submanual writing or typing. Even so, textual behavior and dictation-taking are formally similar and either can be accompanied by other kinds of verbal behavior occasioned by verbal stimuli.

### Relations Among the Classes

This account of formal verbal classes has been limited to spoken and written stimuli and responses. We could extend it to other modes, such as writing and reading Braille or producing and reading sign language or sending and receiving Morse code. Sometimes we can ignore the distinction between verbal stimuli and verbal responses, but not always. For example, though we speak of letters and words without
regard to whether they’re written or spoken, the mode matters in teaching. A teacher who has only taught a child to name letters written on a chalkboard shouldn’t expect the child to write the letters when they’re spoken. The stimuli in the former are the responses in the latter, and vice versa. Until they become equivalent, they’re just one part of “knowing the alphabet.”

To teach reading and writing is to teach equivalences between spoken and written modes of verbal behavior. Our everyday vocabulary obscures these distinctions, perhaps because equivalences so come easily to us, or perhaps because language instruction is designed to eliminate them, or perhaps both. In any case, the relations are summarized in Figure 22–1.

THE REPLICATION OF VERBAL BEHAVIOR

All the formal classes involve the replication of verbal behavior in spoken or written form. Darwin discussed parallels between the evolution of species and the evolution of languages (Darwin, 1871). Under the pressures of modernization some languages have become extinct and many others are threatened. The replication of verbal behavior isn’t mere reproduction. Based on a long history in which we’ve learned relations among spoken and written stimuli and responses, we say words are the same whether spoken or written. Thus, saying what has been written or writing what has been said are instances of replication even though they carry across different modalities. These relations extend the effects of verbal stimuli over time and space as the verbal behavior produced by some is passed on to others. Furthermore, replications allow instructions to be followed in the original speaker’s or writer’s absence, later and elsewhere, as when we repeat to ourselves the details of a task someone has asked us to complete or write notes on which we can later act. Replication must come first, but once in place powerful contingencies maintain it.

We’ve emphasized classes defined by verbal modes, but other formal relations may be differentiated even within a mode. For example, a student who has learned only to translate from English to German may have difficulty when asked to translate in the other direction. The problems are compounded when both spoken and written languages are involved. Language instruction usually recognizes these distinctions; a course in conversational French is expected to emphasize the spoken mode, whereas one in scientific Russian is expected to emphasize the written mode.

Each mode, spoken and written, has special characteristics. Spoken verbal behavior varies more freely in stress, rhythm and intensity than written verbal behavior, but it’s also more transient. Some verbal properties are independent of mode. For the immediate consequence...
of being able to dial a phone number, it hardly matters whether you hear the number or see it on a cellphone screen, or whether you repeat it aloud to yourself or write it down. Some consequences may affect how you look for it next time (e.g., how hard was it to find it?), but they’re not essentially verbal. Thus, once equivalences are in place distinguishing among the formal classes diminishes in importance.

Parallels in Music

But we may need the distinctions for studying certain topics, such as the language pathologies called *aphasias*, in which deficits are characterized by the verbal classes affected (Sidman, 1971). Some aphasias affect only one of the four possible relations illustrated in Figure 22–1, so we can’t always assume equivalences. But we don’t often run into aphasias. Music provides a more familiar example. In music, the mastery of a subset of the possible formal relations among musical stimuli and musical responses doesn’t guarantee the others will be carried along. Figure 22–2 substitutes singing and reading or writing music for the verbal classes of Figure 22–1. The word *behavior* has the same stress patterns as the word *Maria* in the song by that name in the musical *West Side Story*, so it’s been used here as an illustration.

Some musicians play or sing by ear and others prefer to do so from a score. Some musicians can sing or play a heard melody but many who can do so can’t write the music down. The musical behavior analogous to echoic behavior is common among musicians, but it’s variable with respect to the analogs of dictation-taking, transcription and textual behavior, with some proficient in all three and others proficient in only one or two.

Some talented musicians manage without any musical scores at all on either the stimulus or the response side, so in reproducing music they’re limited to echoic music making. If they’d been correspondingly limited in spoken and written verbal behavior they’d have been called illiterate. But the honed skills of sophisticated musicians together with contemporary recording technologies outweigh the formal limits on how they can replicate music, so distinctions like those we’re considering here simply don’t matter to their audiences.

In verbal behavior, a speaker’s response is a listener’s stimulus and a writer’s response is a reader’s stimulus, and a speaker or writer at one time becomes a listener or reader at another.

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**Figure 22–2** Relations among four formal classes of musical behavior. They involve singing given a heard song or a musical score, or writing the music given a heard song or a score (S, stimulus; R, response). “Behavior!” is here sung to the melody of the song “Maria” from *West Side Story*. 
Music supplements our other verbal examples because it’s more obvious in these cases that mastery of some formal relations doesn’t guarantee the integrity of others. They’re separate classes of behavior that become integrated only given appropriate contingencies.

Verbal behavior and music differ in other ways (Masataka, 2007). Music is more closely related to tone of voice than to other properties of verbal behavior. The functional distinction between tone of voice and substantive properties of vocal discourse is illustrated by the different reactions of two audiences to a speech by Ronald Reagan (Sacks, 1985). Psychotics without affect responded only to the speech content whereas aphasics responded only to its affect; only those responsive to both dimensions found the speech persuasive. If affective vocal functions are like those of other emotional displays, they might have provided a vocal substrate on which other functions of verbal behavior were built. Emotional behavior predates language, and other evolving functions of verbal behavior may have been overlaid on it later while properties like tone of voice retained their emotional functions.
Chapter 23
Antecedents and Consequences of Words

...the relation between a name and that which it names is fundamentally asymmetrical.
— Horne & Lowe

The formal classes involve verbal responses occasioned by verbal stimuli. They’re characterized by one-to-one correspondences of verbal units. In transcription, for example, each word of a text has a unique equivalent in the transcribed version. But we learn many verbal relations that don’t involve such formal correspondences, and these relations interact in powerful ways, as when combinations of basic arithmetic interverbsals such as two plus two equals four or three times five equals fifteen combine in our solution of a mathematics problem. Skinner called such relations intraverbal (Skinner, 1957). They come in three varieties: through membership in common thematic or semantic classes, as when hearing cow and barn makes us just a bit more likely to say farm; through effects of verbal stimuli setting the occasion for specific verbal responses, as when we’re likely to say blue if someone says red, white and...; and through the temporal integration of verbal units into larger sequences, as when we say One picture is worth a thousand words or A word to the wise is sufficient (additional intraverbal behavior is involved in deriving the implication that A picture to the wise is redundant).

INTRAVERBALS: THEMATIC CLASSES

The intraverbal relations in any adult repertoire are the result of hundreds of thousands of reinforcements under a great variety of inconsistent and often conflicting contingencies. Many different responses are brought under the control of a given stimulus word, and many different stimulus words are placed in control of a single response” (Skinner, 1957, p. 74). Skinner wasn’t writing about M&Ms. His reinforcements aren’t edibles but rather the simple consequences of day-to-day interactions, like a nod or a change in expression; some consequences are verbal, like acknowledgments or other replies. Reading a word in a certain way because of its context might sometimes qualify too. Small-scale consequences following from listening or reading can accumulate over time; these are Skinner’s hundreds of thousands of reinforcements.

We encounter many words groups in common situations, so they may come to vary together as members of verbal classes. Such classes are said to be thematically or semantically related. For example, transportation words include car, bus, plane, train, as well as groups within groups, like vehicle, automobile, taxi, sedan within the class car, and the classes can be further differentiated by makes and models. The complex interlocking of such classes is evident in literature and poetry, and many verbal games appeal to thematic classes (Botticelli, Wordsmith, MadLibs). Free association provides further examples of thematic relations. A verbal response may be occasioned by combined thematic and formal properties of a verbal stimulus. For example, the echoic heard-word rhyme may make a slight contribution toward my saying “I heard that word” instead of “I heard what you
We might say thematic classes consist of words with common meanings, but to do so we’d have to define meanings. But meanings aren’t properties of words; they’re properties of our responses to them. For example, if you repeat a familiar word like your own name over and over, you may find it loses its meaning; some response to it drops out after several repetitions. A red traffic light means stop and a green one means go, but when I stop on red and go on green, I’m responding to red and to green and not to their meanings. Written words in a language no one understands have no meaning, and when we say a word has many meanings (as in bat in a belfry and bat at a baseball game), the meanings change only in the sense that we respond differently to the word in its different contexts.

In the chaining of intraverbal behavior, one verbal stimulus sets the occasion for another verbal response. The relation between stimulus and response is arbitrary; there are no systematic correspondences between them. Free association is an example (Galton, 1879). The immediate consequences of free associations are usually minimal, and any given verbal stimulus may occasion a variety of different responses, so like the verbal summator the procedure is assumed to tap verbal responses of relatively high probability in the speaker’s verbal repertory. You’re asked to report “anything that comes to mind,” and the word-association experiment reveals some of the relations between verbal responses and verbal stimuli created in your everyday listening and reading.

The same applies to chronologies, geographies and much of our everyday knowledge. No one living saw Washington crossing the Delaware. I might argue I saw the scene in a painting, but even if I’d recognized Washington, could I have known the setting was the Delaware River without a label telling me so? We rarely learn historical details by experiencing them. Instead, given names or dates, we learn to say when or in what order events occurred. “Most of the ‘facts’ of history are acquired and retained as intraverbal responses” (Skinner, 1957, p. 72).

...educational reinforcement sets up many different intraverbal operants involving the cardinal numbers. Four is part of the occasion for five in learning to count, for six in learning to count by twos, for one in learning the value of \( \pi \), and so on. On the other hand, many different verbal stimuli come to control the response four, e.g., one, two, three... or two times two makes.... Many different connections between verbal responses and verbal stimuli are established when different passages are memorized and different “facts” acquired. The word-association experiment shows the results. (Skinner, 1957, pp. 73–74)

Word associations were the basis for some attempts to measure meaning (Galton 1879). If the order of letters in the alphabet is no more systematic than their placement on a computer keyboard. Similar sounding M and N are close together but similar sounding D and T are far apart; the voiced B appears before the voiceless P, but the voiced V appears after the voiceless F, and so on.
listeners produced more varied lists in response to one word than another, the first word was said to be more meaningful than the second. Words that occasioned overlapping lists of associates were assumed to be closely related. For example, common associations to both *infant* and *baby* might include *crib* and *bottle* but probably neither would be responses to *guitar*. The different degrees of overlap among the associates are consistent with what we already know: *infant* and *baby* are closer in meaning than either is to *guitar*.

In its simplest forms, intraverbal behavior has been a major focus of research on human verbal learning, perhaps because of the ease with which verbal materials can be manipulated as stimuli. The classic experiments of Ebbinghaus (1885/1964) were specifically concerned with the learning of arbitrary verbal combinations. Paired-associates learning (learning word pairs) and serial learning (learning ordered lists, as in learning to count) represent basic cases of intraverbal behavior. Intraverbal relations are a component of standard educational practice, as when a child mastering the multiplication table gives 42 as the response to 6 × 7. But the response is strictly intraverbal only if it doesn’t depend on other intervening arithmetic behavior, such as adding six sevens, counting by sixes or counting the boxes in a 6-by-7 rectangle.

**INTRAVERBAL CHUNKS**

It’s appropriate to speak of intraverbal chains only when successive parts of an utterance serve as discriminative stimuli for later parts. When extended utterances function as independent verbal units, as in rapidly emitted sequences, the language of chains doesn’t apply. By analogy with similar units in the analysis of remembering, they’re intraverbal *chunks*. Maxims like “Haste makes waste” and “He who hesitates is lost,” best regarded as verbal units in their own right, are intraverbal chunks.

Some examples of large intraverbal chunks are Hamlet’s soliloquy, the Pledge of Allegiance, and the lyrics of Simon and Garfunkel’s *Sounds of Silence*, assuming in each case the words have become well learned. Some short verbal sequences can be learned very quickly, but when they’re as extended as these they may take some time. At the beginning, completing the sequence will depend a lot on chaining, perhaps in combination with prompting or reference to a written copy. But even early on, some parts begin to hang together. When I get as far as *To be or not to* I don’t need to consider what I’ve said so far before I continue with *be*. Whether completing of the line occasions *That is the question* will tell me whether this part of the soliloquy is still chained or I’ve begun to integrate it into a larger chunk. Throughout my learning, the soliloquy will be a mix, partly chained and partly chunked. And even for a seasoned Shakespearean actor, much less me, the soliloquy may remain a segmented work where major boundaries separate chunks that are chained together. Ay, there’s the rub.

The case for chunks was extended from non-verbal to verbal behavior by Lashley (1951), who described cases from language and music that made such accounts implausible. For example, in answering the argument that each movement serves as a unique stimulus for the next, Lashley considered the complex sequence of movements required to pronounce the sounds of the word “right” in proper order. The order isn’t given by the sounds themselves, because they can occur in a variety of orders and combinations (e.g., in the opposite order, as in “tire”). If the sound sequence can’t be based on responses uniquely occasioned by stimuli it must depend on a larger organization. Lashley extended the case from sequences of sounds within words to sequences of words within sentences:

The word “right,” for example, is a noun, adjective, adverb, and verb, and has four spellings and at least ten meanings. In such a sentence as “The millwright on my right thinks it right that some conventional rite should symbolize the right of every man to write as he pleases,” word arrangement is obviously not due to any direct associations of the word “right” itself with other words, but to meanings which are deter-
mined by some broader relations. (Lashley, 1951, pp. 115–116)

Lashley used music to point out that the sheer rapidity of some sequences constrains how they might be generated:

The finger strokes of a musician may reach sixteen per second in passages which call for a definite and changing order of successive finger movements. The succession of movements is too quick even for visual reaction time. In rapid sight reading it is impossible to read the individual notes of an arpeggio. The notes must be seen in groups…. (Lashley, 1951, p. 123)

When a skilled typist rapidly types the, each letter can’t be a discriminative stimulus for the next stroke, first because the typist will be executing the next stroke even before the last typed letter exists on the page, and second because as discriminative stimuli these letters can’t be unique if they can be followed by hitting the space bar or any of many other keys depending on what the typist is typing (e.g., the or these or then or thermometer).

Verbal Learning

The area traditionally called verbal learning is concerned with what happens as we learn word sequences, word combinations and word contexts. Its literature is extensive. Here we briefly examine four major classes of verbal learning: serial learning, paired-associates learning, free recall, and verbal discrimination, including verbal recognition as a special case. In typical procedures, verbal stimuli are presented to the learner and then verbal responses are recorded. We take a lot for granted in such arrangements. Describing them simply as verbal discriminative stimuli and differentiated verbal responses omits significant features. For example, the learner’s performance is rarely generated by differential consequences; instead, it’s usually created by giving instructions. The consequences may be hard to specify. The experimenter designates responses as right and wrong. When the learner responds, the experimenter may say “Right” or “Wrong” or the learner may just be shown the correct item. These procedures are said to provide feedback or knowledge of results. It’s tempting to assume telling or showing a learner a response was correct is a reinforcer, but feedback might function only as an instruction: telling the learner a response was correct is like saying, “Respond the same way next time.” Thus, speaking of the reinforcing properties of being correct and the punishing properties of being incorrect may be misleading.

Verbal learning materials have ranged from simple items like numbers and letters through nonsense syllables and words to such complex materials as sentences and extended texts in either written or vocal modes. Written stimuli have the advantage that they’re uniform, easily described and can be presented at well-defined rates and durations. An experimenter who reads a list to different learners might change the inflection or loudness of words over successive readings. Similarly, the choice of written or vocal responses varies with experimental requirements. Learners can usually respond more quickly vocally than in writing, but the vocal response must be recorded whereas the written response is its own record.

Verbal-learning procedures experimentally realized the associationist principles developed by philosophers like David Hume and James Mill, who advocated that human thought is based on the association of ideas. Ideas were said to become connected or associated through similarity or common elements or other dimensions, but especially through contiguity in space or time. Later, with the beginnings of modern chemistry, analogies were drawn between the formation of associations and the chemical combinations of atoms into molecules. Hermann Ebbinghaus, a German investigator, in effect the founder of research on remembering, used himself as the experimental subject. With measuring the formation of arbitrary associations as his goal, he invented the nonsense syllable as an
item that hadn’t acquired verbal functions and therefore wouldn’t be contaminated by existing associations (Ebbinghaus, 1885/1964).

As its name implies, serial learning is the learning of a verbal sequence, as when a child learns to count or recite the days of the week. For example, suppose we try to teach someone the first ten presidents of the United States through serial recall. We show each name briefly and the learner tries to recite the entire list in proper order only after all ten have appeared; we repeat the list until the learner gives one or more correct repetitions. Once the list is learned, we might ask the learner questions about the positions of names in the list, like “Who was the ninth president?” (Harrison), “Which president was Tyler?” (tenth) or “Which president came before Van Buren?” (Jackson). A well-learned serial list, the alphabet, illustrates the roles of context and position. We can recite the alphabet and probably can quickly say which letter precedes or follows any other, but without counting how easy is it to give the 11th letter or the numerical position of S?

Paired-associates learning generates correspondences between items on two lists, as in learning the dates of historical events or the equivalents in one language of words in another. Each verbal stimulus sets the occasion for a verbal response. For example, if the pairs to be learned are titles and authors, they might consist of: Don Quixote–Cervantes; Candide–Voltaire; Moby Dick–Melville; Catch 22–Heller; The Odyssey–Homer; and so on. Each title appears alone for a few seconds. Whatever the learner’s response, the author is then added. The full set is repeated, usually with the order changed, until the learner correctly names each author before the name appears. Questions can then be asked about effects of changing items or reversing stimuli and responses. Paired-associates experiments, however, don’t typically use familiar items and pairings; they’re more likely to use nonsense syllables or arbitrary combinations.

