WARNING CONCERNING COPYRIGHT RESTRICTIONS

The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproduction of copyrighted material.

Under certain conditions specified in the law, libraries and archives are authorized to furnish a photocopy or other reproduction. One of these specified conditions is that the photocopy or reproduction is not to be used for any purpose other than private study, scholarship, or research. If electronic transmission of reserve material is used for purposes in excess of what constitutes "fair use", that user may be liable for copyright infringement.
The Evolution of Intelligence and Access to the Cognitive Unconscious

Paul Rozin
Department of Psychology, University of Pennsylvania, Philadelphia, Pennsylvania

I. Introduction ........................................ 245
A. Abstract ........................................ 245
B. An Example ....................................... 246
II. Adaptive Specializations ......................... 247
A. Introduction ..................................... 247
B. Food Selection ................................... 247
C. Imprinting ........................................ 249
D. Unusual, Inherited Memory Abilities ............ 254
III. The Significant Contribution of Prized Components ........................................ 254
IV. The Inevitability of Adaptive Specializations ........................................ 255
V. Accessibility and the Organization and Evolution of Intelligence ....................... 255
VI. Mechanisms of Increasing Accessibility ........................................ 256
VII. Increased Accessibility Applied to Human Function: Development, Disinhibition, and Psychology ........................................ 260
VIII. Language and the Acquization of Reading ........................................ 264
IX. Education and Accessibility .................... 273
X. References ....................................... 276

I. Introduction

A. ABSTRACT

In this paper, I shall consider intelligence as a phenotype, subject to the same biological principles and evolutionary forces as any other phenotype. As is the case with virtually all complex biological systems, intelligence should be organized in a hierarchical manner, out of component "subprograms." Within an evolutionary framework, these subprograms, which can be called adaptive specializations, usually originate as specific solutions to specific problems in survival, such as prey detection. These specializations, functionally defined, may be simple programs or circuits, or clusters of these, and may contain...

1 I thank Norman Adler, Henry Guttman, Elizabeth Rozin, and W. John Smith for helpful comments on the manuscript, and James W. Kalat for participation in the development of some of the ideas presented here. The preparation of this paper and some of the research reported in it were supported by National Science Foundation Grant GB 8013 to the author.
both plastic and prewired elements. They form the building blocks for higher level intelligence.

At the time of their origin, these specializations are tightly wired into the functional system they were designed to serve and are thus inaccessible to other programs or systems in the brain. I suggest that in the course of evolution these programs become more accessible to other systems and, in the extreme, may rise to the level of consciousness and be applied over the full range of behavior or mental function. Accessibility can be gained by establishment of a physical connection of one system to another or by duplication of one system's circuitry in another part of the brain by use of the "appropriate genetic blueprint. I maintain that the notion of accessibility, or levels of accessibility, is useful in understanding the development and duplication of intelligence, as well as its evolution. This paper is devoted to supporting and co-opting these claims and exploiting the implications of this position for a psychology of learning and education. It is suggested that part of the process of learning and education can be considered as bringing to consciousness some of the limited-access programs, the "cognitive unconscious," already in the head.

B. AN EXAMPLE

Karl von Frisch (1967) has described the remarkable system used by some species of honey bees to exploit food sources. Having discovered a food source (e.g., a clump of flowers), a bee remembers some of the surrounding landmarks and flies back to the hive. On the basis of information gathered on the flight to and from the source, the bee now has information on the distance from the hive to the food source and on the direction, measured as an angle with respect to the sun's position. This information allows the bee to return to the food source and also to communicate its location to other bees in the hive.

Since the sun moves across the sky in the course of the day, the bearing taken relative to the sun would be accurate for a particular time. But the bee brain, despite its pinhead size, contains mechanisms that can compensate for sun movement. It adjusts the angle with respect to the sun as a function of time, so that the flight from the hive to food would always be direct. In other words, the bee essentially has a set of astronomical (e.g., sun arc) data in its head, plus a "clock," as well as a scheme for relating these.

Even from this greatly oversimplified sketch of how bees locate food sources, one cannot help but be impressed by the complexity, adaptability, and appropriateness of this system. In a very reasonable sense, it is a type of intelligent behavior. This example suggests three general points: (1) the existence of adaptive specializations related to intelligence, (2) the important contribution of prewired components in intelligence, and (3) the inscrutability of adaptive specializations (that is, the limitation of use of the bee's impressive navigational communication abilities to certain well defined situations, such as food foraging). I shall consider each of these issues in turn.

B. Adaptive Specializations

A. INTRODUCTION

In the honey bee example, a variety of behaviors and capacities, some quite specific and complex, all fit together to accomplish the successful exploitation of a food source. The cluster of behaviors and capacities is quite comparable in origin and basic biological nature to other clusters contributing to survival in nonbehavioral systems, such as adaptations to conserve body water, regulate blood pressure, or manufacture red blood corpuscles. Since biologists refer to these latter clusters as adaptive specializations, I see no objection to extending the term to "behavioral clusters," such as the bee navigation system. Use of this term serves to put intelligence in a biological-evolutionary context, which psychologists rarely do. Faced with the discovery that the fearsome wolf bitch behaves in a tender and loving manner to her cubs, psychologists or other people are neither surprised nor at a loss for explanation. One can simply say that the circuitry or programs for both aggressive and nurturant behaviors exist in the wolf brain (or, for those behavioristically inclined, in the wolf's repertoire), but have separate connections and are activated under different circumstances. However, many have been reluctant to apply this same logic to intelligent behaviors. These can be viewed as specific adaptations to specific problems rather than as the outputs of a superior, undifferentiated "general intelligence system."

This general view, insofar as it stresses the fit between behavior and environmental demands, has been ably championed in modern times by the ethologists, particularly Tinbergen (1951), Lorenz (1965), and later Hinde (1970) and Mannion (1972) (see also Shuttleworth, 1971; Hinde and Stevenson-Hinde, 1973; Stettler and Hager, 1972, Rozin and Kallat, 1972). From my point of view, the critical notion is that all adaptive specializations, whether involving intelligent behaviors or red blood corpuscle manufacture, are successful attempts at problem solving. I would like to illustrate this point.

B. FOOD SELECTION

In the late 1930s and early 1940s, Curt Richter (1943) and his colleagues conclusively demonstrated the ability of the rat (Rattus norvegicus) to select
foods that would correct a variety of nutritional imbalances. This ability, of obvious value to an omnivore, seems for the most part to be accounted for by a unique adaptive specialization, which allows rats to learn what foods make them sick or well, and thus avoid or recover from almost any possible deficiency. The unique, real-world properties of foods and their metabolic consequences are clearly reflected in this system (Rozin and Kalat, 1971, 1972; Rozin, 1968).

In the real world, there tend to be causal connections between things that enter the mouth and events that occur in the gut or other viscera; this is mirrored in the rat by a strong tendency to "associate" tastes (e.g., as opposed to lights and sounds with gut events) and some other types of visceral events (Garcia and Koelling, 1966; Rozin, 1967; Garcia and Ervin, 1968). This has been called "belongingness" or preparedness (Seligman, 1970). Correspondingly, expectancies associate preferentially with extraceptive events, such as pain emanating from the skin. It would indeed be folly to associate the pain produced by stepping on a tack with what was just eaten (ratted).

