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Human Embryos, Development of Human Specific Behavior, and Personhood: A Biologist's View

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The 21st century biotechnologies of human embryonic stem cell (hESC) use, therapeutic cloning (TC), and preimplantation biopsy (PB), give fresh urgency to defining personhood. Is it morally acceptable to destroy 5-day-old human blastocysts to cure disease, repair injured tissue, or prevent birth defects? In his 1486 essay "On the Dignity of Man," Pico della Mirandola expressed a view of human nature that can help us in our deliberations about personhood. Pico maintained that the capacity for moral choice-making is what distinguishes humans from other creatures. This view suggests that our use of biotechnology ought to respect and protect humankind's choice-making capacity. Examination of a set of attributes necessary for choice-making shows that it emerges gradually between 5 weeks after fertilization and 10 years after birth. By this analysis, blastocysts cannot be persons, and hESC use, TC, and PB do not violate personhood. Possible criticisms of this analysis are acknowledged.

A diversity of ethical problems is raised by 21st century biotechnologies like cloning, embryonic stem cell use, genetic engineering, extending human life spans, and neuropharmacology. Satisfying solutions to some of the problems will require a consensus on questions about the nature of humanity and the condition of personhood. With a few exceptions, biologists I know do not normally contemplate these issues during a normal day in the laboratory or university classroom. Maybe this is because solutions to such nonfigurative questions are not viewed to be answerable by science. In the United States it may also be due in part to an educational system that does little to encourage cross disciplinary thinking. Whatever the reasons for the compartmentalized thinking in many disciplines, the time has come to apply interdisciplinary approaches to the problems of human nature and personhood which for centuries have been treated primarily as the property of philosophy, art, and theology. Certainly, these ways of knowing are essential for a holistic understanding of our species. But the evolutionary origin of our species demands that generative thinking about human nature and personhood also incorporate information from the sciences including the multitudinous subdisciplines within biology, psychology and anthropology. After all, *Homo sapiens* and its 6-7 million year old bipedal primate cousins share an ancestry with thousands of other extant and extinct mammals whose bloodlines are linked to the therapsids, mammalian-like reptiles that lived 220 million years ago. Unfortunately, our thoroughly animal lineage has frequently been underappreciated or straight-out denied by clergy, legislators, and others whose ideas and work are influential in defining for us who we are. Now that 21st century biotechnologies endow us with an unprecedented capacity for self-sculpting, the need is urgent to develop balanced, realistic, and practical approaches to discovering who we are and what we wish to become. My aim in this essay is to apply an interdisciplinary approach to answering a well-defined question about the moral status of early human embryos. The question is whether 5-day-old and earlier stage human embryos ought to be dignified with the status of "personhood."

I begin with a presumption about the concepts of personhood, dignity and moral worth. My presumption is that these qualities are conferred upon human beings by other human beings. I do not deny that a supernatural Creator may also do this, but I do not assume it. My intent in defining personhood as a state or trait conferred upon us by ourselves is to avoid the pitfall of presuming to know which Creator is preeminent in the realm of personhood and what She/He/It had in mind when assigning it.

I consider the ideas presented here to be works in progress. They are not exhaustively described or argued to tight completion. My hope is that they will convince readers of the value of interdisciplinary approaches to difficult theoretical problems in need of solutions with real life applications. I like to think that my approach to and conclusions about personhood differ from those of most theologians in that they are undogmatic and open to criticism and correction. Similarly, I like to believe that they differ from those of most philosophers by being comprehensible to non-philosophers. Finally, I maintain that my approach to the personhood question promotes respect for the diversity of views that exist on this subject.

What I wish to say comes in six parts:

1) definitions of some key terms,

2) descriptions of three specific biotechnologies and how they raise the issue of personhood,

3) an overview of varying criteria that have been used for identifying *Homo sapiens'* uniqueness among other creatures and/or personhood for certain of its members,

4) some information on a young philosopher of the Italian Renaissance, Pico della Mirandola, his view on human nature, and how this might inform 21st century views on personhood,

5) application of Pico's view on human nature to the personhood problem raised by the above three biotechnologies, and

6) acknowledgment of some problems and unfinished business for this analysis.