Paired-associates procedures were developed independently of Ebbinghaus’s work on serial learning by an American researcher, Mary Calkins (1894, 1896). Associations can sometimes be learned on a single trial, but the properties of the association may be more important than how quickly it can be formed. For example, is it symmetrical? Once the stimulus item consistently occasions the response item, will the response item occasion the stimulus item? The naming of written letters is a paired-associates task with written stimuli and vocal responses; if a child who hasn’t yet started to write learns to say “A” when shown a written A, we wouldn’t expect the child to write an A in response to the spoken letter (Polson et al., 1997). The issue has practical implications. In learning Russian, for example, learning to give the equivalent English word in response to a word in Russian doesn’t guarantee you’ll be able to give the corresponding word in Russian when the English word is the stimulus item. You’d be well-advised to learn the symmetry explicitly by studying the vocabulary in both directions (e.g., English to Russian and Russian to English). Such symmetries are prerequisites for equivalence classes as well as the defining characteristics of bilingual skill (Kolers, 1966).

In free recall, the learner is asked to name, in any order, items presented earlier, as when you’re asked to say what was on a misplaced shopping list or what questions were on a test. In verbal learning studies, the list consists of verbal items, but the procedure is like recall of non-verbal stimuli, as when a witness names those present at the scene of a crime. Another commonplace example is when someone asks us to name the people we met at some event.

Verbal discrimination is simply discrimination along some verbal dimension of stimuli, as when a child learns to distinguish vowels from consonants or nouns from verbs or grammatical from ungrammatical sentences. Pairs of items are presented and the learner chooses one item of each pair by naming it, pointing to it or perhaps pressing a left or right button. One special case is that between new and old items, as when a student in a language course distinguishes words already learned from new ones. This is verbal recognition. After an initial list, the learner is given
another one with both new items and items from the first list. The learner must identify the items from the first list. Except that it uses verbal materials, verbal recognition is like everyday instances of recognition, as in recognizing places you’ve visited or friends in a crowd.

Each procedure seems superficially simple, but while mastering any of these tasks, the human learner inevitably does a lot more. The historical transition from serial and paired-associates experiments to those of free recall occurred in part to allow the learner to demonstrate other things learned about lists besides the orders of specific items in them. These various verbal-learning procedures provided baselines for studying factors influencing human learning. For example, the finding that spaced practice is typically more effective than massed practice (Underwood, 1961) is often cited in support of distributing study evenly throughout a semester instead of cramming it in at the end, just before exams. The finding is so familiar it’s surprising it was once regarded as counterintuitive.

Data from serial learning and other procedures typically include serial-position effects. Learners are most likely to recall items at the beginning and at the end of lists: thereby illustrating two principles: primacy and recency. The principle of primacy states that the first items of a list are more likely to be recalled than later ones; the principle of recency states that the most recent items, i.e., those at the end, are more likely to be recalled than earlier ones. But these principles don’t explain serial-position effects; they’re just names summarizing what learners do. The important dimensions of free recall are in the learner and not the list. Learners behave with respect to what they’re learning. For example, in free recall learners often rehearse recent items by repeating them vocally or subvocally. Learners have more opportunities to rehearse early words than later ones, so rehearsal may contribute to the primacy effect. But opportunities to rehearse near the end of lists is limited, so it’s unlikely rehearsal is implicated in recency effects. And if you followed the instruction to go through the list quickly, you probably didn’t have time for rehearsal anyway.

The main difference between serial recall and free recall is in the instructions to the learner. In serial recall, the learner is instructed to name the items in their original order; in free recall, the learner isn’t told order is important, or perhaps is specifically instructed to ignore order. But this doesn’t mean items freely recalled are recalled in arbitrary orders. In fact, the order of items recalled usually differs systematically from the original list order.

In the phenomenon called clustering, groups of items occur together based on properties independent of their location within a list. For example, if a list includes a mixture of color names, animal names and plant names along with words in other categories, the names within each group will tend to be recalled together. In a phenomenon called intrusions, group items that didn’t appear in the list are sometimes recalled along with those that did appear. For example, if one word group on a list included the word wigwam and several other Native American words but not the word tepee, some learners may report tepee even though it wasn’t on the list. The effect is sometimes so powerful that even after feedback some learners remain convinced the intruding word appeared on the list.

As easily as this, learners can be led to say they remember something that in fact hadn’t happened.

Verbal learning procedures usually repeat a list until the learner meets some criterion of correct responding. This is appropriate when we’re interested in the relative difficulty of different types of lists. But when we’re interested in teaching, we can design lists so that, through a progression of changes, they’ll efficiently produce a verbal discrimination. In other words, verbal discriminations are well suited to fading procedures. The following progression of items is an illustration; the correct item of each pair is indicated by bold italics (adapted from Goldiamond, 1966):

A – B
B – D
B – V
O – B
Early in the list, discrimination is based only on the letter B. At the transition from letters to words, a gender difference is introduced, with the male item always paired with the letter B. Later B is included in both items and in subsequent pairs B is removed so the correct item depends only on gender. The gender discrimination in the final pair also includes a reversal of the letter discrimination created at the beginning. The fading from pictures to written items is an effective method for teaching children early reading skills (Gleitman & Rozin, 1973).

THE CONSEQUENCES OF VERBAL OPERANTS: MANDING

Verbal behavior has consequences. As with all operant behavior, these consequences affect later verbal responding. In a simple two-person conversation, each person provides an audience for the other. Audiences vary. We speak into phones, write messages or address groups of people. Often the consequences for the speaker are simply what listeners say later. It doesn’t take a laboratory experiment to show a listener’s response can maintain a speaker’s talk. We usually stop talking to people who don’t react to what we say. To this extent we can say the listener’s responses reinforce the speaker’s verbal behavior. Simple consequences such as yes or uh-huh can reinforce verbal classes such as plural nouns or the substantive content of conversations (Greenspoon, 1955). One general consequences of verbal behavior is that through it a speaker changes the behavior of a listener. Words are ways to get people to do things.

The consequences that reinforce human verbal behavior are many and varied. Sometimes they’re nonverbal—someone comes when called; sometimes they’re verbal—someone answers a question. Sometimes they’re highly reliable—Thank you is typically followed by You’re welcome; sometimes they’re not—not all requests are granted. Sometimes they’re very specific—answers to questions, taking appropriate action. But the shaping of verbal behavior, whether by natural or artificial contingencies, often involves generalized reinforcers. Furthermore, the tendency to speak may depend on some consequences while what get said depends on others.

One difficulty with experiments on verbal shaping was they sometimes attempted to modify the content of verbal behavior with the same consequences that were supposed to keep the speaker talking (Azrin et al., 1961; Greenspoon, 1955; Rosenfeld & Baer, 1970). Verbal behavior is maintained by varied consequences operating in the context of interacting natural contingencies. They can be thought of as complex nested schedules of reinforcement. It’s no wonder we talk a lot.

The Mand

One obvious consequence of verbal behavior is illustrated when we’re given something we asked for. If a child says milk and gets a glass of milk, we can say the milk is likely to reinforce the verbal response. The response needn’t occur in the presence of the reinforcer. For example, a child may ask for milk even if milk isn’t present. Verbal responses that specify their reinforcers have been called mands (Skinner, 1957); demands and commands, for example, specify what the listener is supposed to do.

An analogue from animal research may be useful. Assume a rat in a chamber with one lever producing food and another producing water. If the rat presses the first lever only
when food-deprived and the second only when water-deprived, we could argue the presses respectively are food requests and water requests. Though it would be irrelevant to our argument, we could make the analogy look more convincing by arranging signs that lit up when either lever was pressed, saying *Please give me food* and *Please give me water*. The rat’s vocabulary is limited to two levers, but the relations between the presses and their consequences are just like those relating human verbal requests to their consequences.

Yet this account isn’t quite satisfactory. Imagine a child who sees a new toy, learns it’s called a woozle and then asks for a woozle even though asking for woozles could never have been reinforced before. As a category of verbal behavior, the mand can’t consist of many separate response classes corresponding to each of the many mandable consequences. Rather, it must be a single response class in which reinforcers are specified by the verbal responses naming them in other circumstances; in other words, manding is a higher-order verbal operant. This woozle mand isn’t a name but functions like one. No such class existed in the rat example.

Within the class of mands, some subclasses specify stimuli—*May I have an apple?*—and some specify the listener’s behavior—*Please wait for me*; others called questions specify the listener’s verbal behavior—*What’s your name?* or *Did you see where I left my keys?* These may be further subdivided. For example, we speak of a *prompt* when the appropriate verbal response is already known to the speaker, as in giving a hint to a child who is unable to solve a riddle, and a *probe* when it isn’t known, as in a police interrogation. In everyday discourse, we also distinguish mands based on the contingencies they signal; for example, bribes specify the consequences of compliance whereas threats specify the consequences of noncompliance.
Chapter 24
Contact of Verbal Behavior with the Environment

Facts do not cease to exist because they are ignored.
— Aldous Huxley

Verbal behavior would never have evolved had it made contact only with other verbal behavior. At some point, it must contact environmental events. We speak of this contact as tacting; a tact is a verbal response occasioned by a discriminative stimulus (Skinner, 1957). For example, if a child learns to say “apple” in the presence of an apple, the child is said to tact the apple. The tact doesn’t involve any new process; it’s just a name for stimulus control as it enters into verbal behavior.

TACTING

Superficially they may seem alike, but tacting differs from naming much as textual behavior differs from reading. Tacting is sometimes a component of naming. Unlike naming, however, it can only occur in the presence of the tacted stimulus. We can name an absent object but we can’t tact it. We make the distinction because our responses to past events aren’t determined directly by those events; instead, they’re determined indirectly by our previous behavior with respect to them. We’ll return to naming later.

An unlimited number of tacts is available to mature speakers. We tact objects (chairs and tables, cellphones and books), living things (flowers and trees, birds and insects), weather conditions (rain and snow, sun and clouds), activities (walking and running, working and playing) and innumerable other features of the environment. Some tacts are general (e.g., man, woman) and others are restricted to relatively narrow circumstances (e.g., your name or mine). We can take the wealth of available tacts as a remarkable feature of human language, but we mustn’t let it obscure the simple relation defining a tact: it’s precisely the same as the relation between a stimulus and the response it occasions in a three-term contingency.

It’s useful to consider how we might teach tacts to a nonhuman organism; the exercise forces us to be explicit about their properties. Imagine a food-deprived pigeon in a chamber with a window on which we can project different colors. Three keys are next to the window. When it’s red, left-key pecks produce food; when it’s blue, middle-key pecks do so; when it’s green, right-key pecks do so. The pigeon will eventually peck left during red, middle during blue and right during green. We can call the pigeon’s performance the tacting of red, blue and green. The stimuli are highly specific, so we wouldn’t expect the pigeon to respond to red roses or flags or sunsets as it does to the red window. But the generality or specificity of the relevant stimuli isn’t a criterion for a tact relation. If we doubt whether the pecking will generalize to red in other contexts, we can just call the pigeon’s left peck a tact of this red window.

What of the consequences of the pecks? The pigeon would stop if it wasn’t food-deprived or if food wasn’t a consequence. But even human tacting depends on consequences. We don’t go around tacting everything we see. Consequences aren’t criteria for tacting. A tact may
buttressed, and stand or fall. On the other hand, systems of metaphors needn’t be consistent. For example, the metaphor of discussion as war may only occasionally make contact with that of discussion as exploration, in which issues are gone over in depth and at different levels and from different approaches, the ground is covered, the speakers map out their territories and make direct or roundabout arguments (Lakoff & Johnson, 1980).

Metaphor is pervasive. Children learn it readily and adults can’t ignore it (Winner, 1979). Reaction times are often shorter for metaphorical than for literal usages (Foss, 1988). Metaphor isn’t just the stuff of poetry; it’s a fundamental aspect of verbal behavior, an inevitable product of tactual in complex environments. If there isn’t a word for it, the verbal community invents one. Much of our technical vocabulary evolved metaphorically from everyday sources, and much of the everyday language applying to our own behavior arose through metaphorical extensions. Mind was once a verb (“Mind what I say!”), and many esoteric cognitive or mentalist terms have mundane origins (Skinner, 1989b), as in comprehension from prehendere, Latin for to grasp. These etymologies demonstrate concrete sources of our fundamental concepts. The creative aspect of metaphor, in other words, is in making the abstract substantial, specific and solid or, to mix more metaphors, in bringing it down to earth.

Usages for mind continue to evolve. Although it would once have been an unusual usage, some online dictionaries now list brain as a synonym. But I find it more interesting and more consistent with a behavioral view of the world that some have moved in the other direction, persuasively arguing that instead of looking inward any adequate concept of mind must include the extended environment along with the organism (Killeen, 2004; Noé, 2009; Rachlin, 2014).

The phenomenon of metaphor tempts us to talk about abstract properties captured by words. Yet its most important feature is it allows us to deal with the abstract in terms of the concrete (Lakoff, 1987; Lakoff & Johnson, 1999). For example, the language of abstract dimensions like good-bad or happy-sad becomes a more accessible dimension, up-down, from raised spirits and the heights of cloud nine to lowered expectations and the depths of depression. Hardly any dimension can be more abstract than time, but through metaphor it becomes a concrete spatial one: tomorrow versus yesterday becomes front versus back. We’re so used to saying our past is behind us and our future is before us it’s hard to imagine taking an about-face so the future is in back and the past lies ahead; our timeline turns with us.

Some similar extensions across cultures suggest common contingencies in the human verbal histories that shaped them. The word psychology comes from the Greek psukhein, to breathe, and psukhe, breath. When the psyche was said to leave the body of a mortally wounded warrior in the Homeric epics, it was understood to mean the warrior’s breath and not his soul. A parallel exists between this word and spirit, from the Latin spirare, another word meaning to breathe, but no evidence links these Greek and Latin words etymologically. A similar relation between air and spirit exists in the Latin anima, originally a breath of air but later soul or spirit in words like animate and animosity, and in the Greek atmos, vapor or air as entering into the English atmosphere but breath or soul in the related Sanskrit atman. In all human cultures air is invisible but can be felt in breath and wind. Air and breath are indispensable to life itself, so it should be no surprise the corresponding words have so often been inextricably intertwined.

We haven’t explicitly defined metaphor. As in other cases, our failure to do so doesn’t imply the term is meaningless. We don’t need to specify a stimulus to identify discriminative relations, and we don’t need to specify verbal classes to identify tact relations between words and events. We speak of classes of responses as operants and classes of stimuli as discriminated operators or concepts. Words can function either as responses or as stimuli, so meaning can work as shorthand for the relation of words and events within thematically related verbal classes (Lowenkron, 2004).
THE LANGUAGE OF PRIVATE EVENTS

A crucial extension of the tact is to private events. Tacted stimuli are sometimes accessible only to the speaker, as when we say we have a headache. Such tacts depend on the verbal community for their origins and maintenance. The problem is how the verbal community can create and maintain these responses without access to the stimuli. A parent can teach a child color names because the parent can see the colors the child sees and therefore can respond differentially to the child’s correct and incorrect color naming. So many varied consequences follow from color naming it usually doesn’t matter whether the parent teaches the color names explicitly or simply allows them to be learned through casual day-to-day interactions.

With private events, however, the vocabulary can be taught only through extensions from tacting events to which the verbal community has access. The child may learn to report pain because the parents have access to overt manifestations such as an event that caused injury or the child’s crying or facial expression; if the child has learned the names of body parts, the two kinds of verbal responses may be extended to the tact of pain in a specific place (Skinner, 1945b).

A toothache is a discriminable event, but someone with toothache has a different kind of access to it than the dentist called on to treat it. Both respond to the unsound tooth, but one feels it and the other looks at it and probes it with instruments. They make different contact with the tooth just as a seeing person and a sightless person make different contact with a geometric solid if one is teaching its name to the other; the seeing person does so by sight and the sightless one by touch. One kind of contact isn’t necessarily more reliable than the other. For example, in referred pain a bad tooth in the lower jaw may be reported as a toothache in the upper jaw. In this case, the dentist is a better judge than the patient.

We probably think of private events like our feelings and thoughts as ones to which we have privileged access. But we learned the relevant words from others and in teaching them to us they had access only to the public correlates. If we can be mistaken even about the location of a toothache, what assurance do we have our other reports of private events are reliable? Skinner (1963) makes the point by citing some students who watched a pigeon in a class demonstration and then attributed what they saw mostly to the pigeon’s expectations:

They were describing what they would have expected, felt, and hoped for under similar circumstances. But they were able to do so only because a verbal community had brought relevant terms under the control of certain stimuli, and this had been done when the community had access only to the kinds of public information available to the students in the demonstration. Whatever the students knew about themselves which permitted them to infer comparable events in the pigeon must have been learned from a verbal community which saw no more of their behavior than they had seen of the pigeon’s. (Skinner, 1963, p. 955)

Some time ago my colleague, Philip Hine-line, collected students’ reports of their feelings under various emotional circumstances. I saw an opportunity to extend his results when snow disrupted the exam schedule for a course. I’d told the students I wouldn’t give an exam on the first day after a snow closure, but nevertheless I arrived that day with papers and exam booklets under my arm. As I distributed the papers face down I instructed the students not to turn them over until everyone had copies. When I allowed them to start, it read: “This is not an exam. Describe your feelings when you saw me start to hand out the exam booklets.” I asked them not to put their names on their papers, to preserve their anonymity when I collected the papers and shared some passages with the class.