In the real world, there is an inherent delay imposed by the digestive system between food ingestion and its metabolic consequences. In order to learn about the significant consequences of foods and thus avoid poisons, adjust amount eaten to energy needs, and select nutritious foods, a system would have to bridge this delay. And, in contrast to other systems, where close temporal contiguity between stimuli is a prerequisite to their association, delays of hours can support learning in the feeding system, involving associations between tastes (e.g., saccharine solutions) and visceral consequences (e.g., nausea) (Garcia et al., 1966; Smith and Roll, 1967; Rewak and Garcia, 1970; Rozin, 1969a; Rozin and Kalat, 1971).

Learning about the aversive (as opposed to positive) consequences of foods (e.g., poisons) occurs especially rapidly. Usually, one pairing of a new food with an aversive gastrointestinal event, even with delays of an hour or more, is adequate to produce a strong aversion which may be remembered over many trials.

In the real world of the rat, which might mean a garbage dump, there are often many foods simultaneously available. The special belongingness and long-delay learning mechanisms are built in themselves, capable of leading the rat to adaptive food selection in this complex situation. But they are complemented by some important, often built-in, aspects of the food selection system, which help sort out the various foods. The belongingness principle effectively limits the important stimuli to foods. The food world of the rat seems to be clearly divided into the familiar (experienced at least once) and the new. At any point in time, a rat may have already learned about the positive, neutral, or negative consequences of some of the available food. Needless to say, among such foods the rat avoids those that have aversive consequences. In the presence of new foods, in addition to the above, rats are quite suspicious, and eat primarily familiar, safe foods, especially if they have had previous aversive (poisoning or deficiency) experiences (Richter, 1953; Rozin, 1968). However, new foods are eventually sampled, rather tentatively, in a "testing" manner (Rozsa, 1953).

Rats are particularly inclined to associate new foods with "new" consequences. If a rat consumes a familiar safe food along with a new food, and then becomes ill, it subsequently avoids the new food rather than the familiar food (Rewak and Bedarf, 1967; Kalat and Rozin, 1973). The adaptive value of this feature should be obvious. When faced with a variety of new foods, the rat's natural feeding pattern confounds the complex situation. Rats tend to eat well defined "meals," separated by rather long time periods. Furthermore, within meals, they tend to eat only one type of food. Thus, by exposing themselves to one food at a time, they optimize the operation of the long-delay learning-belongingness abilities in evaluating the consequences of ingesting each food. Just as a normal rat's tendency to avoid new foods in the presence of safe foods is exaggerated in deficiency, the normal rat's tendency to sample one food at a time is exaggerated (Rozin, 1969b).

It should be clear from this brief description that rats come equipped with an impressive set of special learning abilities that dovetail neatly with natural feeding patterns to successfully solve the food selection problems and form a well-defined adaptive specialization.

C. IMPRINTING

In order to breed successfully, adult organisms must possess some form of species recognition and species-specific displays. Since identifying characteristics of any particular species are usually distinctive and very low in variability, a sensitive solution is to build in the appropriate perceptual recognition or performance system. However, for reasons that are not entirely clear, an important learning component, imprinting, appears in many species as a solution to the problem. The advantages of imprinting, no matter as it is almost foolproof, are that it can accommodate local variations within a species and may be more efficient in that it "saves" the genetic coding material that would be needed to completely specify the perceptual or behavior systems. The process will be illustrated by Marler's (1970) superb studies of the acquisition of species-specific song in white-crowned sparrows.

Adult white-crowned sparrows have a characteristic song, displayed in Fig. 1. Marler studied birds singing three different dialects of this song, depending on which part of the San Francisco area they came from (Fig. 1. A, B, C). The dialects are distinct, but all have the basic form of white-crowned sparrow song. In brief, Marler found that if birds were raised in isolation from
a few days after birth, they would not sing a well-developed white-crowned sparrow song when adult, but would sing a very crude song which had some of the basic structure of white-crowned sparrow song (Fig. 1D). If birds reared in isolation were exposed to tape recordings of a particular dialect of white-crowned sparrow song somewhere in the period of about 10 to 50 days of age, they would then sing in adulthood (more than 6 months later) the appropriate full-blown white-crowned sparrow song of the dialect they heard. If exposed to the same song outside of this critical period, they would behave like completely isolated birds, and sing only the crude song. If during the critical period, they heard both a dialect of white-crowned sparrow song and some other bird song, for equal periods of time, (Fig. 1, E and F), they behave just as the group that hears only the white-crowned sparrow song (Fig. 1G).

In short, this type of "learning" has three salient characteristics that differentiate it from most types of learning and are uniquely suited to the problem at hand:

1. It occurs during a critical period, early in life, when the probability is very high that the animal will be selectively exposed to the species song (or, in other cases of imprinting, other aspects of the parent). Clearly, later in life, exposure to other species is much more likely.

2. The set of stimuli on which the animal can imprint is constrained. Even with a close parental tie, a young animal is exposed to many stimuli other than those emanating from the parents. Thus, some focusing or narrowing down seems appropriate. In this case, only songs with the general structure of white-crowned sparrow song fit the crude song template in the bird's head, and thus can modify it. So the crude form is inherited, and the detailed form, including the particular dialect, is learned through imprinting.

3. The imprinted "memory" or template lasts for the life of the organism and is highly resistant to extinction. The young white-crowned sparrow flies around for 6 months or more without singing the song, hears very little of its own species song during the winter, and in its first autumns and the subsequent spring hears the songs of many other species. Yet, it sings a full-blown appropriate song by the following spring.

These specific characteristics are manifested only in certain behaviors; other types of learning in white-crowned sparrows are presumably not characterized by "templates," critical periods, and the like. The imprinting "package" is limited in application or accessibility to certain stimuli at certain times.

Furthermore, the female white-crowned sparrow, who does not sing, seems to develop a sensory representation of its appropriate dialect, so that it can recognize local males. This representation or template is apparently temporally unavailable to the motor system. However, after injection with testosterone, access is achieved, and the appropriate dialect is sung (Konishi, 1965).
D. UNUSUAL, ISOLATED MEMORY ABILITIES

There are a number of instances of outstanding memorial achievements in species far from distinguished for their learning or memory capacity. These include, in addition to the bee already referred to, the memory of salmon for their home-stream odors (Hader, 1966) and the memory of digger wasps (Ammophila campestris) for the location and state of food supply of a number of holes containing its eggs or larvae (Berenbroek, 1941; described in Tinbergen, 1951). Usually in such cases, in the life pattern of the species, there is one problem requiring memory for stimuli that cannot be genetically programmed, since the particular stimuli depend on characteristics that vary in different localities. For example, Aronson (1951) has shown that certain gobid fish can find their way from one tidepool to another, at low tide, by jumping accurately over rocks. Random jumps would harm them or leave them stranded on rocks. In fact, the fish behave without error. Aronson eliminated obvious sources of direct sensory information on the location of neighboring pools. Furthermore, when placed in an unfamiliar pool, the fish will not jump. It appears that during high tide, the fish swims about and into the rock crevices and forms an accurate map of the area, which is stored in memory and utilized at low tides.