Definitions

Definitions are important. In the majority of articles and books I have read about personhood, terms like embryo, human life, human being, and person are either undefined, used differently by different authors, or even used differently within the same work by the same author. Also, incorrect use of the term fetus by some writers has encouraged some to mistakenly believe that embryonic stem cells are derived from tissue of aborted fetuses. Confusion can be avoided by beginning with clear definitions of these terms.

Human life refers to any cell or group of cells that is alive and possesses a functioning human genome. By this definition, human cells of any type growing in a culture dish constitute human life, as would an egg, a sperm, a fertilized egg, and cells, tissues, organs, and individuals from any later stages of development. Human cells to which one or a few genes from a different species have been added and functionally integrated into the intact human genome would also constitute human life. What proportion of an engineered genome must be human in order for the cell to qualify as human life is an interesting question but not germane to this discussion.

Human being designates an organism that belongs to the species *Homo sapiens*. By "organism" I mean a cell or group of cells with interdependent parts that can exist autonomously in its environment. This definition includes individuals we may call persons, but it may not be limited to persons. The fertilized ovum is a human being by this definition, and so too are entities at all stages of prenatal development, whether inside the womb or in a glass culture dish. All living postnatal *Homo sapiens* are human beings including those who are asleep, otherwise unconscious, comatose (with or without life support apparatus), or without memory. By contrast, a severed toe is not a human being, but the entity that loses an appendage remains a human being since it constitutes an autonomous composition of interdependent parts.

Human embryo and ***fetus*** both refer to prenatal human beings. *Embryos* exist at stages of development from fertilization through the end of organ formation which is at about 8 weeks. Thereafter until birth the entity is called a *fetus*, a term that also implies that the being is beginning to look like the adult form of its type.

Person I reserve for human beings upon which dignity has been conferred. One property of dignity is the right to continued existence. It is a bit embarrassing as a biologist who recognizes the continuity between all living things and the dynamic nature of species to be restricting personhood to *Homo sapiens*, and the problems with doing so have been clearly described (Kushe and Singer, 1986; Tooley, 1998). My defense is to say that I do not feel like a "speciesist" on the personhood issue and that it is primarily for expediency in discussing the moral status of human embryos that I have made persons a subset of human beings here.

Three Specific Biotechnologies

Recent advances in cell biology and human reproductive biology raise the questions of what criteria are to be used for conferring personhood and when human beings first meet these criteria. Although not a new problem, it now needs discussion and a practical resolution with an urgency that matches the rate of biotechnological advances in these disciplines. This essay addresses three specific biotechnologies that make personhood an urgent issue for very early human embryos: 1) the derivation of human embryonic stem cells from 5-day old embryos, 2) therapeutic cloning, and 3) pre-implantation embryo biopsy. How does each of these technologies bear upon the human embryo and for what purpose?

Human Embryonic Stem Cells. In November, 1998, James Thomson and his co-workers at the University of Wisconsin reported having used cells from 5-day old human embryos to establish human embryonic stem cell lines that retained the ability to differentiate into several types of adult cells and tissues. The therapeutic potential of human embryonic stem cells for treatment of diseases like Type I diabetes, Parkinson's, Alzheimer's, and congestive heart failure and to repair tissue damaged by stroke, heart attack, or spinal cord injury was immediately recognized. Before such therapies can be performed though, much research is needed to discover how to induce human embryonic stem cells to develop along specific pathways of differentiation to give rise to specialized cells like neurons, cardiac muscle cells, and insulin-producing pancreatic cells. Prior to 1998 most Americans had never heard of embryonic stem cells or cell lines. Now six years later the terms are much more familiar, but my experience is that there is widespread confusion about their meanings. Since an understanding of the origin and basic nature is of human embryonic stem cell lines is crucial for evaluating the argument I will present here, let us now consider properties of 5-day-old human embryos and how Thomson and others have created embryonic stem cell lines from them.