Despite the instructions, most of them described not feelings but the situation (“There wasn’t supposed to be an exam today” or “I wasn’t prepared for a pop quiz”) or wrote a question about the situation (“I wondered what’s going on”). The reports of feelings were almost exclusively limited to names (“I felt nervous” or “Fear!” or “I felt anxious”). A very
few reported physiological events ("My heart raced"), and among those most were metaphorical ("My heart fell to the floor"). Had I asked again after a bit of discussion, I’m sure “Relief” would also have been high on the list. But the point is that when we talk about our feelings very often what we say is more a commentary about our environment than about something happening inside us.

This cross-section of results came up over several classroom variations, even when the instructions specifically encouraged descriptions of feelings rather than descriptions of the situation. But maybe no surprise, because few of us have been explicitly taught how to describe our feelings or what goes on in our own bodies. There are opportunities here. Given what we know about teaching breast self-examination, shouldn’t we be doing better at teaching people to detect symptoms preceding a heart attack and discriminating them from heartburn and sore muscles? How many other medical conditions exist for which patients might contribute to their own diagnoses by learning to discriminate properties of their own bodies?

Private events can include behavior as well as physiology. Once we learn to tact properties of the public behavior of others, we may come to tact the same properties of our own behavior, whether public or not. If one person works hard at something with little compensation and another does so only with substantial compensation, we usually assume the task was more important to the first person than the second. The same observations of our own behavior may lead us to say what’s more or less important to us (Bem, 1967). What we say about our beliefs or about the causes of our actions may follow more directly from our discriminations of our own public behavior than from anything private (Kiesler, Nisbett, & Zanna, 1969). This isn’t to deny private events. It’s instead a cautionary note: the language of private events can distract us from the public causes of behavior.

The main problem with tacting private events is that the verbal community doesn’t have the necessary access to shape and maintain it. For example, when someone leaves a social gathering on saying “I have a headache,” it isn’t clear whether the verbal response tacted some private event or just allowed the speaker to escape from unwanted company. On such grounds, some have argued private events have no place in a science of behavior (Baum, 2011; Catania, 2011b). But like the language of public events, that of private events depends on the public practices of a verbal community (Day, 1969; Skinner, 1945b; Wittgenstein, 1953). The implication is we know what’s public better than we know what’s private, because the verbal community can teach us the language of public events more consistently than it can teach us the language of private events. How did it teach us to say we understand something, or we’re in love, or we’re uncertain, or we’re happy or sad? We know from examples like breast self-examination that sometimes we need to be taught even about our own bodies, so shouldn’t we be similarly concerned about how we’re taught about our own feelings and states of mind?

Verbal behavior doesn’t always require stimuli to be simultaneously available to both speaker and listener. Some important consequences of verbal behavior occur when the speaker tacts an event unavailable to the listener. If I’m telling someone over the phone about something I’ve found at a website, the other person can’t see what I’m seeing but may be able to do something about it by switching to the same site I’m looking at. The relation between tacting a public event and tacting a private one is the same as that between tacting when both speaker and listener have access to what is tacted and tacting when only the speaker has such access. The argument that dual access is possible only in the website case can be addressed by recalling the different kinds of access in our dental example. The language of private events has its own special difficulties, but we needn’t invent new categories of verbal behavior to deal with it.

Skinner (1945, pp. 131–133) suggested “at least four ways in which a reinforcing community with no access to a private stimulus may generate verbal behavior with respect to it.” The verbal community may differentially respond to reports of private events based on (i) common
public accompaniments, (ii) collateral behavior, (iii) shared properties of public and private events, as in metaphorical extension, and (iv) generalization from public to private behavior along the dimension of response magnitude. For example, a child’s report of pain (i) may follow a public event like a fall or a cut; (ii) it may be accompanied by crying. Furthermore, (iii) a report may derive from properties of public objects producing certain kinds of pain, such as sharp edges producing sharp pains; and, finally, (iv) a report of talking to oneself can generalize from cases when the talking is overt to those when it’s no longer of public magnitude. These four categories give listeners a basis for differentially reinforcing verbal behavior occasioned by private events. Skinner excluded only the property of privacy itself from these contingencies.

Developmental accounts are often expressed in mental language, as when a child’s vocabulary of remembering, forgetting and never having known is said to depend on the child’s theory of mind (Wellman, 1990). Children usually learn remember before forget, and knew before never knew. They ordinarily learn through natural contingencies in the context of being asked questions and answering them. To find out more we can see what it takes to teach the words explicitly as tacts. Suppose one day a child is taught tacts for some objects. The next day the child is asked to tact those and some new ones. The child’s tacting is sometimes successful and sometimes not. Now we can differentially reinforce three different responses: given successful tacting, I remembered; given an original object and unsuccessful tacting, I forgot; and given a new object and necessarily unsuccessful tacting, I don’t know. Developmental programs that look only at when different verbal responses are usually learned by children tell us little about the contingencies that shaped them.

As programs for teaching the tacts I remember, I forgot or I never knew, our procedures make the public correlates explicit. It would be misleading to seek the controlling variables for these reports inside the child, because they were based on public events available to the verbal community. By demonstrating how a verbal community can shape such vocabularies, which sometimes appear as components of cognitive accounts of behavior, we move toward an experimental analysis not only of the child’s verbal behavior but also of the verbal behavior of those who study it. Theories of mind are to be found not in the heads of children but rather in the behavior of the theorists proposing them. Mental vocabularies may not serve us as guides for experimental analyses of the verbal behavior of children, but when they appear in the behavior of researchers we shouldn’t neglect them as potential objects of such analyses.

**NAMING AS A HIGHER-ORDER CLASS**

What about naming? It may include tacting as a component, but our everyday vocabulary extends to so many cases any formal definition will probably be unsatisfactory in one way or another. Let’s again consider the pigeon whose pecks tact red and green and blue lights. It’s a good bet you’d object to any argument suggesting the pigeon was naming those colors or the different key pecks were the pigeon’s names for the colors. And you’d be right to object. But the reason isn’t that we do something different when we name colors; instead, it’s that in naming we do something like what the pigeon does but we also do a lot more.

In a few cases tacts are clearly very different from names. For example, hello is occasioned by special social situations: we’re introduced to someone, or someone we haven’t seen recently comes up to us, so we say hello. It’s difficult to say exactly where to draw the line between situations that qualify and those that don’t, but these sorts of situations occasion the hello as surely as a dog occasions dog or a cat cat. We wouldn’t call it a name, but hello qualifies as a tact. Another example is thank you. To the extent we say thank you only given certain social situations involving someone having done something for you, thank you too qualifies as a tact, but here again we wouldn’t call it a name. **Tacts, in other words, are examples of stimulus control in which the**
response is verbal; they’re not defined by properties of the stimuli occasioning them. Naming involves something more.

Naming is a higher-order class involving arbitrary stimulus classes (the things or events we name) and corresponding arbitrary verbal topographies (the words serving as names); their relationship is bidirectional, as when we can name something seen or look for something named. Tacting is at the heart of naming, but tacting alone isn’t enough. Consider what a child must do before we’re satisfied the child knows the name of something, like shoe as a name for one of those things you put on your feet. Not only do we expect the child to say shoe when we hold up a shoe and say What’s this? We also expect the child to look around when we say Where’s the shoe? and then point to the shoe if it’s in sight.

Superficially this looks like an equivalence relation, or at least a symmetry relation, because the stimulus object and response word in the first part of the example seem to switch places in the second. But that’s assuming too much, because, unlike a pigeon’s pecks on samples and comparisons, a seen object can’t be exchanged with a point at it and a heard word can’t be exchanged with a spoken one (Horne & Lowe, 1996, p. 234). Furthermore, a point won’t be effective unless the child looks not at the caregiver but at where the caregiver is pointing. Thus, joint attention is another critical prerequisite for naming (Dube et al., 2004; Tomasello & Farrar, 1986). It’s a component of the behavior of the listener.

Starting by about six months of age, before they’ve begun to tact, children begin to master listener behavior (Gurteen, Horne, & Erjavec, 2011). Between the ages of one and six years, they increase their vocabularies at an average rate of five to eight words per day; by six, a child is likely to have a productive vocabulary of thousands of words (K. R. Wagner, 1985). Many function words (e.g., more, bye-bye, allgone) are included along with common nouns (e.g., mama, milk, chair) in the early vocabulary. What common features must the learning of each new word include to allow the child to learn so many new words so quickly?

Along with tacting, another prerequisite for naming is echoic behavior. The child is otherwise unlikely to produce a new word spontaneously. Echoic behavior depends on the replication of the phonetic components of verbal stimuli rather than of their acoustic properties, so they’re not mere imitations. They require a verbal history (Camões-Costa, Erjavec, & Horne, 2011; Horne & Erjavec, 2007). But given the bidirectionality, what about equivalence classes? They seem prerequisites for naming and other higher-order verbal classes, but they may instead have naming as their prerequisites (Horne, Hughes, & Lowe, 2006; Horne, Lowe, & Harris, 2007; Horne, Lowe & Randle, 2004; Lowe et al., 2002; Lowe, Horne, & Hughes, 2005; Randell & Remington, 1999).

Naming has still another prerequisite besides tacting and echoic behavior. If a child already does some naming but hasn’t yet learned the name glove, we might hold one up and say This is a glove; the child might say glove and point at it. A little later the child may point to the glove when we ask Where’s the glove? or say glove when we hold it up and ask What’s this? The child may do this even never having answered these questions before with respect to gloves. Once the child has come this far, it won’t be long before the child is rapidly acquiring new names: socks and hats, tables and chairs, cats and dogs, and so on.

The prerequisites for doing so include at least three components: (i) listener behavior, in looking for things and pointing based on what someone has said; (ii) echoic behavior, in repeating names when they’re spoken; and (ii) tacting, in saying the names given the objects (Horne & Lowe, 1996). The child’s responses to the questions about the glove are novel behavior and emerge as members of a higher-order class, naming. The various social and nonsocial consequences of naming are individually small, but collectively they sustain a lot of behavior. Soon the child may initiate naming instead of waiting for it to be initiated by others. It’s common for a child who has learned some naming to turn the questioning around. On encountering something that doesn’t have a name yet, the child points and asks What’s this?
Naming is generated from the ordinary interactions between children and their caregivers. Once it’s available as a higher-order class within a child’s repertory, it allows for expansions of vocabulary in which the introduction of new words in functional relations (such as tacting) involves those words in a range of other emergent functions. These include but are by no means limited to intraverbal behavior, echoic behavior and orienting toward or pointing at named objects. We’re learning more about the verbal functions that constitute naming, the kinds of contingencies in the natural environments of children that shape and maintain those functions, and the role of naming in enlarging and amplifying other functions of verbal behavior. All of this puts us in a better position to extend our analyses to applications, as in teaching naming to children on the autism spectrum (degli Espinosa, 2011).

Language Development

Children who grow up in Italy speak Italian and those who grow up in Brazil speak Portuguese. They learn the specific vocabularies and grammars of their native languages, and most become fluent long before they begin formal education. Although there are many descriptions of language development in children, there’s still much to learn about its critical factors (R. Brown, 1973; Moerk, 1992). Like vocabulary, grammatical skills progress rapidly between the ages of one and six years, as the child’s syntax moves from single-word utterances to those of two words or more, sometimes described as roughly telegraphic (e.g., stove hot, daddy go car), and then to constructions more and more closely approximating the syntax of adult speech. Collecting data on language development in children poses problems of translation as well as other technical challenges. For example, a young child’s more probably has the sense of give me rather than of expressing a quantity (Moore & Frye, 1986).

Children must learn irregular constructions, like go, come and break, as well as regular ones (Kuczaj, 1977). Among young children, regular but nonstandard past-tense forms are common: goed, comed, broked. But they don’t always start with regular forms. Often, the child first learns the standard but irregular forms as individual words: went, came, broke. After some standard regular past-tense forms are learned, the irregular forms are displaced by regular but nonstandard ones, even though the irregular ones were part of the child’s vocabulary for some time. Months or years later, the standard irregular forms reappear and become permanent parts of the child’s verbal behavior. The progression from standard irregular to nonstandard regular and back to standard irregular past-tense forms is consistent with a progression from mastery of individual words through stereotyped intermediate classes to fluent language.

The acquisition of grammatical structure has been central to debates over structural linguistic accounts and functional behavioral ones. Just as anatomical features of birds and bats determine the different ways they fly, special characteristics of our species may determine the structure of human language and how it develops. But even if it should be shown that human language is limited in its structural properties or in how its structure develops, the finding would have little bearing on the functional questions raised in the analysis of verbal behavior. An anatomical analogy is relevant: an account of the different properties of flight in birds and bats doesn’t bear on where or when they take off or land; so too an account of language structure doesn’t bear on when we speak or what we talk about.

If the significant consequences of verbal behavior range from direct outcomes like getting something we asked for to indirect ones like hearing a comment bearing on something we just said, these will all contribute to the shaping of verbal behavior. If these consequences include correspondences between sounds we’ve heard and sounds we’ve produced ourselves, as in the ontogenic shaping of echoic behavior, it’s not too great a leap to extend such correspondences from those phonetic properties to the semantic and syntactic properties of our verbal behavior.
Chapter 25
Verbal Behavior Conditional on Verbal Behavior

Verbal behavior, like any other event, can be tacted. No new kinds of relations are involved, but verbal behavior gets complicated when it’s built on other verbal behavior. Verbal behavior that depends on other verbal behavior and modifies the effects of that other verbal behavior on an audience is called autoclitic (Skinner, 1957). We rarely utter mands or tacts or other verbal units by themselves, and even when we utter them in combination they seldom appear as a simple succession of units. Instead, they’re articulated with each other in complex ways. Skinner introduced two types of autoclitis to deal with these properties of extended verbal behavior.

The first, a descriptive autoclitic, involves the tacting or discrimination of one’s own verbal behavior. It tells the listener something about the rest of what a speaker is saying, as when we prefix a comment with a qualifier such as I just saw that… or I’ve just been told that…. These autoclitis modify the effect on the listener of the rest of the sentence by letting the listener know the source of what follows. They may also have instructional functions that operate on the speaker as well as the listener (Hübner, Austin, & Miguel, 2008).

Intraverbals seem superficially like descriptive autoclitis but don’t qualify. They also depend on and may modify the effects of other verbal behavior, but they don’t require discriminations of one’s own behavior. For example, if you say Red, white and… I don’t have to discriminate anything about my own verbal behavior to finish off the intraverbal sequence by saying blue. The verbal stimulus Red, white and… sets the occasion for the concluding word whether I say it or you finish it for me.

Skinner called a second category relational autoclitis. These involve verbal units that can’t stand alone because they must be coordinated with other verbal behavior. An example is the plural –s; we hardly ever say it all by itself in the presence of multiple objects or events. This category doesn’t depend on discriminations of one’s own behavior. Instead, it’s based on the ways multiple determinants of a verbal response can come together, as when species and number and action and other properties combine so we say things like the shaggy dogs run or the little cat walks. Both autoclitic categories involve verbal behavior conditional on other verbal behavior, but they operate in ways that make them fundamentally different.

DESCRIPTIVE AUTOCLITICS: DISCRIMINATING OUR OWN VERBAL BEHAVIOR

Many verbal responses tact the conditions under which other verbal behavior is emitted and thereby modify the responses of the listener. Consider the phrases I doubt and I’m sure in “I doubt the coffee is ready” and “I’m sure the coffee is ready.” Each modifies how the listener is likely to act on the statement that the coffee is
tional control from the language of tacting, especially in the interactions of the chimpanzees Austin and Sherman (Savage-Rumbaugh, Rumbaugh, & Boysen, 1978). The syntheses of complex interactions in such studies have special value because they force all of the assumptions about what counts as verbal to be made explicit (Epstein, Lanza, & Skinner, 1980). You can't tell a pigeon or a chimpanzee what to do; instead, you must shape all the components to be integrated into the final performance.

The performances of nonhuman organisms will become ever more sophisticated as human investigators provide them with ever more sophisticated environments. Differences like the extent of operant control over the vocal apparatus will remain; some will be more obvious than others. Kanzi, an eight-year-old bonobo monkey (Pan paniscus), appeared capable of sentence comprehension beyond the reach of its relative, the chimpanzee (Pan troglodytes), and perhaps comparable to that of a two-year-old human child (Savage-Rumbaugh et al., 1993). We've already seen how verbal communities are crucial in shaping and maintaining human verbal behavior, so we shouldn't be surprised if the details of verbal contingencies matter. For example, judgments of adequacy of the discrimination between requests such as Get juice from kitchen or Take juice to kitchen, or their ape language equivalents, depend on contextual features of the requests such as whether juice is always present when the requests are made; if it is, then the discrimination is probably based on the difference between get from and take to, but if juice is present only given the request to take it to the kitchen, then the discrimination may depend only on whether juice is present when a request has juice in it.

Once some feature of human language was demonstrated in the behavior of a chimpanzee or a pigeon or any other nonhuman organism, that feature could no longer be regarded as uniquely human. Too often attention then turned to the definition of language instead of the experimental analysis of its properties. Given these debates, we can't say whether chimpanzees are capable of language; the answer depends too much on how we define language. We certainly can say, however, that their behavior includes many of the relations between stimuli and responses that fall into our taxonomy of verbal behavior.
The May 1950 issue of Astounding Science Fiction featured a purportedly nonfiction article by L. Ron Hubbard entitled “Dianetics: A new science of the mind.” It set out an account of painful engrams acquired early in life that disrupt us in the present; revisiting them can help make us “clear.” This was the kernel of what Hubbard later turned into his controversial religion, Scientology, of Tom Cruise fame. I read it when in high school and it seemed worth trying, so I persuaded some friends to participate. We got together in my room, I had one of them lie down, and I proceeded with what was essentially a hypnosis session. Following Dianetics guidelines, I first had him relax and get sleepy. Then I sent him back to his childhood. After some probing he described walking down a path and then jumping up on a wooden fence where a protruding nail cut his thigh. When I brought him back he didn’t recall the event, but when he checked his leg it had a corresponding scar. Later his parents confirmed such an incident had really happened. I thought I was on to something, but my other friends decided against serving as subjects. I hypnotized a couple of friends during high school and college, but for some reason Dianetics lost its appeal. Probably just as well. But when I took Schoenfeld’s undergraduate course and he talked about hypnosis as total control by verbal stimuli, I was prepared to listen. One way to think about hypnosis is that it narrows the listener’s attention to the hypnotist’s voice; all else is excluded. Some people seem more susceptible to hypnotism than others.