III. The Significant Contribution of Prewired Components

Most of what the bee does in navigation and communication is mediated by built-in circuitry. Representations of the basic features of the sun arc and possibly other astronomic variables, plus the clock mechanism, seem genetically determined in that they are independent of specific early experience and constant within races of a species. Obviously, the particular location of the sun with respect to today's food source is given by experience. Furthermore, given changes in the sun arc both with season and with the latitude at which a particular bee happens to find itself, it would be folly to genetically program the specific parameters of the arc. In fact, some experience observing a piece of the sun arc is critical to adequate navigation (Lindauer, 1961). However, the bee need not have direct experience in a particular part of the day in the past, in order to orient correctly to food when first released at that time. By and large, it seems that those aspects of the system (including the communication code and fundamental anatomical principles) which are quite constant are prewired, while those that vary from day to day contain a more plastic, experiential component. In this system, environmental input often has the function of calibrating a prewired system.

The division between experiential components and genetic programming is seen most clearly in the navigational systems of some fish (Hader and Schwansman, 1960), which are also based on orientation to the sun. In one species which lives in only one hemisphere, the direction of sun movement across the sky is genetically coded within the navigational system. In a related species that straddles the equator, the direction of sun movement is not presupposed, but is acquired by experience.

When intelligence is viewed in the context of problem solving, the relative importance of genetic and experiential components in the solution depends on the type of problem. Each has inherent advantages. Experience does not necessarily provide more successful or more complex solutions.

The bee example represents a class of adaptations that have been described by Lorenz (1965) as "calibration of aiming mechanisms, adjustment of computers, and setting of internal clocks." I shall use the term calibrational learning for all these, meaning to imply that there is an elaborate prewired system, which is capable of producing fairly precise adjustments of an animal to its environment. The main function of environment, experience, or memory, in these instances is to provide reference points, so that the precise function inherent in the organism can be calibrated. Calibrational mechanisms tend to be found in navigational, homeostatic, and perceptual systems.

Space perception in humans provides an example of such a system. When displacing prisms are worn, subjects misjudge the location of unseen targets when they reach for them with their hands. This makes sense, since the elaborate "isomorphism" between points in visual and kinesthestic space (that is innate or acquired) has been systematically disturbed. What is remarkable (Harris, 1965) is that, after only a few minutes of reaching practice, the subjects can reach accurately. Brief "practice," lasting minutes and involving possibly only a small portion of the total visual and kinesthestic fields, may lead to a general readjustment of relationship between the arm and the eye. It is as though two "maps" of the world each remain intact, but were sliding with respect to each other. This can easily be described as a recalibration.

The contribution of prewired circuitry to the complex behaviors that we often describe as intelligent has been generally understated. This may result, in part, from emphasis by American learning psychologists on a few powerful and well-documented learning paradigms, in which plasticity has a dominant role, and the contributions of complex prewired circuitry are not salient. The bee navigation example is at the opposite extreme: the "intelligence," or, for that matter, "intense" in the phenomenon comes largely from the prewired circuitry. If a full astronomical table were built into the bee, so that environmental calibration was not required, the bee's behavior and its underlying mechanism would be just as fascinating and would certainly still seem intelligent.

Most animal components with a plastic component fits somewhere between the extremes of traditional learning paradigms and calibrational phenomena. The adaptive specializations already described illustrate some of the various types
of interactions of plastic and preserved components. For example, the pre-wired crude song template in the white-crowned sparrow is critical a component of song learning as the plastic mechanism that shapes it into a specific dialect.

In short, the biological framework espoused here and by the ethologists allows for a wide variety of plastic mechanisms, and a wide variety of interactions between them and prewired circuitry. The only limitations are what is feasible, given the properties of the basic neuronal building blocks, and the constraints of a gradual evolution in which intermediate forms must be expected to have some selective value.

IV. The Inaccessibility of Adaptive Specializations

Adaptive specializations, by their nature as solutions to specific problems, tend to manifest themselves only in the narrow set of circumstances related to the problem that directed their evolution. The same genetically brilliant bees may perform poorly in a simple conditioning experiment and do not show highly sophisticated computerized capacities in all other types of behavior. For most of a bee's problems, the navigational system would be of little use, so that it might be an evolutionary waste of resources to program the "hardware" to make it generally available. In other words, bees cannot use their navigational computer for other purposes, nor is it possible that Boeing 747's cannot roll over on the ground. There are no advantages for certain capacities in certain contexts. Similar restrictions in accessibility would hold for the white-crowned sparrow's template matching machinery, the goby's visual memory, and the rat's long-delay learning system. I describe this restrictive feature of adaptive specializations by saying that they are inaccessible to other systems. As I will indicate later in this paper, that concept of inaccessibility, and the understanding of the circumstances under which inaccessible programs can be made accessible, of central importance in psychology and biology.

A particularly clear example of inaccessibility comes from low-level inferential systems in visual perception. Highly complex and sophisticated, "intelligent" systems seem to pervade the visual system. These systems are inaccessible to consciousness and are probably tightly wired into the visual system. Much of their sophisticated circuitry would appear to be built in. The phenomenon of size constancy is an example. The fact that a given object appears equal in size at different distances from the eye, and hence with different-sized retinal images, requires a rather complex explanation. It can be partially explained as a compensation mechanism that trades off distance and retinal size reciprocally. This, of course, requires a measure of retinal size.

which seems straightforward enough, and a measure of distance or depth, which is arrived at by a complex process (Hochberg, 1973). One factor in the calculation of distance is convergence: the angle between the major axes of the two eyes varies (becomes larger) with the closer the object, since the image of the focal object projects on the fovea of both retinas. Hence, a measure of convergence could supply distance information, and with retinal size information, lead to a size-constancy effect. Such a compensatory system could well be built in, at least it appears to be operating in children of 70-85 days of age (Bower, 1964). However, experience must play some role, if for no other reason than that the interocular distance (critical in determining amount of convergence) obviously increases with age, and therefore must be recalibrated.

In fact, a full determination of depth involves many factors other than convergence, such as texture, texture occlusion (how much of the texture or "grain" is occluded by the object), aerial perspective, familiar size. Familiar size is clearly a close that heavily involves experience. Only acquired knowledge of the "real" size of an object can account for its suitability in size constancy to an unfamiliar object. In some complex way, various depth cues, such as those listed above, combine into a total distance estimate. Weighted against retinal size, and influenced by familiar size and other factors, the result is size constancy. The whole elaborate information gathering and evaluation process, and others like it, were named "unconscious inference" by Helmholtz (1867). Clearly, this system is inaccessible to consciousness and "tightly wired" into the visual system. Otherwise, how could it be that classical training of artists involved, in part, "learning the rules for portraying depth which are actually the depth cues themselves" (Hochberg, 1973).

Another example comes from the perception of motion. When subjects observe an illuminated dot on the circumference of an invisible and rotating circle, the path of the dot appears to be forward moving and "bounding" off an invisible floor (see Fig. 2, top) (Wallach, 1959). If now the same movement sequence of the dot is repeated, but with a light at the center of the circle, the dot on the circumference, describing the same objective course, is interpreted as rotating around the hub of a wheel (Fig. 2, bottom). Thus, in a complex way, contextual information is integrated to provide a reasonable, relatively simple, and consistent interpretation of a pattern of objective movement. This, and many other examples from perception of motion (Hochberg, 1973) imply the operation of systems which take many factors into account, integrating over space and/or time, and usually resulting in a consistent, unitary perception. The processes involved are clearly inaccessible (again, Helmholtz's unconscious inference), and seem to be geared toward deciding on the simplest interpretation of an array.
V. Accessibility and the Organization and Evolution of Intelligence

The notion of accessibility leads to a theory of the organization and evolution of intelligence. Since all reasonably complex animals have quite a few sophisticated circuits or programs (adaptive specializations) in their brains, I suggest that a major route to increasing flexibility and power over the environment, surely hallmarks of intelligence, would be to make these more generally available or accessible. This would have adaptive value when an area of behavioral function could profit from programs initially developed for another purpose.