To be functional, verbal behavior must do things, but it can’t do things by itself. It’s effective only through the mediation of other people. Some nonhuman behavior may minimally qualify, as when a horse is taught to turn in response to a touch of the reins to its neck (the turns then reinforce the trainer’s behavior). The directionality is like that for hypnotist and subject or for officers and those under their command, but in their cases control is limited to certain domains. The directionality makes the example of the horse and trainer differ crucially from that of a child and an adult teacher. For the latter only, verbal contingencies soon become reciprocal, and these reciprocities define verbal behavior. Verbal behavior is maintained by the practices of verbal communities, and here we’ll consider some consequences following from these practices.
I could provide sample utterances and the time course of the shaping. But at least I discovered that the bit of attention I gave when he uttered those first-person words was reinforcing enough to change his talk. I had heard the literature on verbal shaping was controversial, but my doubts vanished once I had him talking to me about himself. And verbal shaping would come in handy later.

Effects of Shaped Verbal Behavior on Other Behavior

In one experiment (Catania, Matthews, & Shimoff, 1982), students’ presses on two buttons occasionally produced points exchangeable for money; a representative apparatus is shown in Figure 26–1. When a light above the left button lit, a random-ratio (RR) schedule operated for pressing that button; when one above the right button lit, a random-interval (RI) schedule operated for its presses. Between alternations of the two schedules, during red, students filled out guess sheets, including sentences to be completed for the left and right button of the form the way to produce points with this button is to.... Their guesses were shaped with differential points worth money. In shaping guesses, an experimenter assigned points to each guess, writing point values next to each one and passing the sheet to the student through a partition.

When the guess shaped for one button was press quickly and for the other press slowly, response rates on the buttons changed in corresponding directions, without regard to schedule contingencies. Thus, shaping press slowly for the left button and press quickly for the right button produced relatively low RR rates and relatively high RI rates, opposite to those usually produced by these schedule contingencies. What the students said about their responding more powerfully determined what they did than the consequences of their responding; students who slowed down on the RR button lost points they’d have earned if they’d responded faster. In a procedure in which students were told what to guess, however, correspondences between guesses and response rates were inconsistent.

Sometimes guessing press fast was accompanied by fast pressing and press slow by slow pressing, but sometimes the guesses were accompanied by equal rates on the two buttons or rates differing in the opposite direction.

Verbal shaping involves treating successive verbal responses as varying along semantic dimensions, but judging which ones are closer or farther from the behavior to be shaped can be tricky. It’s easy to pick out words related to fast or slow and time or number, but a student who comes up with a guess like four fast then three slow might just vary those two numbers on all trials thereafter. The possibilities for varying the numbers are unlimited, so the student may be caught in a verbal trap, so that our further attempts to shape simpler guesses are unsuccessful. Furthermore, it matters whether what we shape is a description of behavior or a description of contingencies operating for the behavior.

Figure 26–2 shows data from a variation on these procedures (Catania, Shimoff, & Matthews, 1989). Again, an RR schedule operated for left-button presses (L) and an RI for right-button presses (R). This time the guesses shaped were descriptions of contingencies instead of descriptions of performances. The sentences to be completed for left and right were of the form the
The guesses successfully shaped were variations of number of presses for the left button contingency and variations of time intervals for the right button contingency. The progress of shaping, shown by the shaded areas, was complete when guesses were earning the maximum of eighteen points per guess period. The shaped contingency descriptions were accurate, but they weren’t accompanied by substantial differences in the RR and RI rates of button pressing.

Whether descriptions of contingencies produce corresponding changes in performance depends on other verbal behavior. For example, one student, correctly identifying two schedules as RR and RI (though not in technical language), went on to say point deliveries increased with higher RR rates but not with higher RI rates. Another, also correctly describing the schedules, instead said that because points in both were unpredictable, point deliveries were unaffected by presses. Responding showed rate differences appropriate to the reports. In other words, what you do in an environment may depend on whether you describe what you do there or instead just describe how it works without saying what you might do.

Verbal shaping was quickly effective when we switched from targeting contingency descriptions to targeting performance descriptions (dashed vertical line); it produced variations on press fast for left RR button guesses and variations on press slow for right RI button guesses. Rates of button pressing diverged as performance guesses became more consistent over cycles. Unlike procedures that merely sample verbal reports, this one identifies the direction of effect in the relation between verbal and non-

Figure 26–2  Left (L) and right (R) rates over cycles of multiple random-interval (RR) random-ratio (RI) schedules of points delivered for button pressing. Shading shows points for verbal behavior (guesses) during verbal shaping. Unconnected points represent an interruption between sessions. Details in text. (Adapted from Catania, Shimoff, et al., 1989, Figure 1)
verbal behavior, because we know which came first. The verbal behavior changed during shaping; then came the change in response rates. In different circumstances, of course, the direction could go the other way, as when students whose pressing is fast or slow accurately describe their own behavior.

The Development of Correspondences

Correspondences between shaped verbal behavior and relevant nonverbal behavior come about because verbal communities reinforce consistencies relating what we say to what we do. Research with children shows these effects start early. An experiment with four- to six-year-olds arranged reinforcing consequences consisting of the successive lighting of lamps in an eight-lamp column; when the whole column was lit, the child earned a present, such as a box later exchangeable for pictures for the child’s scrapbook. When the top window showed a star, presses there worked according to a random-ratio (RR) schedule; when the bottom one showed a tree, presses there worked according to a random-interval (RI) schedule. As is typical for verbal humans, the schedules didn’t produce consistently different response rates even at this age. The child occasionally talked with a Garfield hand puppet, who appeared from time to time through a small curtained aperture (Catania, Lowe, & Horne, 1990). Figure 26–3 illustrates the setup.

After some sessions, Garfield appeared between schedule components and began talking to the child: e.g., *This game looks like fun.* Can you teach me how it works? The reinforcers used to shape what the child said about the performance including lights in the column and enthusiastic reactions from Garfield: e.g., *That’s what I’ll try when I play the game.* The child was never told what to say or what to do, but the verbal shaping procedure had to be adapted to each child’s vocabulary. Fast and slow typically mean different things to children than to adult experimenters. For example, children will usually say fast or slow for how quickly their hands move rather than for how often they press. It was therefore usually more effective to shape alternatives such as *press a lot without stopping* and *press and wait.*

Performance was more variable than with adults, but successful shaping of verbal behavior was typically accompanied by corresponding rates of pressing. As with adults, shaped verbal behavior produced corresponding rate changes even when they were opposed to the usual effects of schedule contingencies, as when the child who came to say *With the star you press and wait* responded slowly during star even if the schedule was RR. Figure 26–4 shows reversals of response rates that accompanied reversals of one child’s verbal behavior.
Chapter 27
Prejudice as Verbally Governed Discrimination

The very ink with which all history is written is merely fluid prejudice.
—Mark Twain

Before he sings “You have to be carefully taught” in the musical South Pacific, Cable says “It’s not born in you.” The show debuted in 1949; the song was controversial. It was protested in some places because it was said to justify interracial marriage and implicitly threaten the American way of life. But saying it’s not born in you gets it right. You do have to be taught “to hate all the people your relatives hate.”

Whether it’s based on race, gender, ethnicity or any other dimension, discrimination in its societal sense is a product of interacting with others. If your behavior has different consequences depending on the reactions of those you interact with, you’ll learn to discriminate based on those reactions. Being taught is something else. If you’ve never met any members of some group and social contingencies shape your verbal behavior, you may behave differently toward the first ones you meet, without ever having interacted with any others like them. Your behavior will be based only on what you’ve heard or what you find yourself saying. When that happens, the outcome may look like discrimination, but it’s a different kind. We must distinguish between contingency-shaped discrimination, shaped by differential consequences, and verbally governed discrimination, which sometimes qualifies as prejudice.

But what do we say when you’ve learned to discriminate based on some dimension, like gender, and then you continue the practice on encountering someone you’ve never met before? Maybe when you meet a woman for the first time you treat her differently than if she had been a man. No surprise if you generalize from all your past interactions with men and with women to this new instance. This is generalization of discriminatory behavior.

But discrimination isn’t in itself the problem. For example, differential behavior based on gender has its origins in a long phylogenetic history, as in the sexual selection of potential mates by women. Should we then include this example as prejudice or as a member of an existing class? Perhaps it’s true that men are more likely than women to behave violently. If so, does it matter how you learned it?

The problem parallels that of defining operant classes. I tend to favor the language of contingency-shaped versus verbally governed discrimination over discrimination versus prejudice, perhaps because it finesse the question. As a working solution, I’ll treat all prejudice as verbally governed discrimination but with the proviso that, based on different histories, not all verbally governed discriminations qualify as prejudices. That’s because the term prejudice is usually regarded as a pejorative. It’s usually risky to introduce colloquial terms into technical usages. The issues are complex, and at this stage of our analysis maybe clarifying the contingencies is all we should hope for.

Verbal behavior can create prejudgment. It may lead you to behave differentially toward others though you haven’t participated in non-verbal contingencies involving them. Push it far enough and you might be ready to favor some children over others in the classroom or to pass over some people for advancement in the work-
place or to incite violence that targets only those in certain groups. It can get more complicated, of course, when discrimination and prejudice combine as multiple causes in specific instances. But that doesn’t mean the distinction can be ignored. If discrimination and prejudice arise in different ways, they must be dealt with differently when they create problems.

**BUILDING UP AND BREAKING DOWN EQUIVALENCES**

The Catholic Nationalists and Protestant Unionists of Northern Ireland differ in their preferred colors, names, symbols and sports. Through the inevitable contingencies and contiguities in their environments, these elements will have come together in their respective stimulus classes, one made up of the Catholic stimuli and the other made up of the Protestant ones. Equivalence-class procedures can be used to probe the properties of these two classes (McGlinchey & Keenan, 1997). Catholic and Protestant learners easily mastered new equivalence classes involving only neutral stimuli but had trouble mastering new ones in which Protestant and Catholic stimuli were linked through a neutral node. For example, if C in a CN match for one class consisted of a Catholic stimulus such as Irish green and P in an NP match consisted of a Protestant stimulus such as an image of marching Orange-men, so the class always included both Protestant and Catholic stimuli were linked through a neutral node. For example, if C in a CN match for one class consisted of a Catholic stimulus such as Irish green and P in an NP match consisted of a Protestant stimulus such as an image of marching Orange-men, so the class always included both Protestant and Catholic stimuli were linked through a neutral node. Acquisition was slow if successful at all; learners typically failed CP transitivity tests, even though both C and P had been linked to the neutral N. These effects were stronger in older than in younger children and were often locked in by age eleven or so. These outcomes were somewhat less likely among learners who attended universities with a substantial mix of Catholics and Protestants in the student body.

Equivalence classes are typically established in the laboratory with arbitrary stimuli, such as visual shapes or nonsense syllables. Meaningful materials can enhance acquisition (Fields et al., 2012), but they can do the opposite if the relations run up against incompatible classes that are already well-established. In the Catholic and Protestant communities of Northern Ireland these stimuli were familiar and already seen as belonging to one or another of two incompatible classes. Existing classes established over an extensive social history may be difficult to override with the relatively weak contingencies available in a laboratory.

To the extent such classes are created by nonverbal contingencies, they illustrate contingency-shaped discrimination. To the extent they’re created by verbal environments, they illustrate verbally governed discrimination. Either way, they make the point that we mustn’t limit our attention to what it takes to create equivalence classes; it’s also important to know what it takes to break them down. Equivalence relations can sometimes change rapidly, as when you discover the players or management of a sports team for which you’ve been rooting have behaved unethically or have taken a political position with which you strongly disagree.

One way to break down boundaries is to mix together groups that would otherwise have remained separate, so they’re more likely to learn about each other through both verbal and nonverbal contingencies, as when President Truman desegregated the military after World War II. Another is by introducing new classes incompatible with the old ones, as in creating schoolroom working groups that cross racial or ethnic or other lines, or as in representing diversity in the casting of dramas and comedies and even advertisements.

But either route can produce fragile outcomes. Existing prejudices can enhance rather than reduce divisions across ethnic or racial or religious lines when groups come together, especially if the prejudices lead to conflict. Desegregation can be rolled back and pronouncements in the media can support boundaries instead of helping to break them down. Geography and economics can lead to de facto segregation.
Even relatively benign preferences can create problems. For example, those who try to create integrated neighborhoods must contend with the finding that when people move into a neighborhood, a preference for having at least one or two neighbors matching your own racial or ethnic identity usually leads to segregated areas (Schelling, 1971; Tauber, 1965). This happens even among those actively seeking diversity. Unintended consequences hide around every corner and integration calls for careful planning.

It’s probably important to note that we’re not here concerned with reasoned judgments. A white author wrote of a black home intruder who intimidated her but left without harming her or her infant son (Seiffert, 2004). She felt guilty (“the pangs of her liberal conscience”) because thereafter she felt unable to respond to young black men without prejudice. She was victim of the natural consequences of nonverbal contingencies. Consciousness raising can’t remove effects like these, though it may ameliorate them. Profiling invites similar concerns, because it too may pit natural contingencies against verbal governance. Pulling over some cars but not others based on the race of the driver is inappropriate if done to fulfill a quota. But if the surveillance video of a crime scene clearly displays the race of the driver of a getaway car, it would be counterproductive not to disclose the information to those in pursuit. If both count as profiling, the implication is that profiling is sometimes fully justified, and the problem is drawing the line between what’s justified and what isn’t. But then what should the criteria be for where it is drawn?

FROM DICHOTOMIES TO CONTINUA: RACE AND GENDER

Naming itself is a verbal category that can contribute to the creation of boundaries separating groups. On examination, many dichotomous verbal classifications break down into two or more discrete categories. This is analogous to categorical perception of consonants, as when continuous changes in the acoustic formants that determine whether a phoneme is a p or a b are heard as one or the other, with those in the region of the abrupt transition from one to the other rarely if ever reported as blends of the two.

Racial differences are often discussed in the language of black and white. Skin color varies within both African and Caucasian populations; not only do the distributions overlap, but they’ve been blended together by a complex history of miscegenation and interracial marriage. There was a time when it was widely held that even one drop of black blood was enough to make someone black; some still hold to that view. Based on the assertion that one drop made so much difference, Malcolm X said “That must be mighty powerful blood!” (Etzioni, 2003, p. 30). Verbal dividing lines can’t be justified when populations vary continuously along dimensions like skin color. Once populations have blended and overlapped, there’s no good way to decide where the dividing line should be. Subdividing populations into even more categories, as when some are singled out as mulattos, only creates added complications. Racial identifications and race itself are verbal categories. The more we learn about the human genome and our shared phylogeny, the clearer it becomes that they are verbal constructs rather than biological entities.

It remains to be seen whether racial lines will become further blurred with increases in the number of interracial families. But even if that happens, racial differences will sometimes be correlated with economic or class or ethnic or religious ones, so those who find it useful to exploit differences will no doubt still seek opportunities to create prejudice (cf. Coates, 2015). Differences can become further exaggerated when self-maintaining social groups like megachurches and fringe political parties reduce their interactions with others. The effects of verbal shaping are especially likely to be amplified within groups of individuals who mainly talk to each other.

Other dimensions along which verbal boundaries can override continuities are gender and sexual identity. Individuals can vary in anatomy, hormonal balance, cultural history and other sexual characteristics. Distinctions have been
drawn between lesbians, gays, bisexuals and transgender individuals, and between those and others sometimes called straight. But the origins of such different categories may rest in part with cultural practices contributing to designations of gender. For example, long-standing obstetric traditions have affected the treatment of infants born as hermaphrodites or with ambiguous genitalia (Dreger, 2015). Obstetricians who have delivered these infants have too often resolved the ambiguities surgically, sometimes without even informing the parents. An infant may then mature with the hormonal balance of a male and the genitalia of a female, or vice versa. If continua of anatomy and of hormonal balance are compromised, especially for those in the middle of one or another of these continua instead of near the more culturally accepted male or female extremes, then different combinations can yield different sexual identities.

Though it’s difficult to justify where lines should be drawn, here again it makes sense to acknowledge the full spectrum of gender potential instead of arbitrarily cutting it up with prejudicial labeling. But dichotomies can also be locked in by environmental constraints, such as gendered bathroom facilities. Unisex bathrooms are perhaps one step toward a solution, but the prejudices originate in verbal behavior and can’t be addressed adequately merely by such verbal means as writing laws about them.

Discriminating Within and Between Classes

When I worked summers in Harlem Hospital during my student days, the people there gave me lots of support as I learned how to do my job. The work of most exceeded what was required of them. A few worked exactly to the limits of what their job description called for and no further, and a few cut corners whenever possible. There was also a small cohort of those who resented my presence and found ways to let me know. But though I rarely use the adjective, the behavior of nurses and other medical staff was often awesome. I can say in retrospect that I was learning discriminations based on differences among my black coworkers. I think that mattered especially because discriminations within a racial or ethnic class are likely to correspond with those already established outside the class, and can therefore create new equivalences cutting across existing lines. This person is easy to get along with but that one isn’t; this person is outgoing but that one’s reserved; this person likes puns but that one doesn’t. Once I was discriminating along those other dimensions, discrimination based on race became irrelevant. You can’t get to know things like this about people and still say “they all look alike to me.”