Using a computer analogy, it is as though there are specific circuits wired to only certain inputs and/or outputs. Thus, only numbers entered into a certain register might activate the addition program. If this program were now connected to other inputs (made more accessible), the additive power of the machine would be extended. Similarly, if separate addition and logarithmic conversion circuits in the same computer could be connected to each other, a multiplication ability would emerge.

I call all the specific, tightly wired, limited-access machinery in the brain the cognitive unconscious. Part of progress in evolution toward more intelligent organisms could then be seen as gaining access to or emancipating the cognitive unconscious. Minimally, a program (adaptive specialization) could be wired into a new system or a few new systems. In the extreme, the

program could be brought to the level of consciousness, which might serve the purpose of making it applicable to the full range of behaviors and problems.\(^7\)

Intelligent function, in this scheme, is conceived in terms of a hierarchy, in which specific components become available to more and more systems. As Simon (1967) has pointed out, complex systems should almost always be hierarchical, since it would be extremely difficult to build (or evolve) them otherwise. A single error in the nonhierarchical assembly of a complex system could destroy the whole system, whereas in a hierarchical system, only the subcomponent involved would be destroyed. For this reason, as Simon points out, the watchmaker who assembles component sections of the watch, and then joins these together, is much more likely to end up with a watch than his competitor who sequentially assembles the whole thing. If the second watchmaker drops the watch at any point, he is likely to have to begin all over again. In organic evolution, there would be yet further pressures for hierarchical organization, since each subcomponent must not only be stable, but have some adaptive value. The watchmaker need not worry that a particular assembled component on his bench have any time-keeping properties.

Given that behavioral adaptive specializations exist, it seems natural that these stable systems should be components in more complex systems. And indeed, one often sees common mechanisms at work in different behavior systems. How much more reasonable that the common elements in such systems were "invented" only once, and simply reapplied (accessed) in other situations.

The increased-accessibility view of the evolution of intelligence contrasts with the general-process view, which probably has more adherents among American learning psychologists. In this view, intelligence is considered in

---

\(^7\)Jeronim's (1975) interesting ideas on the evolution of the brain and intelligence, although focused on interpretation of changes in brain size, make potential contact with the view presented here. He sees intelligence and related measures of brain size as related to complexity of information-processing capacity and ability to construct a satisfactory model of the real world. This involves, among other things, interpretation of the major sensory systems. He makes the point that the reptiles, largely visual animals, perform a great deal of their visual processing peripherally, that is, in the eye (what I would call a place rather inaccessible to other systems in the brain). The originally nocturnal mammals relied more on other sensory systems, such as audition, with processing carried out more centrally. With invasion of diurnal niches, some groups of mammals (e.g., primates) utilized visual information much more, but continued much of the visual processing, on the model of audition. In Jeronim's view, the location of all these programs for vision, audition, etc., within the same part of the brain facilitated integration of the systems. In the terms used here, the coarticulation of visual processing allowed mutual accessing of the auditory, visual, and other sensory systems.
terms of learning capacity, and the evolution of intelligence as gradual accretion of new learning capacities (Bitterman, 1965).

One critical contrast between the two views hinges on the importance of new abilities, for the adaptive specialization-accessibility view focuses on reappraisal of old abilities. It seems unlikely that a new capacity, at its inception, would be broadly available, as implied by a general process view, since broad availability involves more connections, programming, and recognition than would be necessary. Under the reasonable assumption that environmental problems are usually the immediate selecting force for a particular ability, the simplest, most efficient, and least disorganizing approach would be to wire the new circuit into the relevant program.

Another critical contrast between the two views concerns the emphasis Bitterman and others place on learning as the critical component in intelligence. Although "plasticity" is clearly a fundamental component of intelligence, as argued above, it is only one component. Consider an animal with an enormously complicated built-in program to handle one specific problem. It might advance greatly in power (intelligence) if it could apply that sophistication to another problem. This application might involve a learned or evolved connection into a new system. However, from the point of view of intelligence, the new program being accessed would be at least as interesting as the process of accessing it. In the same sense, plugging one computer program into another is not adequately described by examining the plug. The adaptive specialization-accessibility view sees traditional learning as one of a wider set of plastic mechanisms (e.g., calibration mechanisms) sensitive to environmental factors, which, in varying combinations with genetically determined programs, leads to successful solutions to problems.

The accessibility view causes difficulty for traditional attempts to arrange animals on a ladder of increasing levels of intellectual capacity. Looking at peak performance, for example, bees come out extremely high. To say the "mammals" have a "ladder" that the "fish" climb is dangerous. First, it arbitrarily selects skills of importance within the framework of traditional learning theory as critical determinants of intelligence. Second, it assumes that, because some fish do not show a particular type of learning in a situation selected by an experimenter, they are incapable of such learning. Clearly,

* A more general difference between the two classes (as inferred from a small sample of species) is suggested by recent work (e.g., Perd and Gonzalez, 1974). Some fish (and one reptile) species show a very simple and straightforward relationship between magnitude of reinforcement and the strength of reinforced behavior. For example, resistance to extinction increases as the magnitude of reinforcement in training increases for goldfish and one turtle species (Chrysemys picta picta), while resistance to extinction decreases in rats and other mammals studied under the same circumstances. This finding, and some related findings on contrast effects have led Perd and Gonzalez (1974) to suggest that "... the behavior of fish is regulated in terms of the strict principle of reinforcement (Fish ... Thorndike ...)." According to this principle, reward acts directly to strengthen the functional connections between stimulus and response; whereas the behavior of rats is regulated in terms of the learning about and subsequent anticipation of reward.

However, this conception must be qualified by the observation that learning about foods (taste-aversion learning, see Section II,8) in rats seems to fit more with the simpler "fish" model. It does not show some of the higher-order effects (e.g., "blocking") which are seen in other areas of rat learning and have led to the view of the rat as an anticipator of events or information processing (Selman, 1970; Selman and Hager, 1972; Kalat and Rodin, 1972). Nonetheless, a modified distinction of the type described by Gonzalez and his colleagues may hold true: phenomena requiring notions like anticipation or expectancy may not be found in the polychomatic vertebrates.

* A more general difference between the two classes (as inferred from a small sample of species) is suggested by recent work (e.g., Perd and Gonzalez, 1974). Some fish (and one reptile) species show a very simple and straightforward relationship between magnitude of reinforcement and the strength of reinforced behavior. For example, resistance to extinction increases as the magnitude of reinforcement in training increases for goldfish and one turtle species (Chrysemys picta picta), while resistance to extinction decreases in rats and other mammals studied under the same circumstances. This finding, and some related findings on contrast effects have led Perd and Gonzalez (1974) to suggest that "... the behavior of fish is regulated in terms of the strict principle of reinforcement (Fish ... Thorndike ...)." According to this principle, reward acts directly to strengthen the functional connections between stimulus and response; whereas the behavior of rats is regulated in terms of the learning about and subsequent anticipation of reward.