The same kinds of arguments can be made with respect to another class of classes, as when in American culture we talk about people as being in the lower or the upper or the middle class. To the extent that people in different socioeconomic classes tend to mix more with those in their own class than with those in others, much happens at the level of verbally governed discrimination rather than discrimination grounded in personal interactions. Here again we see continua arbitrarily divided, in this case in a trichotomy, or, on other grounds, as in determining poverty levels by income rather than access to resources. It’s difficult to see how these divisions can be addressed if they aren’t accommodated by educational institutions. For some, those institutions have been the only route for escaping from the constraints of class; whether they continue to play that role remains to be seen. Probably H. G. Wells was right: “Human history becomes more and more a race between education and catastrophe” (Wells, 1920, Chapter 41)

ATTITUDES, INTENTIONS, AND ATTRIBUTIONS

When we talk about other people, we sometimes describe what they do by citing their attitudes or intentions. A child might be said to have a respectful attitude or a confrontational one; we might call one person laid back and another uptight. We might say we didn’t mean to do
In its full complexity, verbal behavior involves interactions among different processes. Just as a taxonomy of basis processes is required for analyzing nonverbal behavior, we need one for verbal behavior. It includes classes different from those in the everyday vocabulary. Textual behavior isn’t equivalent to reading, though it may be its precursor. Transcription isn’t equivalent to pictorial copying, but depends on established units of written verbal behavior. Tacting isn’t equivalent to naming or referring, and yet as stimulus control of verbal behavior it’s where verbal behavior is anchored to environments. The effectiveness of verbal behavior depends on the coordinations of these and other elementary components. By themselves they aren’t even particularly verbal, but in fundamental ways our verbal behavior is built on them.

Verbal contingencies extend how we act on our environments. Verbal behavior is typically shaped by social contingencies, but nonsocial contingencies can also be effective, as when an engineer’s calculations lead to changes in the specifications of a project. Such cases clearly depend on an extensive social history of behaving verbally, but interactions between writing and reading are functionally similar whether writer and reader are the same or different individuals.

**THE LISTENER’S OR READER’S BEHAVIOR**

The speaker’s verbal behavior provides discriminative stimuli for the listener; the listener’s behavior is what’s occasioned by these stimuli. The listener’s responses to verbal stimuli can be as varied as the responses to any other events. Some nonverbal responses occasioned by verbal stimuli are obvious enough they don’t require special consideration. Whether the critical stimulus is a red light, a traffic officer’s outstretched hand, the word stop or a tree fallen across the road, stepping on the brakes illustrates stimulus control. There’s no need to distinguish among such stimuli even though some are products of verbal behavior and others aren’t.

Listeners aren’t passive; they often behave verbally along with the speaker, saying things to themselves, planning replies and so on. Sometimes we act as our own listeners or readers, as when we carefully attend to what we’re saying or think aloud or read something we’ve just written. Products of our own behavior can serve as discriminative stimuli and occasion our own further behavior (Skinner, 1989a).

As with nonverbal stimuli, not all responses to verbal stimuli are operant. For example, if a spoken word is paired with a stimulus that elicits autonomic responses (e.g., shock), the word may come itself to elicit these responses. This phenomenon, sometimes called *semantic conditioning* (Riess, 1946), is a verbal equivalent of the respondent conditioning of nonverbal responses. Responding generated by these procedures generalizes across semantic as well as phonological dimensions of verbal stimuli. For example, if electric shock is paired with a vehicle word, such as truck, the conditioned galvanic skin response is more likely to generalize.
to other vehicle words, such as car or bus, than to words simply having some letters in common with the original word, such as duck. Semantic conditioning may contribute to instructional effects such as a child’s adherence to warnings about a hot stove.

Multiple causes may conflict with rather than support each other. If words are printed in different colors, it’s difficult to tact the colors rapidly if the words themselves are incompatible color names, as when the word red is printed in green (Stroop, 1935): we read words and don’t ordinarily attend to physical properties such as the color in which they’re printed. This relation between stimuli and the verbal responses they occasion clarifies some logical paradoxes of the language of reference. For example, consider the statement, This statement is false. If it’s true, then it must be false; if it’s false, then it must be true. Clearly it can’t be true and false at the same time. This is a paradox of logic but not of verbal behavior. One verbal response can tact another verbal response, but it can’t tact itself. In other words, the statement is not a response to itself, but It can’t be true and false at the same time might be a response to it.

In dealing with the formal relations, we argued that the symmetry of stimulus and response relations favors a vocabulary words in general rather than in terms of words in specific vocal or written modalities. Similar correspondences exist in relations between tacts and environmental events. These correspondences may be important when we speak of meaning, because the language of meaning is independent of whether words function as stimuli or as responses. This may be the most important way in which equivalence classes enter into verbal behavior.

When a listener repeats what a speaker has said and we say the listener understood the speaker, we aren’t usually satisfied in calling the relation echoic. The several relations between rain as a verbal stimulus and rain as a verbal response are among the criteria for talking about naming, but more is involved here than naming. Presumably we judge understanding or meaning not by any single relation between stimuli and responses, but rather by the integrity of different sorts of relations. We say someone understands something said when the person repeats what has been said not because another person said it but for the same reasons the other person said it (Skinner, 1968, p. 139). Such behavior implies consistent relations among verbal and nonverbal responses.

**FROM ACTION TO ACTING TO LITERATURE: CREATING WORLDS**

We spend time telling stories to each other and much teaching has been devoted to what makes a narrative work, as in creative writing courses. Some issues are structural. Stories start out with a setting, but then something happens, and finally things are resolved; this has been described as an “and—but—then” or “and—but—therefore” template (Olson, 2015). It has some resemblance to our three-term ABC contingency. But what is it about good narrative structure that keeps the reader or listener attentive throughout a story? This is a question about behavior and function (Hineline, 2016). We have in this paragraph an “and” and a “but,” but we’re still some way from filling in the “then” or “therefore” (cf. Hineline, 2016).

As we move from watching an actual incident to watching it acted in a play or a film and then to reading the script for the actual incident and then to reading a description of it in a story, the common feature holding the cases together must lie in consistencies of stimulus control over verbal and nonverbal behavior. We can understand at least some of what happens when we watch a play or film or television drama, because in those cases we’re responding to stimuli with a reasonable resemblance to what we’d see and hear if we were observing similar actual events. Part of the history of the movies is its progress toward ever more realistic presentations, in the transitions from silent films to sound, from black and white to color, from flat to 3D, and on ever larger screens. But those presentations are produced for us. What happens when instead we
When I started out as a student in the branch of experimental psychology that became behavior analysis, it seemed obvious the basics we were learning would sooner or later have real-world applications. But in retrospect plenty was going on even then. Skinner (1968) was developing teaching machines and soon Keller (1968) was contemplating a system called the Personalized System of Instruction. The field became more specialized, so what began as its only journal in 1958, the *Journal of the Experimental Analysis of Behavior* (JEAB), spun off its companion, the *Journal of Applied Behavior Analysis* (JABA), in 1968. Until then, JEAB published both basic and applied research and large proportion of contributors published in both areas, which were regarded as parts of a single field.

Ferster worked with children, then called psychotic, showing their behavior could be modified by simple consequences (Ferster & DeMyer, 1961); bringing them out of their shells to make contact with their environments laid the groundwork for behavior analytic services for children on the autism spectrum. Lindsley (1956, 1992) worked with psychiatric patients and developed celeration charts to track Precision Teaching. Dews (1958) explored the sensitivity to drugs of behavior maintained by reinforcement schedules and in so doing paved the way for research in psychopharmacology and behavioral toxicology. Ayllon and Azrin (1968) developed token economies for use with psychiatric patients. Goldiamond designed treatments for stuttering and tics (Flanagan et al., 1958); Bijou (1966) and Bijou and Baer (1961) demonstrated the feasibility of applications for children from both normally developing and challenged populations. Gilbert (1978) set the stage for behavior analysis in the workplace.

These were human applications, but meanwhile Brady (2007) trained chimpanzees so their behavior could be monitored while they safely rode the first suborbital flights in preparation for human ventures into space, and Verhave (1966) produced a system in which pigeons outperformed humans in maintaining quality control in an assembly line. Animal applications now include clicker training for pets (Pryor, 1999), dogs who detect drugs or explosives in airports (M. Williams & Johnston, 2002), and pouched rats who find unexploded landmines (Poling et al., 2011), among many others. Behavioral medicine has been extended to breast self-examination (Pennypacker & Iwata, 1990), and techniques for highlighting where a radiologist’s eyes linger longest hold promise for enhancing the reading of diagnostic images (Kundel, Nodine, & Krupinski, 1990).

Charlie Ferster once summed up behavior analysis by saying we solve problems by changing the environment. Skinner managed his own environments in many ways, building a better crib for his younger daughter, arranging a space devoted exclusively to his scholarly writing, and
dealing with problems of aging (Skinner, 1945a, 1981a, 1983, 1999; Skinner & Vaughan, 1983). Others added to personal applications, especially regarding the stimulus control exerted by consistent environments. For example, attend to and reinforce the behavior you value rather than taking a partner for granted; go somewhere else to discuss family issues or politics rather than letting disputes intrude into the bedroom; and (still pretty good advice) do unto others as you would have others do unto you.

A further step is to record your own behavior and to study the variables that affect it. In some courses I’ve had students conduct self-experiments along the lines recommended by Neuringer (1981). Students who looked at study data like pages read often found their assumptions about their own study practices were wrong. A student who thought herself a night person discovered she worked more efficiently in the morning. A student who thought he did better with music in the background discovered he worked more efficiently in silence, but another whose music masked noisy neighbors did better with the music on. I was dubious whether it was worth the trouble for one student to collect data on how much she studied when her husband was there. Of course she got less done when he was there, but the payoff came when she shared her data with him and he resolved to work at interrupting her study less often. Instead of making assumptions about your own behavior, it often helps to check it out by collecting data.

Some of the early promise of behavior analysis is being fulfilled. What was speculation has become real. I hesitate to stop at this point. Even my incomplete roster of what was there from the formative days suggests no single chapter can do justice to the range of its applications (Fisher, Piazza, & Roane, 2011). Some topics were discussed in other chapters: e.g., breast self-examination; functional analysis of self-injury; treatment of aggression in dogs. What follows here is merely an idiosyncratic sampling.

THE AUTISM SPECTRUM AND OTHER DEVELOPMENTAL CHALLENGES

I begin with a whirlwind tour of the area of application that continues to dominate applied behavior analysis (ABA) both among its practitioners and on the international stage. Definitions of autism and medical insights into its sources remain in flux and treatment fads come and go. Vaccination is not the culprit, but environmental pollutants and bacterial loadings have not been written off as suspects (e.g., Yong, 2016). The treatment called ABA is data-based and surpasses other approaches in its outcomes. It therefore has advantages in obtaining recognition by some third-party payers of medical benefits. The prevention or cure of autism won’t make ABA therapies obsolete, because a large population would still need remediation of the behavioral complications that arise throughout the development of children who fall along the autism spectrum. And even if autism had never existed, ABA treatment would remain appropriate for early intervention in other kinds of intellectual challenge, such as Downs Syndrome, and for coping with self-injury and other problemmatic behavior.

The natural consequences of everyday interactions between parent and child build social behavior. If they’re missing because the child rarely makes eye contact and shies away when touched, the scaffolding for more sophisticated behavior won’t be in place. The child who doesn’t make eye contact won’t see the smiles that ubiquitously work as reinforcers for the behavior of other children; the behavior of the child for whom touch is aversive won’t be reinforced by hugs. So much else is built on these reinforcers that even if their absence is the only deficit for a child on the autism spectrum, their cascading effects on the child’s developmental trajectory accumulate over time, especially in the evolution of social interactions. What would otherwise have been shaped by natural contin-
gencies must then be created by artificial ones, like reinforcing eye contact with edibles. Then comes the monumental task of teaching hierarchies of missing skills while also teaching parents and other caregivers how to maintain new behavior once it’s been created through shaping. Along the way disruptive behavior must also be managed. The work is daunting, but it’s well repaid when it’s managed well enough that children starting out with multiple behavior problems grow to be high-functioning young adults.

**ATTENTION DEFICIT HYPERACTIVITY DISORDER AND THE DELAY GRADIENT**

Children diagnosed with attention-deficit hyperactivity disorder (ADHD) show one or more of a spectrum of behavioral symptoms (Sagvolden et al., 2005). They may be hyperactive in school or home settings; they may be inattentive to instructions or school materials; and they may behave impulsively in situations where other children exhibit self-control. Some children show all these symptoms while others show only one or another. Each may be understood as derived from delay-of-reinforcement gradients that decrease more steeply than ordinarily ones, so reinforcers that don’t follow responses closely have less impact on the behavior of the ADHD child than would otherwise be the case.

Delay-of-reinforcement gradients describe how the effects of reinforcers change as a function of the time separating them from preceding responses. If an average gradient in some context declines slowly enough over time that reinforcers are still somewhat effective even if they follow ten or twelve seconds after a response, an ADHD gradient may decrease so rapidly that reinforcers are ineffective unless they follow responses by no more than five seconds or so.

Consider crossing a room to find a toy. A child might do this quickly or slowly. Given an average gradient, starting up the sequence would participate in the effects of the reinforcer either way. With the ADHD gradient, however, the toy as a reinforcing consequence would work on the entire sequence only if the child found it quickly. This is differential reinforcement: given rapid responding, the reinforcer is effective as far back as the start of the sequence; given slow responding it’s effective only for responses near the end. Thus, faster sequences will be selected by their consequences. This strengthening of rapid responding takes time, which may explain why hyperactivity often takes a while to develop and can develop separately in different environments.

In any case, hyperactivity is an appropriate name for behavior in which rapid sequences have displaced more leisurely ones. Of course, if an ADHD delay gradient declines steeply enough that only a single response can ever be within reach of the reinforcer, rapid sequences can’t be differentially reinforced, so hyperactivity won’t emerge. The point is that gradients differing in steepness can produce different degrees of hyperactivity.

The onset of a discriminative stimulus may be followed by a response-produced reinforcer after a shorter or a longer delay. With reinforcers delivered in its presence the stimulus becomes a conditional reinforcer, but its potency depends on this delay. If the gradient is steep, stimulus onsets followed only a long time later by reinforcers may be weak conditional reinforcers, so they’ll be less likely to be looked at or listened to. Attention deficit is an appropriate name for what’s missing when a child doesn’t much look or listen. Its magnitude and the balance between hyperactivity and attention deficit may depend on the steepness of the ADHD gradients.

The child for whom the delay gradient is unusually steep will be less able to deal with or tolerate longer delays, which is perhaps why the attention of such children is so easily captured by computer games, which typically provide very rapid feedback. In reinforcing the behavior of such children the reinforcers must be delivered promptly. This also has implications for impulsivity. Forgoing a small immediate reinforcer for a later larger one is described as self-control, but whether this will happen depends on the steepness of the delay gradient. The steeper
the gradient the less potent the larger reinforc-
ers that follow longer delays, and so the greater
the likelihood of impulsive behavior, behavior
strengthened by more immediate reinforcers. In
other words, these three difference manifesta-
tions of ADHD, hyperactivity, attention deficit
and impulsivity, seem all to be derivatives of a
single variable, the steepness of the delay gra-
dient. If so, individual differences in steepness
could account for variations in the dominance
of one or another of these symptoms in different
children (Catania, 2005a, 2005b).

The case for an interpretation of ADHD as
a product of delay gradients in Sagvolden et
al. (2005) is also strengthened by comparisons
of the schedule-maintained behavior of Wistar
Kyoto rats (WKY) and a closely related strain of
spontaneously hyperactive rats (SHR). The SHR
rats are a useful model for ADHD in children,
not only because their behavior is affected by the
same drugs used to treat hyperactivity in chil-
dren but also because differences between the
delay gradients of the WKY and the SHR rats
can be directly assessed.

Parents and teachers may find some compo-
nents of the ADHD syndrome hard to manage,
but if ADHD behavior is a manifestation of steep
delay gradients in one tail of a continuous dis-
tribution of human variation, maybe individuals
with such gradients are especially well suited for
certain activities or occupations. If so, treating
such behavior as a disorder may be inappro-
piate. Hyperactivity may sometimes be inconve-
nient to others, but in some settings it could turn
out to be a considerable asset.

MEASUREMENT AND
METHODS IN APPLIED
SETTINGS

Working outside the laboratory presented meth-
odological and ethical challenges (D. M. Baer,
Wolf, & Risley, 1968; Bailey & Burch, 2005; Gold-
diamond, 1974). The cumulative record made it
easy to see moment-to-moment changes in
behavior, but it isn’t always feasible to arrange
such recording in schools or treatment centers
or other environments outside the laboratory.
Sometimes behavior is recorded in checklists or
charts or with counters or other devices. In such
cases, observers must have well defined crite-
ria for what counts as an instance of relevant
behavior and what doesn’t; without such crite-
ria, data collected at one time by one observer
may not be comparable to behavior collected at
another time or by a different observer. Consis-
tency across time and observers is referred to as
reliability. The measures must also be relevant to
the behavior of concern. For example, the time
a child spends with an open book may not be
well correlated with the time the child spends
reading: the relevance or appropriateness of
measures is referred to as validity. Recording
instances of countable behavior is often more
productive than recording time spent engaging
in the behavior. For example, there’s a big dif-
ference between completing five arithmetic prob-
lems in one minute and completing only one,
but someone looking only at time spent doing
math wouldn’t see it. Interventions must also be
acceptable to those to whom they are directed,
so they must also pass tests of social validity, as
in assessments of user satisfaction.