However, this conception must be qualified by the observation that learning about foods (taste-aversion learning, see Section II,8) in rats seems to fit more with the simpler "fish" model. It does not show some of the higher-order effects (e.g., "blocking") which are seen in other areas of rat learning and have led to the view of the rat as an anticipator of events or information processing (Selman, 1970; Selman and Hager, 1972; Kalat and Rodin, 1972). Nonetheless, a modified distinction of the type described by Gonzalez and his colleagues may hold true: phenomena requiring notions like anticipation or expectancy may not be found in the polychromatic vertebrates.

* The possibility of placing learning paradigms within the accessibility framework was suggested by Richard Katz (personal communication).
laboratory. It is presumably for this reason that these basic paradigms seem to describe general learning processes. On the other hand, one may find clear instances of this type of learning only in specific, well defined situations in other groups of animals, such as insects. These paradigmatic learning properties may initially appear as adaptive specializations in well defined situations, and become more generally accessible in mammals. The emphasis of the ethologist on the confinement of learning to specific situations may come in part from their concentration on groups other than mammals, in contrast to the psychologists, who came up with general learning "laws" based primarily on the study of mammals.

One could be led to conclude, as Schwartz (1974) has suggested, that "It is odd, but perhaps reassuring, to think that by studying the behavior of pigeons in arbitrary situations, one learns nothing about the principles which govern the behavior of pigeons in nature", but a good deal about the principles which govern the behavior of people." The Skinner box presents a type of "abstract" task in which "manipulated" humans can perform well, since they can apply many programs over a wide variety of situations. Strangely enough, then, the adaptive specialization notion leads to a definition of intelligence along the lines of concrete (limited, specific applicability) to abstract. This concrete-abstract dimension is reminiscent of what many psychologists mean by intelligence. In some sense, it is a measure of accessibility.

VI. Mechanisms of Increasing Accessibility

Let us consider only extending the domain of a program. X, tightly wired into a system A, into a new system B. There are two ways in which X is represented in such an organism: first, as a genetic blueprint and, second, as a set of circuits in the brain. In evolution, one way to extend X to B is to reducticate the X circuit in conjunction with the B system. That is, the program for execution of a given circuit must exist in the genome of every cell, and hence in every part of the nervous system. Although we do not know, in any detail, how a neural circuit unfolds under the guidance of a genetic program, we can be reasonably confident that a genetic blueprint, coded into units like operons, exists, and can be repressed or released in the appropriate environment. Under this view, a specialization (circuit) could be extended by releasing (or derepressing) the appropriate genetic program at the appropriate time in the appropriate neural context. Such extensions have probably occurred many times in the evolution of organisms.

Without such a mechanism, one would be forced to assume that such frequently utilized adaptations as feedback or homeostatic control systems were repeatedly created de novo. Surely, such a widespread mechanism should become generally accessible through the process of genetic reductication.
important form of learning and an important mode of increasing accessibility. It is discussed below in Sections VIII and IX, with particular reference to acquisition of initial reading skills.

There are, then, at least two models for increased access: an evolutionary mechanism, based on duplication of the physical program itself in development by appropriate activation of the genetic blueprint, or preservation of a single physical program, and increasing connections to it by genetic programming or acquisition in the course of an individual lifetime.

VII. Increased Accessibility Applied to Human Function:
Development, Dissolution, and Pathology

The hallmark of the evolution of intelligence notion put forward here is that a capacity first appears in a narrow context and later becomes extended into other domains. This seems to be a quite reasonable interpretation of cognitive development as described, for example, within a Piagetian framework. The general Piagetian scheme (Piaget, 1955; Flavell, 1963) involves movement from concrete to abstract, which means, in this context, specific inaccessible to general-accessible. Thus, programs are at work in the young child which are not yet usable in all situations, available to consciousness, or usable. In the adaptive specialization framework, one would expect a gradual extension of a specialization, first to additional concrete situations, with a possible ultimate extension into consciousness (abstract conception). Piaget represents just such a process, using the term dédoublement to describe it. Thus, conservation involves the logical capacity that "appreciates" the notions of reversibility (if A = B then B = A) and compensation (reciprocal relationship between measures such as height and width of a vessel, which incidentally bears an obvious parallel to the star-distance trade-off in size constancy). This "program" is initially only accessible in the limited domain of numbers. At age 6, children understand that there are the same number of marbles whether spread out or clumped together, but cannot yet apply the same logic to water vessels of different shape, or equivalent clay masses of different shapes. Gradually through the process of horizontal décalage, the "conservation circuitry" extends through mass to volume conservation and finally to area conservation. In general, then, in early stages, intelligence is manifested as unconnected, separate capacities. In support of this type of conception, Lewis and McGurk (1972) comment in a recent review: "... infant intelligence is not a general, unitary trait, but is rather, a composite of skills and abilities that are not necessarily covariant" (p. 1176). Through development, the capacities are extended and connected together. In the final Piagetian stage of formal operations, some capacities become fully emancipated and hence conscious and storable. It does appear that, in this case, ontogeny recapitulates phylogeny.

J. Huggins Jackson (1884) has pointed out that neuropathology has regressive consequences, so that the dissolution of function tends to mirror its evolution and development. This relationship seems to appear most clearly in cases where brain function is systematically depressed, as in ataxia, myelination or atrophy. Within the framework discussed here, dissolution could be seen as loss of access to the most recently "acquired" programs. Indeed, a few studies of the dissolution of cognitive function in senility suggest a gradual return to the limited Piagetian capacities of the child, with the order of disappearance (loss of access) roughly reversing the order of appearance (de Aujarosa et al., 1964; Feldman et al., 1975). There are also reasons to believe that, in recovery of function, the ontogenetic sequence is respected; for example, the stages of development of food and water ingestion and regulation systems in the infant rat clearly parallel the stages of recovery of these same functions following damage to the lateral hypothalamus (Teitelbaum et al., 1971; Teitelbaum, 1973).

Some of the puzzling achievements of savants, or children for that matter, are easily understood within an accessibility framework. For example, the linguistic fluency of both in the face of poor logical-cognitive function is easily interpretable as the function of a language system disconnected from much of the rest of intelligence-generating circuitry. In general, neurologists disagree as to the extent to which the pathology of higher mental function results from destruction of programs or processing centers as opposed to disconnection of intact systems. Certainty both must occur, but Geschwind (1965a,b) has argued persuasively that many cognitive deficits consequent on brain damage can be explained by disconnection of processing centers, which translates into loss of access. A clear example is a variety of acquired alexia [originally described by Dejerine and recently confirmed by Geschwind (1962)]. In the few cases on record, there is sudden loss of ability to read, associated with blindness in the right visual field, but normal visual perception in the left visual field. The lesion, produced by occlusion of a cerebral blood vessel, involves extensive destruction of the left occipital cortex and destruction of the posterior portion of the corpus callosum. The result is that the intact occipital cortex has been cut off from its principal connection to the linguistic hemispheres, and processing of orthographic material is blocked. The loss of capacity in this case, is not loss of processing centers as much as loss of access. Disconnection syndromes, or loss of access, are particularly common, as pointed out by Geschwind (1965a,b) because the fiber tract connections between brain areas are much more compact than the brain areas themselves. Hence, the tracts are more easily compromised by spatially
contiguous lesions, as produced for example, by strokes, bullets, or tumors. Thus, loss of access may be a primary expression of pathology.