These issues are of special significance in
education, but schools may not track what stu-
dents learn in behaviorally significant ways.
Doing so isn’t just a matter of measuring with
reliability and validity. An early lesson learned
by behavior analysts was that general impres-
sions of how behavior is changing over time
can’t be trusted. You must collect data. As with
cumulative records, important properties of
the data must be made easily visible and the
recorded units must be unambiguous (Johnston
& Pennypacker, 1993).

One method for recording learning is in cel-
eration charts (Lindsley, 1992). In a standard cel-
eration chart, the horizontal or x-axis (typically
time or number of opportunities for behavior) is
the usual linear scale, but the vertical or y-axis
(the behavior of interest, usually expressed as a
rate) is scaled logarithmically. In a logarithmic
or log scale, a given interval is equivalent to a
constant ratio rather than a constant difference.
For example, on a linear scale the space between
5 and 10 equals that between 25 and 30 or any other pair with a difference of 5; on a log scale, however, the space between 5 and 10 equals that between 40 and 80 or any other pair where one is twice the other. Here’s a linear sequence of seven numbers: 10, 20, 30, 40, 50, 60, 70. Here’s a log one: 2, 4, 8, 16, 32, 64, 128. In the linear sequence the middle one is halfway between the highest and lowest, in the log sequence it’s closer to the highest than the lowest.

Learning often goes from small early increments to big ones later. The advantage of log scales for examining changes in behavior over time, like a student’s rate of solving math problems, is that equal percent changes over equal times produce lines of constant slope. On a linear scale, early gains would look trivial compared to later big ones and if the scale went all the way to mastery they’d be lost at the bottom. The log scale of celeration charts solves that problem. Such charts are useful in assessing acquisition of academic skills and fluency (Binder, 1996; K. R. Johnson & Layng, 1992). Another important consideration is determining minimal units of learning, sometimes called learn units (Greer & McDonough, 1999). These measurement innovations make the effects of educational interventions quantifiable.

Applications involve different methodological constraints than do laboratory experiments. For example, laboratory research usually can go back and forth between procedures freely, but if an intervention gets rid of self-injurious behavior, it may not be appropriate to go back to the original conditions just for the sake of showing the outcome was produced by the intervention and not something else. Behavior analysis grew out of research with individual organisms, so its most significant applied methodologies are single-case designs (Roane et al., 2011). These include: reversal designs, in cases where it is appropriate to alternate between an intervention and its absence; multiple-baseline designs, in which an intervention is introduced at different times for different participants in the study; changing-criterion designs, which can assess whether changes in behavior follow changes in the magnitude of an intervention; and multiple-treatment designs, in which different interventions are compared by presenting them alternately or in some other systematic way. Applied methods are constrained by the behavior targeted for change and other details. New ones will no doubt be devised for special cases, so here again a sampling must take the place of an exhaustive list.

BEHAVIOR ANALYSIS AND THE BOTTOM LINE

Educational settings aren’t the only ones that need insulation from fads like the crusade against reinforcers under the guise of purported hidden costs of reward. In business, motivational speakers argue for building self-esteem, as if it could serve as a replacement for achievement rather than just being one of its products. Differential attention to competence is too often displaced by noncontingent praise: Good job! On examination, useful interventions in business that seem to have involved generalized attention turn out to involve contingent consequences (Parsons, 1974). Contingencies are obscured by the language of reward, which too often fails to specify what has been rewarded. Some purported problems with reinforcement come about because contingencies are mixed with verbal interventions, and reinforcement can be obscured when human verbal and nonverbal behavior interact (Shimoff & Catania, 1998).

As documented by Daniels (2009), consequences presumed reinforcing in the workplace may instead have damaging effects. Designating an employee of the month leaves out everyone else, and at the end of the month that lucky employee returns to the same old hunt for a parking space anyway. Promotion policies based on timing or seniority rather than on performance fail to target competence. Meeting set goals might have the consequence that the goalposts are shifted the next time around. Getting a good appraisal periodically may be fine, but what maintains the employee’s behavior in the times between? Evenly shared raises or bonuses give as much to those who have done the least
as to those who have worked the hardest. What are the contingencies and where are the reinforcers in these examples? Business provides many examples in which what superficially seem reinforcing practices go seriously wrong. Business practices based on behavior analysis are likely to benefit not only employees and management but also the bottom line.

**BEHAVIORAL PHARMACOLOGY**

Behavioral pharmacology, often also called psychopharmacology, began when Peter Dews (1970) visited Skinner’s pigeon laboratory and recognized that the performances maintained by reinforcement schedules were desirable baselines for studying the effects of drugs on behavior. The effects of some psychoactive drugs depended on whether behavior was maintained by interval or ratio schedules, so operant research could open a window on mechanisms of drug action and offer a methodology for drug screening (Weiss & Laties, 1969). Meanwhile, techniques were being developed to allow the self-administration of drugs by monkeys, creating opportunities for the study of addictions (Schuster & Thompson, 1969; T. Thompson & Schuster, 1964; Wurster et al., 1977).

I got into the picture when, as my first job after my postdoctoral work, I took a position at the Smith Kline and French Laboratories in Philadelphia; SK&F arranged my auditing of a pharmacology course at the medical school of the University of Pennsylvania. But I’d already gotten a nontraditional introduction to the field from Peter Dews, who often visited the Harvard pigeon labs while I was working there. A major point of his was that we should think of drugs as stimuli, differing from other stimuli mainly in their route of administration (Schuster & Balster, 1977; T. Thompson & Pickens, 1971). He also offered three basic principles of pharmacology: (i) no drug has a single action; all drugs have side effects, and what one investigator might see as a bothersome side effect might be regarded as a main effect by another; (ii) enough of anything will block anything; you can’t learn much about the functions of a drug if you deliver it at doses that overwhelm physiological systems; and (iii) when you do drug experiments you can’t draw conclusions from single doses; you must always examine dose-response curves, because the effects of a drug at one dose will probably be different, and maybe even opposite in direction, from what the drug does at other doses.

These principles provided useful guidelines for testing the effects of drugs on baseline responding maintained by schedules of reinforcement (Kelleher, Goldberg, & Krasnegor, 1975). The research soon showed that early classifications of psychoactive drugs were too simplistic. It was inappropriate to call a drug a stimulant if it raised response rates maintained by some schedules but not those maintained by others. Aside from the use of behavioral pharmacology to differentiate among classes of drugs that were behaviorally active, the work showed that behavior was often sensitive to drugs at very low doses. A valuable spinoff was the extension of these methodologies to behavioral toxicology (Weiss, 1983), which has provided data on the effects of pollutants in air and soil and water; these data have been essential prerequisites for setting guidelines for the control of such substances.

**BEHAVIORAL ECONOMICS**

Behavioral economics began when a few behavior analysts recognized that performances and concepts derived from reinforcement schedules were relevant to properties of behavior studied by economists (Rachlin et al., 1976). One point of contact was that behavior analysts and economists had mutual interests in choice. Some economists have since adopted behavioral economics as theirs, but economic behavior shares properties with other varieties of behavior, so behavior analysts can still study them profitably (Bickel, Green, & Vuchinich, 1995).

A familiar feature of economic theory is supply and demand. It’s obvious enough that an experimenter can arrange a supply of some reinforcer, like food, and that the demand for food
can be altered by motivational operations such as deprivation and satiation. The experimenter can manipulate cost of food as a commodity by changing response requirements. For example, a reinforcer produced by a fixed ratio of 100 responses can be thought of as twice as expensive as one produced by a fixed ratio of 50.

Not so obvious is the difference between situations in which (i) the only food reinforcers available are those earned within a session and those in which (ii) earnings are supplemented by additional feeding outside the session. The former is analogous to what economists call a closed economy and the latter to what they call an open economy. Comparisons depend on experimental parameters, such as schedule values and type of schedule, but some experiments that produce increases in response rate with increases of reinforcement rate in open economies produce opposite results with closed economies.

Another economic concept is elasticity. When the demand for a commodity changes substantially with changes in price, its demand is said to be elastic; to the extent that demand doesn’t change flexibly with changes in price, it’s said to be inelastic. For example, demand for leisure items one can easily do without is highly elastic relative to demand for essentials such as electricity or fuel. In experiments arranged as operant analogues of elasticity, the behavior maintained by reinforcers can vary differently given changes in cost if the alternatives differ a lot in elasticity. For example, if a food-deprived organism is also dependent on opiates, a doubling of a ratio requirement arranged for food reinforcers won’t have the same effect as a doubling of an equal ratio requirement arranged for drug reinforcers (Hursh, 1991).

One determinant of elasticity is substitutability, i.e., whether some reinforcers will substitute for others. For example, if coffee costs rise, the effect on demand for coffee will be different in a setting where other sources of caffeine such as tea are easily available than in a setting with no other caffeine source. Substitutability is relevant in experiments that involve different responses maintained by different reinforcers, especially when the reinforcers share properties, as when different foods contain common ingredients.

Behavioral economics has given substantial attention to discounting (L. Green & Myerson, 2004). If you can choose between $100 now and $100 next year, you’ll no doubt choose the immediate $100. But what about $100 now versus $15 next year? If that’s not enough, how large must the delayed amount be for you to prefer it? We typically discount delayed consequences relative to immediate ones. Studies of human discounting typically examine verbal judgments, but such procedures have analogs in nonhuman studies that pit small immediate consequences against larger delayed ones.

Studies of discounting and other economic analogs examine changes in the value of consequences: $100 delayed for a year is said to have a far lower value than $100 available immediately. But interpretations limited to changes in value may leave out the behavior. That may make it easier to communicate with those in economics and other disciplines, but the advantages of behavioral treatments and interpretations may be lost or unrecognized when their main strengths are obscured by verbal transformations.

Furthermore, verbal estimates may differ from choices that are products of actual contingencies. What people say they’ll choose given hypothetical alternatives may not agree with what they choose when confronted with real alternatives. Whether or not verbal mediation is involved, we can’t assume choices like these or economic behavior in general are based on rational decisions (Kahneman, 2011). Instead, we must examine the contingencies. For example, rationality isn’t involved when small immediate reinforcers are selected over large delayed ones. Words matter, of course, but contingencies are the bottom line in the analysis of behavior.

TEACHING: THE UNFULFILLED PROMISE

When I was a Columbia undergraduate, educational applications were in the air. Skinner had
given a lecture on teaching machines at Barnard College. The power of computers wasn’t yet available, so books with special designs or machines that could successively present questions and feedback were alternatives to what later became programmed instruction (B. H. Barrett, 2002; Skinner, 1968). It would be a while before those efforts paid dividends in the precision teaching of Ogden Lindsley (Potts, Eshleman, & Cooper, 1993), Fred Keller’s paced instruction (F. S. Keller, 1968; Twyman, 1998), and other innovations (Goldiamond & Thompson, 2002).

I’d been an only child for thirteen years when I acquired a brother. Robert was about eight by the time I took a seminar on teaching taught by Fred Keller. As my course project in the seminar I took on teaching Robert some algebra, including the distributive law: \( a(b+c) = ab+ac \). One thing I learned was that teaching the law in as many ways as possible mattered: solving specific number problems, working with unknowns, saying what the law meant. By the time the semester ended he understood the distributive law, in the sense of being able to work with it in different ways. I can’t say with any certainty whether the project had any long-term effects, but his subsequent career has consistently involved numbers and mathematics and computer programs.

When I left Columbia for the graduate program at Harvard, one of my main interests was working on programmed instruction. But soon I became caught up in the pigeon laboratory, so the interest was deferred until years later when I began teaching my own courses. When I eventually arrived at UMBC I was fortunate my colleague Eliot Shimoff had already been applying what we knew to education. We collaborated in both laboratory and classroom, so the line between teaching and research was sometimes blurred (Shimoff & Catania, 1995, 2001). That blurring is as it should be, for what’s the point of research if you don’t learn from your colleagues and teach them in turn about what you’ve learned?

Applied behavior analysis has again and again documented what it can do, yet too often those accomplishments have been unrecognized or recognized and forgotten. A prominent example occurred when behavior analytic programs achieved the most substantial teaching effects in early research on Project Follow Through, the largest educational project in United States history up to that time (Bushell, 1978). Alternative approaches produced less student progress in academic skills, but funding and implementation nevertheless favored programs targeting different objectives, such as self-esteem or social skills. Behavior analysts know as well as anyone how to teach children with intellectual challenges. Shouldn’t those skills transfer to the teaching of children at large? Education has sometimes turned to those who know how to teach things to computers, but shouldn’t it look instead to those who know how to teach things to real children?

A principal who had studied behavior analysis discovered that students spent only minutes per week doing math in math classes, so he ran an informal experiment. He asked teachers to increase the time students spent doing math by giving them more math problems to work on in class. It was unrealistic to ask the teachers to grade the extra work, so just the usual math papers were graded and the additional work wasn’t even returned to the students. After a while these students began getting better grades on exams even though they hadn’t gotten feedback on the added work. Just spending more time doing math improved math learning.

Educators must attend to the student’s behavior rather than the teacher’s. There’s no evidence for significant effects of individual learning styles (Pashler et al., 2008), so every student should be able to learn not just in one way but in several different ways: by rote, by understanding, by discovery, and so on, as appropriate to different subject matters. But teachers must also assure that contingencies don’t become aversive; absenteeism is one index of whether school environments provide adequate reinforcers. Keller’s Personalized System of Instruction (PSI) allowed each student to work at her own pace, but its structure conflicted with traditional
course formats and created administrative difficulties (F. S. Keller, 1968, 2009). After flourishing briefly, paced instruction waned; whether there will be a revival remains to be seen (Eyre, 2007).

For far too long, educational systems have focused on what the teacher does instead of what the student does. **What the student does is what the student learns.** The student is not a vessel into which knowledge can be poured. If no contingencies are placed on student behavior, it matters little whether a teacher changes from lectures to presentation software or from large class sections to small ones. Too many proposed educational innovations involve little more than changing the curriculum, but the problems of education won’t be solved merely by changing course content. The more time students spend with the material to be learned, the more they’ll learn, so anything teachers can do to get them to put in more time will usually be a good thing.

I had a colleague in biology who discovered classroom clickers, which allow students’ answers to questions to be tallied on an instructor console. He said at first his students asked a lot of questions and got many wrong, but he gradually tailored his lectures to deal with what hadn’t worked well. They became so polished his students hardly needed to ask questions any more. He was of course dealing with the practicalities of large classes. But I worried that by that point he was doing more while his students were doing less, so maybe he was doing too much for them.

I was surprised when a graduate student complained I hadn’t provided outlines of the topics discussed in class. When I pointed out that every chapter already had an outline, the student wasn’t satisfied. This student was having the same problem as those educators who think the teacher’s behavior matters more than the student’s. Students who produce their own outlines learn more than those who depend on outlines produced by their teachers. Overheads in class and online outlines are popular, but students who depend on them are having things done for them rather than learning to do things themselves. That’s not what education is about.

Effective methods for teaching based on behavior analytic principles have been around for decades (Greer & Ross, 2004; K. R. Johnson & Layng, 1992; Lindsley, 1992; Skinner, 1968). It’s shameful that in contemporary western culture they are so little recognized, much less implemented. Selection by reinforcement is the core of our science, but too many in psychology and education and related disciplines understand it superficially at best (Catania, 2013b). Teachers must attend to the structure of what they teach, but they must also know the functions of their interactions with their students. Above all, they must attend to their students’ behavior. In the best of all educational worlds the shaping should be reciprocal.

In those days when programmed instruction seemed to offer so much promise, some concentrated on teaching one or another specific skill. The targets ranged from reading and basic arithmetic through university-level courses. But some had a different dream: an educational system constructed from simple units like letters and numbers to the reading of words and sentences, and from there to whole paragraphs, not simply at the level of reciting the contents but instead answering questions and expanding on them. Critical thinking would be introduced early on. From there the next step would be pages and sections and eventually whole chapters. These could be contained in a convenient teaching device called a book; today we might prefer a tablet that can hold many such devices). Students who reach this point have been weaned from their teachers. They’ve learned how to learn; they provide examples of higher-order classes writ large. I hope some of my readers qualify. Perhaps this is what Skinner intended when he wrote his oft-quoted sentence, “Education is what survives when what has been learnt has been forgotten” (Skinner, 1964/1980).

It’s difficult to assign the authorship of the claim that Darwinian selection is so simple anyone can misunderstand it. The claim also holds true for Skinner’s selection by consequences. Darwinian selection remains a foundation for biology, despite tweaks and reassessments,
but it would be difficult to sustain the case that selection by consequences plays a similar role in psychology. But effective sciences breed applications, and by that measure behavior analysis has demonstrated its effectiveness. I’m inclined to agree with the statement, variously attributed, that behavior is too important to be left to psychologists: “…whether behavior analysis will be called psychology is a matter for the future to decide” (Skinner, 1990, p. 1210). Selection by consequences is the foundation of behavior analysis. Applications and all, it’s our science now.
We’ve considered phenomena of elicitation, reinforcement, discrimination and conditioning, among others. I think it’s time for a review. Let’s do one in the context of examples of social behavior involving parents and a child. Beyond mere observation, our simplest procedure is stimulus presentation. No signal precedes the stimulus and no response needs to occur before it’s presented. Suppose a nursing mother starts out by feeding her newborn infant independently of his behavior (we’ll assume the child is male not for sexist reasons, but rather so we can easily distinguish the mother and the infant as she and he). Her presentation of the nipple is an instance of stimulus presentation and may affect the infant’s behavior. He’s likely to turn toward her breast and begin to suckle. From the nursing mother’s point of view, the suckling is also a stimulus and elicits the letting down of her milk. This glandular response moves the milk toward her nipples, where it becomes available to the suckling infant.