An example of this, in addition to acquired amnesia, is the frequent preservation of short-term memory, as measured by digit span, in the face of severe cognitive regression in senility (see Rosin, 1976b, for a general discussion of this issue). The failure of digit span to regress to childhood levels while other functions do can be puzzling, since the superior digit span of adults may be partly attributed to intelligent functions, such as grouping or organization. After all, digit span is part of many standard adult intelligence tests, and correlates rather high with other, more common-sense measures of intelligence. A loss of access view explains this phenomenon by assuming that senility has not resulted in elimination of organization-chunking and other intelligent processes, but rather their confinement to a narrow area of function, which may include some short-term memory processes.4

VIII. Language and the Acquisition of Reading

The usefulness of the notion of levels of accessibility, and some problems it raises about the process of education, will be discussed in these final sections on language and reading.

Human language is an adaptive specialization. It is particularly valuable for my purposes because it highlights the notion of inaccessibility, since learning to read involves gaining access to parts of the language system. Language has been in use for tens of thousands of years in our species and obviously serves many adaptive functions. It is remarkable how this incredibly complex system, which describes facts with a special academic field for its study, seems to develop so easily in almost all members of the species. After 4 to 5 years of life, without explicit organized instructions, children demonstrate remarkable linguistic facility. They are able to generate new sentences that they have never heard, and understand complicated constructions. Only in the last few decades have linguists made major advances in unravelling the phonological, syntactic, and semantic principles underlying this performance. That is, the rules of sentence production or comprehension, which are obviously present in the head of virtually all 5-year-olds, have escaped a satisfactory description for thousands of years. Language seems to be represented by a sophisticated set of program in the brain, which is inaccessible to conscious reflection.

4 There are other instances of loss of access in normal function. Forgetting itself is often described as loss of access. The process of automatisation may be another example. Highly practiced tasks or capacities (e.g., perception of letters in words, bicycle riding), though often acquired in terms of well-defined units, become smoothly perceived or executed routines, in which the components are ultimately difficult to recover. In some cases, these component skills may have lost their access to consciousnes.

[Although not entirely inaccessible, even in children—see Gietman et al. (1973)] It is indeed striking how a child who cannot appreciate the simplest logical relationships, such as overlap of classes, can show high level mastery over this incredibly complicated system. The precocious linguistic performance of children has prompted a number of leading investigators to assume that, with respect to language function, there is a considerable amount of innate prestructuring in the brain (Chomsky, 1965; Lenneberg, 1967).

Much of the evidence favoring an important role for genetic determination in human language, and for language as an adaptive specialization, has been reviewed by Lenneberg (1967). The major lines are as follows.

1. The complexity of linguistic behavior far outstrip other sorts of conceptual behavior in children.

2. The biological-genetic regularity of language development: Early language development unfolds in a pattern quite similar to motor development (e.g., walking), that is, as though it were a maturational phenomenon (Lenneberg, 1967). The universality of certain features of all languages (e.g., existence of word categories, such as noun or verb) and the regular development in stages support a highly biologically determined system.

3. Specializations in speech production and reception: Certain anatomical features of the human speech production (Liberman, 1973) and speech reception systems (Liberman et al., 1967) seem to have been specially and uniquely evolved to handle material like speech.

4. Hemispheric specialization for language: Data from split-brain and other patients have demonstrated that a significant portion of linguistic function, most clearly that having to do with speech production, usually lies in only one cerebral hemisphere (Sperry et al., 1969; Gazzaniga, 1970; Milner, 1973; Levy, 1974). Thus, we can talk about a physical location for some of the circuitry. Geschwind et al. (1968) have reported a patient who suffered severe brain damage, which resulted in destruction of the brain tissue surrounding the area in the left hemisphere that receives language. This patient was a talking machine; he would repeat everything said to him, yet there was no evidence that the material presented made any contact with any nonspeeching functions. Therefore an anatomically identifiable functional speech receptor and production system exists. It can perform the incredibly complicated task of converting the pattern of sound waves representing a particular utterance, as represented in the auditory system, into a set of "equivalent" commands to the articulatory apparatus.

5. A final argument for language as an adaptive specialization has to do with the inaccessibility of the phonological system. I will discuss it below, in the context of understanding reading.

It is striking that reading, unlike speech, is rarely acquired spontaneously, and almost always requires systematic and extended instruction. More inter-
eating is the fact that many children who master English speech without any apparent difficulty have great difficulty in learning to read. Yet reading seems to be much the easier task: spoken language mastery has already occurred, and the only problem for English speakers seems to be learning an additional mapping of some 26 symbols onto the already learned sounds of speech. Reading is a very new event in our species, since writing is at most 5000 years old, and literacy was an accomplishment of a very select few until this century. Valuable as reading skill is now, one could say that it has not yet had time to emerge as an adaptive specialization. My thesis is that reading the English alphabet involves gaining access to the phonological system, which is tightly wired into the auditory-speech system. The problem then is accessing the phonological system: pulling it out of the cognitive unconscious, or at least connecting it somehow into the visual system (this view is expressed in Rozin and Kalat, 1972; Gleitman and Rozin, 1973a, b, 1976; Rozin and Gleitman, 1976; Mattingly, 1972; Savin, 1972; Liberman et al., 1974). One might ask what aspects of the phonological system are so hard to connect into the visual system? Since writing systems have unfolded in an historically orderly way, this order might be a clue to the different components of reading and writing, and the relative complexity of each (Gelb, 1952). Earlier systems are varieties of "picture writing" schemes (scriptography) in which ideas rather than words are represented (e.g., "man eat corn" would be represented by a picture of a man eating corn). Later, schemes for the representation of the words of speech (logography) by characters with some visual resemblance to the meaning of the word were invented (e.g., "man eat corn" would be represented by the sequence of pictures: man eat corn). This type of logographic system is approximated by present-day Chinese and has the critical characteristic that the sound of the language does not mediate between the orthography and the meaning. Later systems of writing gradually became more and more dependent on the sound stream of speech (a process called phoneticization). In earlier stages, the unit of the sound stream represented in writing was the syllable. Many syllabaries were developed independently in ancient times (e.g., Sumerian cuneiform), and some exist today. According to our best information (Gelb, 1952), the alphabet, which essentially maps a smaller unit of speech, the phoneme, was invented only once and spread from its Mediterranean origin to much of the world (see Gleitman and Rozin, 1976, for an extended discussion of this material). Logographic systems do not require mapping into the sound system of speech, so according to this view they should not be terribly difficult to learn. After all, learning to assign the same "car" to a certain shaped thing in the real world and "dog" to a different thing is not very different from calling one written character car and another dog. In fact, this appears to be relatively easy for children: almost all children easily learn at least a few words by sight. Even children having great difficulty learning to read English can easily learn a substantial number (30) of Chinese characters and their English spoken translations (Rozin et al., 1971). In fact, many inner city children in the third or fourth grade, after years of schooling in reading seem only to have learned a modest number of whole words and their spoken equivalents, even when taught by "phonics" methods. The main difficulty seems to arise at the level of phoneticization, and in the particular unit or level of phoneticization. Lila Gleitman and I believe that the major problem concerns the level of the unit of phoneticization: the alphabet maps into phonemes, and these units are deeply embedded in the specialized speech system. Evidence for this position comes from two quarters: speech perception and reading instruction. For a more extensive discussion of these issues, see Gleitman and Rozin (1973a, b, 1976); Rozin and Gleitman (1976), Mattingly (1972), Savin (1972), Liberman et al. (1974), and the volume edited by Kavanagh and Mattingly (1972). Recent work, done largely by Liberman and his colleagues at the Haskins Laboratory (Liberman et al., 1967) indicates clearly the nature of the problem. The work shows that contrary to what might be called common sense, the sound stream of speech is not divisible into separate elements (phonemes) that correspond to the separate alphabetical letters. There are not, in other words, three separate or separable sound events in the spoken word bag. It does appear that in the organization of the speech system in the brain there are three separate elements in the word (see Fig. 3) bag. According to Chomsky and Halle (1968) and others, at the deepest level these are represented as "systematic phonemes," which become converted through a series of rules peculiar to the particular language, into sequential commands for b, a, and g, which are sent down from the brain into the articulatory apparatus. However, the musculature of the mouth, pharynx, etc., responds sluggishly, so that, for example, the g command arrives in the mouth while the muscles are still following the a instruction. Furthermore, the shape of the vocal cavity, which largely determines the quality of the sound, will be quite different when the g command arrives in the word bag as opposed to big, so that the same g command to the same set of muscles will produce different events in the mouth. As a result of this (see Fig. 3), the isolatable phonemes of the articulatory commands overlap in a complex way in the sound stream. Liberman has referred to this overlapping effect as "shingling." What the reader of the alphabet must learn is that at some underlying level, represented in the phonological system but not clearly in the sound stream, speech utterances can be segmented to the phonemic level. And yet this segment cannot always be clearly illustrated, since some consonants cannot be pronounced in isolation. Thus, for example, the stop consonants like d or p.
cannot be pronounced without appending a weak vowel, called the schwa, yielding *duh or *puk. Children are often instructed to blend the word dog, for example, by combining the three elements, *duh, *uh, *guk. If they dutifully follow instructions, they will get *duh-uh-guk, no matter how fast they blend. This can be shown by combining the three segments on a tape recorder and playing them rapidly. The reason is simply that there is no schwa in dog. The *d command does different things to the mouth in the context of a following uh or o command. This can be seen in Fig. 6, which shows the sound patterns necessary to produce two common English syllables, *di and *du. Note that there is no clean break—corresponding to the *d and *i or *u.