Assume now the mother switches to demand feeding, feeding the infant only when he begins to cry. The feeding becomes a consequence of a response, crying. This relation is, of course, a response-stimulus contingency; we translate it as the effect of a response on the probability of a stimulus. In this instance, the infant isn’t fed unless he cries; without the crying the probability of being fed is zero. This is, of course, just one example of a contingency. Responses can raise or lower stimulus probability; they can turn things off as well as turn things on; and they can change other contingencies, though our examples here don’t require such levels of complexity. The contingency between crying and feeding is likely to affect the infant’s behavior. We can expect an increase in crying, but only some time since his last feeding, when milk has again become reinforcing through a motivating or establishing operation, deprivation.

Let’s add stimulus control. We superimpose a discriminative stimulus on either of the other operations. First consider the mother’s behavior. When she feeds the infant, the suckling produces the letting down of milk into her breasts. Once she begins feeding the infant when he cries, the crying becomes a reliable antecedent of the feeding and the mother discovers she begins letting down her milk as soon as he begins to cry. The stimulus, crying, is followed by another stimulus, the infant’s suckling. This relation should be familiar as an example of Pavlov’s respondent conditioning. When Pavlov presented dogs with light and then food, the dogs began to salivate after light as well as after food, just as the mother lets down her milk during the crying as well as during the feeding.

A discriminative stimulus can also be superimposed on the consequential operations of reinforcement or punishment. Now the infant has grown a bit and sleeps through the night. The mother begins feeding him when he begins to cry during the day but not at night. These times are correlated with daylight and darkness, and soon the infant begins to discriminate between them. Nighttime crying decreases relative to daytime crying, and later subtler discriminations allow the mother to begin to shape other kinds of behavior to replace the crying. Until
PART X. Conclusion

then, during daylight the infant is fed when he cries but when it’s dark he isn’t; in other words, light and dark signal the different contingencies. During light, crying raises the likelihood of a feeding; during dark it doesn’t.

When we examine behavioral situations, it’s often useful to describe them in terms of appropriate operations; sometimes a proper description requires a combination. For example, suppose the mother learns that when her infant begins to make fussy noises near bedtime, he’s likely to fall asleep quickly if she picks him up and rocks him. His fussy noises set the occasion for rocking and his subsequent falling asleep sets the occasion for tucking him into his crib. With regard to the mother’s behavior, both parts of this sequence involve stimulus-control operations superimposed on consequential operations. The rocking produces a consequence, the sleeping infant, that’s in turn a discriminative stimulus for the tucking in; a stimulus contingent on responding in one part of the situation serves as a discriminative stimulus in another.

These examples involve interactions between the infant’s behavior and the mother’s. In the context of such interactions, the infant learns to give special attention to social stimuli. These later become significant in many kinds of social behavior, such as attending to what others say, taking turns in conversation and saying things that affect the behavior of others. Maybe you’ve noticed that many of the human examples we’ve used to illustrate basic processes involve children with little or no verbal behavior, such as young infants or children with autism or other developmental challenges. This was no accident, because the basic contingencies are most effective when they’re uncontaminated by talk. Verbal behavior is a special kind of social behavior that comes later in the interactions of parents and children.

KINDS OF CONTINGENCIES AND CONTINGENT STIMULI

Stimuli involved in response-stimulus relations are contingent stimuli. We’ve used the mother’s milk and the infant’s suckling as examples, but stimuli are of varied sorts. We could replace them with aversive ones. The shouting of an abusive parent might occur independently of the child’s behavior; or it might occur only after some response, such as crying; or it might occur only in the presence of some other stimulus, as when the child learns that his father shouts only when his mother is around; or it might be that if he cries his mother always quiets his shouting father, so her presence is an occasion when he can avoid or escape from his father’s shouting by crying. These are all examples of aversive contingencies.

It’s sometimes convenient to distinguish different types of contingent stimuli. Organisms work to produce or remain in the presence of some, called appetitive, rewarding or reinforcing: food, entertaining company, money, among many others. They work to remove or stay away from others, sometimes called aversive, noxious or punishing: noise, dull company, extremes of heat or cold, among many others. Some stimuli have obvious biological significance while others acquire their significance during the organism’s lifetime. It’s difficult to classify any stimulus unambiguously as a reinforcer or a punisher, especially given the relativity of reinforcement and punishment. And, having admitted appetitive and aversive stimuli as classes of contingent stimuli, we must also recognize that relatively neutral or insignificant stimuli can enter into contingencies. If the infant reaches out and touches his mother, for example, his movement is a response and contact is its consequence. Obviously, no stimulus is likely to be completely without significance; these classes represent points or regions in a continuous range of stimulus types rather than three discrete categories, and the categorization of stimuli can change with establishing or motivational operations.

A response may lower as well as raise the probability with which events occur. Suppose the father finds the infant’s cries aversive. If the infant is especially likely to cry if his diaper hasn’t been changed for a while, the father can avoid the infant’s crying by changing the
diaper. The probability of crying increases as time passes without a diaper change, and decreases whenever a diaper change occurs. In other words, changing the diaper is the father’s avoidance response. A response-stimulus contingency is defined as the effect of a response on stimulus probability, and we distinguish among contingencies in terms of whether the effect is an increase or a decrease in probability. In this last case, in which the diaper change avoids the infant’s crying, the stimulus is aversive and its probability is reduced by the father’s response.

Now suppose the infant has fallen asleep and while watching television the father accidentally awakens him by turning up the sound too loud. The infant begins to cry. The contingent stimulus, the crying, is again aversive, but this time a response, turning up the sound on the television, has raised its probability. The crying may punish the turning up of the sound, in that the father may from now on be less likely to do so while the infant is sleeping. Changes in probability are, of course, not limited to all-or-none cases. For example, the infant might not be fed every time he cries, and he might not awaken and cry every time someone turns up the television sound.

In classifying contingent stimuli, we recognize relatively neutral or insignificant stimuli as well as appetitive or aversive stimuli. Contingencies also range from those in which responses raise stimulus probability to those in which they lower it, and within this range is the special case in which a response has no effect on stimulus probability. This special case is equivalent to stimulus presentation, which may involve the response-independent delivery of appetitive stimuli or aversive stimuli or relatively neutral or insignificant stimuli.

Kinds of contingencies and contingent stimuli are summarized in Table 32–1; each can be combined with a discriminative stimulus. For any procedure, it may be instructive to locate it or its various stages among the classes shown in the table.

Now the infant is older and his mother allows him to crawl around and explore some rooms in his home. After he’s done this a few times over several days, the mother takes him to a room in the corner of which is a new toy chest. She opens the chest and gives him a favorite toy. The next day she puts him down in another room and he immediately sets out for the room with the toy chest, getting there quickly and without making any wrong turns. His exploration of the room on the previous days involved behavior that produced relatively neutral consequences. But when something more significant was introduced, the new chest with some of his toys in it, the child proved he had learned the layout of the rooms. The example is analogous to an experiment on latent learning.

Consider one more example. The mother has often taken the infant to the pediatrician’s office for routine exams. Time in the waiting room has reliably been followed by seeing the pediatrician in the examining room. One evening the infant becomes ill and the mother takes him to a hospital urgent care unit instead of the pediatrician’s office. There the pediatrician checks the infant’s

| Table 32–1 Kinds of Response-Stimulus Contingencies and Contingent Stimuli |
|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| **Type of Contingent Stimulus** | **Response Raises Probability of Stimulus** | **Response Doesn’t Affect Probability of Stimulus** | **Response Lowers Probability of Stimulus** |
| Appetitive, rewarding, or reinforcing | Positive Reinforcement | Stimulus presentation | Negative punishment |
| Relatively neutral or insignificant | Sensory consequences | Stimulus presentation | Sensory consequences |
| Aversive, noxious, or punishing | Positive punishment | Stimulus presentation | Negative reinforcement |
symptoms and then gives him an injection. The injection makes the infant cry. A few days later the mother takes the infant to the pediatrician’s office for a follow-up exam. Even though he hadn’t gotten the aversive injection in the examining room, the infant begins to cry as soon as he and his mother enter the waiting room. When the pediatrician’s significance was changed by the injection, the crying in the waiting room proved the infant had learned the contingent relation between the waiting room and seeing the pediatrician. The waiting room and seeing the pediatrician are analogous to the initially neutral stimuli of a procedure called sensory preconditioning. Constructing other examples that correspond to the various cells in the table is a worthwhile exercise.

One way to judge the relative significance of events is to compare the probabilities of the responses they occasion. If we were interested in the child’s playing with toys and eating, we might see which he did when both toys and food were freely available. When the child becomes older, an opportunity to play with friends might function to reinforce eating if he’s reluctant to finish a meal, but if he’s just encountered some cousins he’s never met before at a family get-together and is reluctant to play with them, it might help to see whether the opportunity to eat a favorite food could reinforce playing. In other words, the effect of a contingency may depend on the relation between the responses that produce and are occasioned by contingent stimuli. We are again reminded that motivating operations are concerned with the conditions determining the effectiveness of contingent stimuli as reinforcers or as punishers.

These classifications don’t guarantee any stimulus or response will have just a single function: a stimulus in a contingent relation with one response may be in a discriminative relation with another; a response elicited by one stimulus may be involved in contingencies with others. For example, the mother’s presence may be a contingent stimulus when she comes at the infant’s cry and a discriminative stimulus when the infant learns things happen when she’s there that don’t happen when she’s not; the infant’s cry is sometimes elicited by events, such as painful stimuli, while at other times it occurs because such events as the mother’s presence are its consequence. We come to understand behavioral situations by separating out stimulus and response relations that enter into them. That’s the business of experimental analysis.

On close examination, some distinctions implied by our taxonomy seem to diminish in importance. In the analysis of behavior, classifications often have fuzzy boundaries and distinctions can become arbitrary. We noted such a case with respect to presenting or removing stimuli: is water effective as a reinforcer because of its presentation or because it terminates dry mouth or other events correlated with thirst? In the final analysis, we discarded the distinction between presenting and removing stimuli in favor of a behavioral account that considered the relation between the responding that produced a reinforcer and the responding produced by that reinforcer. All consequences of responding can be characterized as environmental changes.

Every procedure takes place in some environment, so we could next get rid of discriminative stimuli, observing as we did so that we can deal with them by incorporating them into our response definitions. Thus, if a child’s requests for candy are granted when his grandparents are present but not when they’re absent, the response of this contingency can be defined to include only those requests he makes when his grandparents are around. If later analysis shows us we can’t even define response classes independently of contingencies, we might ultimately decide to dispense with that distinction too. But distinctions like these have been useful along the way. We can, so to speak, throw away the ladder after we’ve climbed it.

Eventually the child is likely to become a fluent speaker. When we moved by way of social learning from learning without words to learning with words, we discovered our basic operations were relevant to verbal as well as nonverbal behavior. Verbal classes such as tacting and manding were, in effect, names for the relevant processes entering into verbal behavior. They also provided contexts within which we
more fully developed the implications of higher-order classes and recognized potentials for novel behavior in adduction and other sources of emergent behavior. Speaking metaphorically, we’ve traveled a long way.

We’ve typically preferred the concrete to the abstract. We’ve built our accounts of the complex from simpler parts, much as biologists have built their accounts of complex organisms from analyses of cells and their components. We didn’t have to invent new processes to fill in gaps. By proceeding this way we kept our approach parsimonious. Our frequent appeals to the details may sometimes have seemed constraining, but environments are properties of the world about which we can often do something. We needn’t be weighed down by prejudices about human behavior evolved over many centuries. Thinking analytically about behavior and the environment is liberating, not limiting. It keeps us from traps created by unconstrained theorizing and unwarranted assumptions about the sources of behavior (Skinner, 1961).

TWO PATHS IN THE STUDY OF LEARNING: A CAPSULE HISTORY

The study of learning has at times been regarded as a foundational component of experimental psychology, but in the late 19th century it was overshadowed by other issues, such as those of sensation and perception. By the turn of the century, research on animal behavior had been stimulated by the work of Darwin (1859), and the fundamentals of research on human memory and verbal learning had been provided by Ebbinghaus (1885/1964). Both historical lines found homes within university laboratories, but despite their academic proximity they remained separate.

Early in the 20th century, John B. Watson (1913) addressed what was called his behaviorist manifesto to a psychology marked by substantial disagreements about its methods and subject matter. Researchers claimed access to the content of consciousness through introspection but couldn’t agree on such fundamentals as the basic mental units. Was green a unitary sensation or a combination of the sensations yellow and blue? In this context, Watson advocated behavior, not consciousness or mind, as the only legitimate subject matter of psychology. He excluded mental events such as images as proper areas of inquiry on methodological grounds. His version of behaviorism came to be called methodological behaviorism, he rejected the study of private events. That study would call for a new kind of behaviorism, radical behaviorism, perhaps because in looking at the behavior of the scientist it turned its own science upon itself.

Many early studies of animal behavior were devoted to invertebrates (Jennings, 1906; Loeb, 1900; Lubbock, 1882) but attention gradually shifted to vertebrates. Instrumental learning was introduced by the mazes of Small (1899–1900) and Yerkes (1907) and the problem boxes of Thorndike (1898). Thorndike moved from animal studies to analyses of human learning, but in doing so was exceptional. Others usually made the extension from animal to human behavior through theoretical statements rather than experiments. Pavlov (1927), for example, addressed human language in his theory of the second signal system, but his main impact was through his canine research (Todes, 2014). Distinguishing instrumental learning from respondent conditioning in the early decades of the 20th century set the stage for elaborations of discrimination learning, in the progression from jumping stands to rat chambers and pigeon boxes (Lashley, 1930; Skinner, 1930, 1938). The phenomena of reinforcement schedules followed later (Ferster & Skinner, 1957).

Preoccupation with the scientific legitimacy of psychology disposed researchers to look to other sciences for principles of scientific method, and gradually the behaviorism of Watson (1919) converged with the operationism newly developing in physics (Bridgman, 1927) and with the logical positivism in the philosophy of science (Ayer, 1946). Behaviorism became prominent and the 1930s and 1940s became a period of grand behavioral theories. Applications to human behavior and to language became an
issue in the competition among the systems of Guthrie (1935), Skinner (1938), Hull (1943) and Tolman (1948), among others, but attempts to integrate animal learning with research on language gradually lost influence as the fortunes of early behaviorist theories based on stimulus-response associations declined. Even so, in relying on operational definitions, methodological behaviorism became the foundation of virtually all contemporary experimental psychology, though it has veered from its foundations in other ways.

Meanwhile, the field of human learning and memory went its separate way. The precedence of Ebbinghaus dominated studies of serial-position effects, massed versus spaced practice, meaningfulness, and so on. Thorndike and Woodworth (1901), inspired perhaps by questions about the educational value of such classical disciplines as Greek and Latin, began to investigate transfer of learning. The practical relevance of studies of human learning seemed obvious, and the effects on verbal learning of such variables as sleep and distraction and motivation became the basis for advice on study habits. The theoretical underpinnings were the same as those of animal learning, but even though laws of effect, contiguity, association and generalization gave a superficial appearance of unity, the two experimental lines that had originated as separate entities remained so. Beyond common appeals to theoretical principles like association and lip service about mutual relevance, these research traditions didn’t much influence each other.

It can reasonably be claimed that these two aspects of learning still remain separate (Catania, 1985). We might even ask the point of treating them together. Perhaps animal learning and conditioning and human learning and remembering should go their separate ways. But here I’ve argued otherwise. Such a course would be a mistake for several reasons: learning phenomena studied with animals also occur in human behavior; the nature of complex human learning is clarified by analyses in terms of more elementary processes; perhaps most important, human behavior especially is characterized by the interplay between verbal behavior and the nonverbal behavior on which it depends, and we still have much to learn about each.

We must identify the properties of behavior we hold in common with other organisms along with those unique to us. Given the myriad properties of human verbal behavior, both elementary phenomena of animal learning and conditioning and the complexities of human learning and remembering must come together in any effective account. Our treatments of equivalence classes, awareness and instructional control couldn’t have proceeded without analyses of antecedent stimuli. Important varieties of human behavior such as autoclitics and self-control are based on both verbal behavior and discriminations of our own behavior, so any analysis failing to build on the more elementary processes of stimulus control and contingencies is bound to be deficient. Uniting these two approaches to learning is a task long overdue; behavior analysis encompasses all varieties of animal and human learning and is well-equipped for it.

**TWO PATHS IN THE STUDY OF VERBAL BEHAVIOR: ANOTHER CAPSULE HISTORY**

The history of the two approaches to learning we’ve just considered was mostly before my time. Not so for two competing approaches to verbal behavior and language. Skinner had begun outlining his treatment of verbal behavior long before he had a conversation about behaviorism with the philosopher Alfred North Whitehead during a dinner for the Harvard Society of Fellows in 1934 (Skinner, 1957, pp. 456–460). Whitehead asked Skinner to account for his saying “No black scorpion is falling upon this table.” Skinner accepted the challenge.

Skinner regarded *Verbal Behavior* as his most important work. I was fortunate to get the chance to read it early. During the Spring semester of 1957, along with a half dozen or so other Columbia College undergraduates, I took a weekly seminar on verbal behavior jointly
conducted by three faculty members: Ralph F. Hefferline, Fred S. Keller, and W. N. Schoenfeld (Catania, 1997a). During the first several weeks we spent our time on a mimeographed document, Skinner’s William James lectures, which he delivered at Harvard University in 1947 and which was a forerunner of the book. Each class began with a thorough summary of the current material by one of the faculty members. We finished with the lectures about midway through the course, when the book based on them was published and finally became available. As we progressed through the book we had the advantage of having read the lectures, with which we compared it.

In the Fall of 1959 I was in the audience as a graduate student in the Harvard Department of Psychology when an MIT linguist named Noam Chomsky gave a colloquium on his new transformational grammar. Skinner was in attendance, but Chomsky didn’t mention his forthcoming review of Verbal Behavior, which must already have been written because it appeared shortly afterwards (Chomsky, 1959). It overshadowed many favorable reviews of Skinner’s book (Knapp, 1992). Chomsky was mainly concerned about language structure, and for many years it was assumed his critique had destroyed Skinner’s position. Linguists too often concentrate more on whether verbal behavior is grammatical than on how it functions (Catania, 2003b; Jackendoff, 2002; Pinker, 1994). Most behavior analysts who read Chomsky’s review, including Skinner, concluded Chomsky missed the point of the book, so no reply seemed necessary (R. A. Harris, 1993). Years passed before responses to Chomsky’s arguments appeared (e.g., MacCorquodale, 1970). Unfortunately, in the meantime some concluded Skinner didn’t write a reply because he couldn’t produce an effective one.

A critical precursor of contemporary psycholinguistics was the effort to write programs for computer translation from one language to another. That history included the evolution of computers in Allied efforts to break military codes during World War II and later applications of mathematics to problems of language structure during post-Sputnik efforts to translate Russian technical materials into English. Language translation was a major focus as the United States and the Soviet Union faced off against each other during the Cold War. Early attempts simply to substitute words in one language for their equivalents in another were unsuccessful for a variety of reasons. For example, many words have multiple equivalents: should bar be translated as a noun, either a lever or a place to drink, or as a verb, to stop?; and grammatical distinctions in one language may be absent in another; Russian doesn’t use articles, so how do you decide whether an English translation of a Russian noun should be preceded by a or the or no article at all? Backed by the prestige of Alan Turing’s mathematics (Hodges, 1985) and growing computer technology, linguists argued their field was the only one that could produce effective computer translations. Grant monies were at stake, and at the time Skinner’s Verbal Behavior (1957) probably looked like competition.

Major components of linguistics include syntax, concerned with grammatical structure; semantics, concerned with problems of meaning; and phonology, concerned with the structure of speech. Pragmatics, concerned with the functions of language, is closest to the concerns of analyses of verbal behavior, but tends to get less attention within linguistics than the other areas. Linguistic accounts often focus on structure whereas behavioral ones often focus on function, so debates over the relative importance of the fields are usually about as useful as those, now long gone in biology, over whether anatomy or physiology is the more important.

Among the controversial issues was whether consequences play a role in the child’s acquisition of language, and especially in the child’s acquisition of grammatical structure. It was claimed behavioral accounts could not deal with productivity, the child’s capacity to produce new sentences the child could never have heard before. Appeals to the poverty of the stimulus argued the child’s verbal environment isn’t rich enough to support acquisition of grammar; if so, some grammatical features must be “prewired,” in the sense they’ll emerge even without rel-

The case for the poverty of the stimulus argues that verbal environments don’t include the ungrammatical instances that should be there to support claims that a child’s grammatical behavior is shaped through natural contingencies, either because such instances don’t occur in the speech children hear, or because such instances aren’t corrected when children make them, or both. For example, if a child is questioned about a laughing frog muppet, the child may hear Is the muppet who is laughing a frog? but won’t ever hear Is the muppet who laughing is a frog? (Crain, 1991). The child later asks questions with the former grammatical syntax and rarely if ever with the latter ungrammatical one. What keeps the child from making the latter error?

The simplest reply is that all possible negative instances aren’t necessary for learning. For example, the echoic shaping of phonetic structure doesn’t demand an environment including nonnative as well as native speech sounds, any more than that a pigeon discriminating between green and red needs exposure to the entire spectrum (Moerk, 1992). With syntax, a verbal environment including contrasts between at least two grammatical structures provides differences on which learning can be based: for example, both active and passive voices are grammatical but provide a contrast that may enable later discriminations of grammatical versus ungrammatical (Palmer, 1996, 1998).

During the nineteenth century eclipse of Darwinism (Bowler, 1983), many believed Darwinism was dead because existing genetic theory provided no grounds for the variations needed by selection. That eclipse ended in the early twentieth century when genetics showed that mutations could provide those variations. Behavior analysis has been similarly eclipsed (Catania, 1987), and here too the issues have been about where the variations come from. Chomsky had argued that behavior analysts had nothing to say about productivity, the child’s capacity to utter novel sentences. Yet contemporary behavior analysis can identify not one but many sources of novel behavior.

Even if it were proved children don’t have to learn all the details of grammar because some are built in, that wouldn’t mean there aren’t lots of other things about verbal behavior they’ll still have to learn. In fact, there’s plenty of evidence that rich verbal environments in which parents spend lots of time interacting verbally with their children can make vast and lasting differences in their verbal competence (B. Hart & Risley, 1980, 1995; Moerk, 1992). Contingencies matter. The effects, described as meaningful differences in the everyday experience of young American children, appear in vocabulary growth rate, school performance and IQ scores. What else emerging from the analysis of behavior could have greater relevance?

I believe we’re at last emerging from our eclipse. It wasn’t total. Along with other colleagues, I began teaching both undergraduate and graduate courses using Skinner’s book. It was a way to maintain a small verbal community within which to practice the language of verbal behavior. Meanwhile, with the growth of applied behavior analysis, verbal behavior has become a crucial part of therapies targeting the verbal deficits of autism-spectrum children. It makes a difference to know manding is a good place to start and to understand that building a solid foundation of tacting and other basic verbal classes is a prerequisite for more complex verbal skills. You won’t find those distinctions in linguistics. Based on the growth of online chat sites in which groups of parents discuss Skinner’s *Verbal Behavior*, some believe more people have read the book since its 2007 fiftieth anniversary than in the entire half-century following its publication. As we learn more about the third variety of selection it has illuminated, it’s a good bet its light will grow even brighter over time.

**LEARNING AND EVOLUTION**

Biology has evolved from a theoretical discipline to a descriptive one. The double helical
structure of DNA was once a theory of sorts, but when Watson and Crick (1953) constructed their model and showed how it worked detailed confirming investigations followed soon after. Now we can look at the molecule. Biologists and their colleagues in related disciplines have created a taxonomy of fundamental biochemical and other processes. That taxonomy provides the parts, and biologists can show what a biological system does and how it does it by demonstrating how those parts fit together and interact (Carroll, 2005, p. 10, 13, 295). The contemporary microbiologist doesn’t trade in theories of cell metabolism but instead shows how cell metabolism works. Seeing how behavior works is perhaps trickier sometimes, because behavior doesn’t sit still for us while we look at it. It’s now more respectable than once it was to speak of taxonomies for categories other than plants and animals (Ross & Spurrett, 2004, p. 604), so it’s appropriate for us to expand our taxonomy.

A source of controversy is the relation between behavior and physiology, and the nervous system in particular. Those studying the neurophysiology of learning need to know what happens in behavior to know what they should look for in nervous systems. A neurophysiologist who thinks learning is mainly stimulus-response associations will look for different things than one who thinks learning is a product of ontogenic selection. Skinner compared the relation between behavior analysis and neuroscience to that between genetics and biochemistry: “It is the function of the science of behavior at the present time to give neurologists their assignments, as it was the function of genetics prior to the discovery of DNA to give modern geneticists their assignment with respect to the gene” (Skinner, 1988, p. 60; see also p. 461).

Parallels with biology often provide hints for useful directions in the analysis of behavior. That should be no surprise: after all is said and done, behavior remains central to biological systems. Despite the origins of behavior analysis in philosophy and psychology, we’re part of biology and must cultivate our intellectual ties with the biological sciences. If we do so, we can anticipate continuing insights from ongoing developments in those disciplines (Carroll, 2005; Kiecker & Lumsden, 2005; West-Eberhart, 2003). Attending to them will serve us well.

In discussing types of selection, we’ve argued that properties of learning parallel those of evolution, because the selection or survival of patterns of behavior in an organism’s lifetime has much in common with the selection or survival of individuals in the evolution of species (Catania, 1978; Skinner, 1966, 1975). Our discussion of social learning made a similar case for the selection of cultural practices (Catania, 2001b; Dawkins, 1976; M. Harris, 1977; Skinner, 1981b). Our own verbal behavior makes this variety of selection of special interest. Each type of selection involves variation that provides the source materials on which it operates, and each involves some mechanism for selecting what survives. Whatever else happens at every level, behavior gets selected and environments do the selecting.

The parallels between Darwinian natural selection and operant selection also extend to the problems of acceptance each has faced. Like Galileo’s displacement of the earth from the center of the universe to an orbit around the sun and Freud’s challenge to the central status of human consciousness, these accounts overturned traditional ways of thinking about our place in nature. Phylogenetic and ontogenic selection faced similar substantive challenges. For example, artificial selection was familiar in Darwin’s time; what was questioned was whether selection could operate naturally. The operant parallel is provided by shaping, another artificial selection procedure, as when an experimenter shapes a pigeon’s figure-8 turns or as when a behavior therapist shapes the vocalizations of a nonverbal child on the autism spectrum. The effectiveness of shaping is self-evident; what’s questioned is whether it operates naturally to produce the varied patterns of behavior we see in everyday life.

It’s not good enough to argue that in humans the effects of shaping are often masked by verbally governed behavior. We’d like to have documented cases in which the changes in contingencies are identified early and tracked, but typically we only have outcomes, after the
natural contingencies have done their work. For example, we assume ontogenic selection was involved in shaping the skill with which grizzly bears catch salmon in the rivers of the Pacific Northwest, but we mainly see the differences between the inefficient performances of the young novices and the well-coordinated actions of the experienced adults; we don’t see the shaping itself, because it continues over too long a time.

Shaping can be hard to see if you don’t know what to look for. If you’ve done actual shaping you’re more apt to notice it when it happens naturally than if you’ve only read about it. Thus, the parents who always wait a while before attending to a crying child may not notice they’ve gradually shaped louder and more annoying cries. The attention reinforces the crying, and annoying cries are, by definition, the ones most likely to get attention. If you watch what a parent does when a child throws tantrums, it’s usually easy to guess where the tantrums came from.

Time is another factor in the acceptance of both types of selection. For Darwinian natural selection, the question once was whether the earth had existed long enough for such selection to have taken place. Upward revisions of the age of the earth resolved the problem. The comparable problem is easier to deal with for operant selection. Even with rapid breeders like the fruit fly, genetic experiments take days. Shaping, however, can be demonstrated in minutes. If reinforcers can do so much to behavior when contingencies are deliberately arranged over relatively short periods of time, isn’t it reasonable to assume they’ll also affect behavior when natural contingencies operate over substantial periods in an organism’s lifetime? Many contingencies can take hold of behavior over the course of a year in the life of a young child. Compared to how long most artificial cases of shaping last, a year is an extremely long time. Some contingencies are subtle, especially given the broad range of events serving as reinforcers. The behavior they produce may be desirable or not. Given what artificial contingencies can do quickly, natural contingencies should be able to do a lot in a long time. It’s more appropriate to be alert for the effects of such contingencies than to assume they don’t exist.

In Darwin’s account of evolution, the relations among populations of organisms couldn’t be expressed in terms of similar topographies. For example, males and females within some species differ more from each other in form than some pairs of organisms within completely unrelated species (the social insects provide striking instances). For Darwin, the important basis for distinguishing among populations was descent. To define relations among populations, look at where they came from. Darwin’s achievement, in fact, was more description than explanation. His account of evolution didn’t depend on any theory specifying the mechanics of evolution. Even though he couldn’t say exactly how selection did it, he had described how evolution works.

In the analysis of behavior, we deal with populations of responses. These populations are sometimes not well-defined. The problem isn’t very different from Darwin’s. Darwin clearly recognized the arbitrary nature of the concept of species, but unambiguous definitions of species were no more critical to his account than unambiguous definitions of stimulus or response classes are to a behavioral account. When we distinguish among words by the circumstances in which they’re uttered (e.g., fire as a mand, a tact, an echoic or a textual response), we’re simply distinguishing among classes of verbal responses based on their origins. Ambiguous cases will necessarily occur because, just as organisms have many ancestors, responses have many origins. If that weren’t so we wouldn’t need analysis.

We might do well to see whether our analyses of social contingencies can effectively be extended to human behavior on a larger scale. Can analyses of verbal behavior contribute to our understanding of the rapid cultural changes that led to such moral revolutions as the demise of dueling and the overthrow of slavery and still ongoing changes in the role of women (Appiah, 2010)? Can analyses of conditional discriminations contribute to our understanding of the social contingencies that foster tolerance (Meyer & Brysac, 2012)? Can analyses of the side effects
of reinforcement and of aversive control contribute to our understanding of how social and political precursors determine not only whether conflicts are peacefully or violently resolved, but also how one or another mode of resolution may favor the kinds of political and cultural systems that follow (Chenoweth & Stephan, 2011; Nevin, 1996a, 1996b, 2003, 2005)? Our research enhances our understanding of concepts like self and causality and volition and judgment and explanation, but it does not—indeed cannot—displace them (Field & Hineline, 2008; Hineline, 1990; Killeen & Jacobs, 2016; Neuringer, 2014; Nevin, 1969; Rachlin, 2014). By clarifying our place in the evolution of life on our planet, we may strengthen our stewardship of human social institutions and human environments.

BEHAVIOR ANALYSIS AND BEHAVIOR SYNTHESIS

So where do we as individuals fit in all this? Skinner described himself as “a locus—a place in which a number of variables come together in a unique confluence to yield an equally unique achievement” (1957, p. 313), and elsewhere as “a locus, a place in which certain genetic and environmental causes come together to have a common effect” (1972/1999, p. 398). We can find the same point echoed by Igor Stravinsky, in program notes for his own recording of his most famous work: “I was guided by no system whatever in Le Sacre du Printemps…. I heard and I wrote what I heard. I am the vessel through which Le Sacre passed.” We may recall the “lucky mud that got to sit up and look around” in Vonnegut (1963, ch. 99), but Skinner and Stravinsky were not passively looking; their quotations are about their creations. And we as behavior analysts have learned to do more than merely look around. We’ve learned to solve problems by changing our environments; we’ve learned what behavior can do.

Behavior analysis begins with complex behavior and breaks it down into its components. These are the elements of our behavioral taxonomy. They can be combined in various ways, when it may be appropriate to speak of behavior synthesis, which is another name for applied behavior analysis. For example, we can synthesize some kinds of sequential performances through chaining procedures. In a more complex instance, we can combine discriminative stimuli, reinforcement schedules and delays of reinforcement so the resulting contingencies are analogous to those when we speak of self-control. In the verbal domain, we can integrate echoic behavior, tacting and listener behavior into a higher-order class called naming. If our syntheses are successful, we can use them to clarify the properties of behavior; if they are unsuccessful, we can use them to identify components of performance missed or taken for granted in preceding analyses (e.g., as when we study variables affecting the likelihood of commitment responses in self-control procedures, or as when we discover, in designing an animal analogue of some human performance, that verbal behavior must have had a role we hadn’t allowed for). Because many important human problems involve creating new behavior (e.g., teaching children with disabilities), the applications of our methods are often matters of behavior synthesis (Fisher et al., 2011; Lattal & Perone, 1998; Madden, 2012).

The term learning has receded into the background in all this; perhaps it’s outlived its usefulness. New behavior has many sources. We can modify behavior hierarchies, shape new responses, construct higher-order classes, generate discriminations, form equivalence classes, solve problems and create novel behavior through adduction. Our understanding of these phenomena depends at least in part on whether we’ve developed a vocabulary consistent with and worthy of them. We can assume our current behavioral vocabulary will evolve as research progresses. Yet in emphasizing behavioral procedures and outcomes, it adheres closely to what’s done and what’s observed as we expand our science and apply it. The success of behavior analysis will be measured by its survival in the behavior of those who practice it and by the effectiveness of the behavior syntheses following from it.
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I deleted Appendixes II, III and IV from this file.
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A NOTE ON THE COVER ART

The central image on the front cover is *Peaceable Kingdom* by Edward Hicks, one of several variations on this theme. Reading clockwise from the upper left, the framing works are: Monet’s *Cliff at Etretat*; Bruegel the Elder’s *Tower of Babel* (“great” version); Rembrandt’s *Conus marmoreus* (shell); Henri Rousseau’s *Apes in a Grove*; Rodin’s *Thinker*; Earth from space; sample sketches of Darwin’s finches; Daumier’s *Don Quixote*; Seurat’s *La Grande Jatte*; George Richmond’s portrait of Charles Darwin; Rockwell’s *The Problem We All Live With*; a Canaletto view of San Marco Square in Venice; Volterra’s bust of Michelangelo; da Vinci’s *Vetruvius Man*; and Constable’s *Hay Wain*. Allusions to each, some more subtle than others, appear at various points in the text.

Along with relevant terms and phrases, the back cover includes figures from the text, segments from Muybridge’s photography of animal motion and amateur art by the author (some is distantly related to the front cover art). The central image, just above center, is B. F. Skinner. Other photographs, reading clockwise from noon: Bea Barrett and George Reynolds; the author with Eliot Shimoff during a classroom pigeon demonstration; Harvard’s Memorial Hall; the author in San Marco Square in Venice; Ivan Pavlov; Deisy de Souza and João Todorov; Terje Sagvolden as a speck in the distance taking a picture in the mountains near Tromsø, Norway; an infant in an Aircrib; Nat Schoenfeld and Fred Keller; Pauline Horne and Fergus Lowe; and Naoko Sugiyama with Koichi Ono and other Japanese scholars.