One might think that one could extract the *d of a tape of the *di syllable by clipping off the *i. If this is tried, by gradually cutting off the end of the tape, one hears a shorter and shorter *i in *di, and then suddenly a chirping sound which has no particular resemblance to speech. There is no pure *d isolated in the sound stream. Furthermore, it is extremely difficult to understand, on the basis of examining the sound patterns of various syllables with initial *d, for example, what common characteristics lead to the perception of *d (Liberman et al., 1967).

But our speech system is built to make just such categorical phoneme distinctions. The upshot of the Haskins work is that the smallest sound unit

FIG. 3. Scheme for the production of speech sounds. This display is a representation of what happens at the various levels in the speech system during the utterance of a single syllable *bang. Time is represented on the horizontal axis, and levels of the speech system (from mental command to articulatory movement) are represented vertically. The figure illustrates two fundamental transitions in speech production. The first is the transition from commands to the articulatory apparatus from the brain (top level) to the actual movements in the articulatory apparatus (middle level). Note that separate commands for each of the three phonemes in *bang are assumed to be sent down from the brain, in the appropriate temporal order. At this level, the phonemes are articulatory. These commands interact in a complex way with the speech apparatus, depending on the previous state and further anticipated states. A second transition from gesture (movements of the articulatory apparatus) to sound adds much complexity and shaping, since it is the shape of the oral cavity and other such features that determine the characteristics of the sound uttered. The net result of the two transitions is a complex sound pattern (bottom level), in which the three basic phonemes can no longer be isolated, because of overlapping (Liberman, 1970).

Evolution of Intelligence

FIG. 4. Sound patterns sufficient to produce the perception of the syllables *di and *du. The abscissa (horizontal axis) represents time in milliseconds. Thus the time taken for the utterance of *di is about 300 msec, or 0.3 second. The ordinate (vertical axis) represents the frequency of sound in cycles per second. The dark bands on the graph represent the presence of energy at the indicated frequency and time. Thus, for the syllable *di at all but the beginning 50 msec consists of two steady bands of acoustic energy, one at a few hundred cycles per second, and one at about 2400 cycles per second. The first 50 msec consists of a gradual die in frequency to the level of the two steady frequency bands. As indicated in the text, it is tempting to assume that the initial 50 msec, involving changes in the two basic frequency, represent *d. However, if only three segments of the sound are perceived, people hear a "hat chirp," not resembling *d at all. If more sound is added, including some of the two steady frequencies, the bird chirp abruptly changes to a short *d. Note also that the sound patterns at the beginning of the two syllables look grossly different, even though both are heard by the listener as the same sound category, *d. The sound spectrograms (visual representations of sound patterns over time) shown here are idealizations. They do indeed sound like the appropriate syllables to the human ear, but the actual utterance of these sounds by humans is much more complex. The bands shown in this figure actually form the axes of relative concentration of sound energy (Liberman, 1970).
that is relatively context independent and separately pronounceable is the syllable. Although the two sounds in to cannot be separately pronounced and easily blended, the two syllables in today are both easily pronounced and blended.

A second line of evidence for phoneme inaccessibility comes from reading research. Reading teachers are aware of the difficulty of getting children to blend phoneme "sounds" into recognizable words, or getting children to understand that dog and dig start with the same sound. Children have great difficulty in understanding this notion, even though they have no trouble discriminating words like do, dig, pip, and big. This has been shown nicely in an experiment by Blank (1968). She confirmed a previous finding that children with reading backwardness performed poorly on the Wepman test (1948), in which a child must judge whether two consecutively spoken words were the same or different. The word pairs either differ in one phoneme (e.g., web-web) or are the same. Children who claimed that particular pairs of different words were the same were later asked to repeat these same words when each was spoken by the experimenter. They made the appropriate responses, clearly distinguishing, in this imitation task, between words that they had claimed were the same. Clearly, they could hear the differences, but not tell about them.

![Diagram](image)

**FIG. 5.** Conceptual outline of the syllabary curriculum. In the first stage, artiodacty-
ology, children learn to interpret pictures and thus get to meanings directly from the
page. In the second stage, logography, they learn picture-symbols that stand for words and
construct simple sentences with them. In the third stage, phoneticization, direct
orthographic representation of the sounds of speech rather than the meanings is intro-
duced. Attention is called to sound segmentation of speech by a "speaking slowly"
game, in which long words are broken into syllables and pronounced slowly (e.g., bun-pair). The children must guess the word they hear. To exemplify the idea that
symbols represent sounds, they play a nonsense game. A few odd and entertaining
noises (such as "clucking" with the tongue or whistling) are each given a
symbol equivalent. Children then learn to read off symbol sequences by making the
proper noise sequences. Refuses (e.g., can, awl) are used to emphasize the use of words
for their sound value. Blends of two words (syllables) that form new words are also
introduced in a game format. In the fourth stage, an English syllabary consisting of
about 70 common English syllables and the words made by blending these syllables, is
introduced. Whenever possible, pictorial symbols are provided along with the written
form of each syllable to help in identifying and remembering them. However, for some
of the more abstract items (e.g., or, the), no pictorial aids are provided for obvious
reasons. Children progress through this syllabary primarily by playing word
construction games with the syllabic elements and reading 15 progressively more difficult story books.

The segmentation cues separating the syllables are gradually made less salient (see also
Fig. 6). Once some fluency in this syllabary is gained, the fifth stage, introduction to the
alphabet, begins. Alphabetic (phonemic) elements are introduced gradually, beginning
with initial s, a sound relatively easy to pronounce in isolation. It is blended onto the
already learned syllabic elements (Rustin and Gitlinman, 1974).
The notion that phonemes are less accessible than syllables is supported by data on different orthographies. Syllabaries have been invented many times in history whereas the alphabet seems to have been invented only once (Galb, 1972). This implies that syllabic segmentation is easier to discover. There are also reports of rapid and easy acquisition of current or recent syllabic orthographies. The Cherokee language, written in the last century in syllabic notation, was widely read; literacy rates in the Cherokee compared favorably to those of neighboring white settlers (Walker, 1969). A significant part of modern Japanese is written as a syllabary, mixed with Chinese-type logographic characters. It is striking that there is virtually no reading disability in Japan (Sakamoto and Makita, 1973). Furthermore, the syllabic aspect of Japanese writing is often learned spontaneously by preschool Japanese children (Sakamoto and Makita, 1973).

In light of these considerations, Lila Gleitman and I (Gleitman and Rozin, 1973a,b; Rozin and Gleitman, 1976) have tried to introduce English reading by recaptulating the history of writing, moving from accessible to inaccessible. We have devised a curriculum (outlined in Fig. 5) in which we begin with semasiography; children learn to interpret pictures that represent an action or story, thus gaining meanings directly from the pictures. We follow this with construction of simple sentences from iconic symbols (logography), then introduce the idea of phoneticization with rebuses and other devices, and then move from accessible sound units (syllables) to inaccessible ones (phonemes) (Gleitman and Rozin, 1973a; Rozin and Gleitman, 1974). Children learn to read and blend common English syllables before introduction of phonemic units. Thus, they learn about phoneticization (e.g., the rebus) and the notion of building large sound units from smaller ones. They practice this by learning to read a simple English syllabary. Only after they have understood the notion of phoneticization and can fluently blend syllables, are they exposed to the more abstract alphabetic-phonemic units. (The conceptual stages of this syllabary curriculum are illustrated in Figs. 5 and 6.) We can report that inner-city first grade children with a poor prognosis for reading can acquire the basic skills of syllable blending and reading of syllabic materials quite readily (Rozin and Gleitman, 1976; Gleitman and Rozin, 1973a). This success presumably occurs because we have separated three components (phoneticization, blending, and the phonemic units) which are ordinarily taught simultaneously. A syllabary avoids the abstract unit problem, and concentrates on phoneticization and blending. But since our writing system is alphabetic, and English does not lend itself to transcription with a modest number of syllables, we are still faced with the ultimate problem of the accessibility of the phoneme. Note that this problem is not inherently related to the writing system: it could as well be described in terms of speech.
segmentation (see Rosner, 1972). And it is a problem for which we do not have a ready solution. We know of no basic principles of learning that offer helpful guidance in achieving access to something that is already in the head.

We only know that almost all nonreaders do not have access to the phoneme concept, whereas virtually all literate readers of English have achieved it, and in fact, consider the principle so obvious that they find it difficult to believe that it is a stumbling block in reading acquisition.

IX. Education and Accessibility

Difficulty with teaching the conception of the phoneme raises the general issue of the role of access to the cognitive unconscious in the process of education. The need to learn what is already in the head, as is the case in reading acquisition, seems to arise often in education. For example, teaching the rules of grammar, which are at best imperfect representations of a much more sophisticated system actually in the head, can easily be described as art in part expressions of the normal, though usually unconscious, operation of the memory, which spontaneously organizes and connects presented materials.

In general, what is taught in the process of education can be described as either gaining access to knowledge already in the head, or revealing relationships in the outside world (i.e., understanding the Copernican system). Since a significant amount of learning seems to be about what is already inside, it would seem worthwhile to describe the circumstances and principles underlying access to the cognitive unconscious. To my knowledge, the problem has not been stated in this way before, so it is not too surprising that there have been so systematic attempts to solve it. The physiology or psychology of learning, memory, or cognition may address this problem as such. Yet it seems to be quite fundamental; it is, possibly, a different type of learning. It of course resembles what is sometimes called generalization and transfer, but differs in that the reference material or ability, instead of being put into the brain by a training procedure itself, is part of the basic unconscious of the brain.

In the absence of systematic theoretical guidance, common sense appears to be the best short-term guide in dealing with actual problems in education. It was basically common to that of the linguists and myself to approach the problem of access to the phoneme the way we did. We attempted to isolate the access problem, by separately teaching related concepts that did not involve this difficulty (phoneticization and blending). By teaching a more concrete and accessible reading system, we hoped to provide motivation in children, as they would experience success in one type of reading system. We presumed that whatever happens in access to the phoneme, time spent attending to the problem would favor acquisition. After all, most children do seem to gain access by the time-honored procedure of “practice makes perfect!”; that is, steady drill, often of the form of babble box. But most critically, we assumed that the way to approach the small and abstract unit was through a more concrete, more easily comprehensible unit which shared many properties with the inaccessible unit. The approach was to gradually approximate the phoneme, using a syllabic base, and to go from the most context insensitive phonemes to those phonemes least pronounceable and most context dependent. In this respect, our program is similar to Rosner’s (1972) independently devised approach of phonological awareness. Rosner has dealt directly with the sound segmentation problem and does not involve writing—reading at all in teaching this fundamental concept. As we do, he moves from concrete to abstract. Children begin by imitating patterns of sound, such as hand claps, which have clear boundaries and definitions. He then moves the children through smaller units, from words through syllables to phonemes. Children deal with these materials in a variety of ways, including repetition of patterns and manipulation of patterns. For example, they are asked to repeat patterns deleting an element: ‘Repeat /I am home without home, or repeat all without the sound. This sensible procedure seems to have had some success in increasing ability to deal with alphabetic—phonemic units (Rosner, 1974).

There is other support for the general efficacy of movement from concrete to abstract to achieve increased accessibility. It comes from the area of clinical neurology and was called to my attention by Philip Teitelbaum. I have pointed out that both phonemic segmentation and recovery of function can be described as instances of increased access. If this parallel holds (see Teitelbaum, 1973, for a discussion of recovery—development parallels), then the principles of recovery of function and the techniques used to achieve it may become relevant to reading and other educational processes. A study on recovery of independent finger movement in people with spastic paralysis is particularly instructive (Lauretana et al., 1959). Marked improvement has been produced by facilitating movements that the patient is incapable of making on his own. For example, at one stage, patients can flex all fingers simultaneously, but cannot flex individual fingers. Individual fingers of the patient are extended, thus facilitating flexion (via the stretch reflex) in these particular fingers. It is not surprising that with this aid the patient can flex individual fingers. What is surprising is that this exercise significantly facilitates recovery. Teitelbaum (1973) has described this procedure as facilitating the highest intact center in a damaged hierarchy. This notion provides a new and refreshing approach to the process of education, using recovery of function as a model. Adapted to reading acquisition, it maps onto the procedure I have described: working at the most abstract unit the child can
handle, and practicing at this level, while constantly probing the next level. This is one sensible approach to solving the problem. It may or may not work. If it works, its mechanism of operation will have to be understood.

Meanwhile, we can patiently wait in the hope that more of the secrets locked in our cognitive unconscious can be harnessed to serve our daily intellectual lives.

References


Paul Rozin

Evolution of Intelligence