By 5 days after fertilization, the human embryo is at a stage of development called the *blastocyst*, a group of about 150 cells a bit smaller than the head of a pin. The blastocyst is a miniature, hollow ball of cells containing a small mass of nondescript cells, the *inner cell mass*, growing against the inside wall of its hollow interior. Implantation during a normal pregnancy results in the blastocyst becoming attached to the inner wall of the uterus. Ultimately, cells of the single-cell layer thick wall of the blastocyst give rise to the fetal component of the placenta, and the *inner cell mass* grows into the fetus. To obtain human embryonic stem cells, the inner cell mass is removed from the blastocyst, placed in a glass or plastic culture dish, and its cells disaggregated and grown in a nutrient-rich culture medium. Cultured in the laboratory like this, the cells appear to be able to proliferate indefinitely producing more and more cells like themselves. The cells are then referred to as an embryonic stem cell line, all of them being derived from a single blastocyst. Presently about 20 lines of human embryonic stem cells are available in the United States for federally funded research. A presidential decree in 2001 banned production of any additional human embryonic stem cell lines. The reasons cited were that 1) using blastocysts in this way shows or encourages disrespect for human life, and 2) enough stem cell lines were already available for research. Research funded by the private sector was not affected by this ban. Consider now how human blastocysts come to be available for human embryonic stem cell research.

At in vitro fertilization (IVF) clinics, eggs are fertilized in glass test tubes. The resulting embryos are grown to the blastocyst stage outside the womb in preparation for their introduction into a hopeful mother's uterus for implantation. For each attempt at assisted reproduction by IVF, several more embryos than needed for one implantation procedure are produced. This is to help insure that at least 3-5 healthy appearing blastocysts are available for implantation (all normally do not successfully implant), and also to have available additional embryos should the first implantation attempt not result in a pregnancy. Surplus blastocysts are put into suspended animation by freezing them in liquid nitrogen. They can then be retrieved and reanimated from their frozen state if they are needed for additional attempts at implantation. Tens of thousands of unused, surplus embryos are presently in frozen storage at IVF clinics in the United States and around the world. After a period agreed upon by the clinic and its clients, surplus embryos are removed from storage and discarded. The 2001 ban on producing new human embryonic stem cell lines did not address the eventual fate of surplus blastocysts stored at IVF clinics.

Therapeutic cloning. In February, 2004, South Korean researchers reported the successful cloning of a human being to the blastocyst stage and from it the derivation of a line of hESCs. The motivation for this successful experiment was to aid in development of a procedure called therapeutic cloning. The experiment involved replacing the chromosome-containing nucleus of a woman's egg cell with the chromosome-containing nucleus from a somatic (body) cell form another individual, activating the egg cell to begin undergoing DNA replication and cell division, allowing the embryo to develop to the blastocyst stage, and then using the blastocyst to derive a line of human embryonic stem cells as described above. The clinical value of this procedure is that the resulting embryonic stem cells and any cells derived from them are perfectly immunologically compatible with the individual from which the somatic cell nucleus was taken. Introduction of such cells into that individual for the treatment of disease or injury would not elicit a rejection response, so there would be no need to chemically suppress the immune system as part of the treatment. As for normal human embryonic stem cell research, therapeutic cloning requires the destruction of a human blastocyst to obtain an inner cell mass for the production of embryonic stem cells.

Pre-implantation biopsy. It is now possible to quickly test for the presence of certain disease-causing genes by biopsy of an early human embryo created *in vitro*. A single cell can be removed from a pre-implantation stage embryo for genetic testing without disrupting the future development of the embryo because of the great developmental plasticity of the cells during the early stages of embryogenesis. This procedure is called pre-implantation biopsy and is now used primarily by couples in need of assisted reproduction by IVF. This could change though if the expense of IVF were lowered so that it becomes a feasible option for couples simply wishing to exert some control over the genotype of the embryo that becomes implanted. Recently it was reported that fetal biopsy can now detect several hundred genetic diseases and other conditions that some may consider to be handicapping, like deafness and dwarfism (Harmon, 2004). Pre-implantation biopsy makes possible a future, widespread selection and discarding of blastocysts based on genotype, a "pre-implantation eugenics." Such a practice would of course be accompanied by its own ethical issues that are not subjects of the present discussion.

Relevant to us here is the fact that all three of these biotechnologies - human embryonic stem cell production, therapeutic cloning, and pre-implantation biopsy - bring up the question, "Is the blastocyst a person?" Therefore, let us consider next what characters might warrant the conferring of personhood status upon certain human beings.

Criteria for Human Uniqueness and Personhood

Since "person" has been defined here as a subset of *Homo sapiens*, surveying approaches and criteria that have been used to identify what makes us different from other animals, perhaps deserving of some special dignity, is of value in the attempt to discern when a human being meets the criteria for personhood. Finding more than 30 criteria for human uniqueness mentioned by authors from diverse disciplines, I examined the list to see if it might be systematized in some way. I found that each of the putatively human-specific traits could be classified under one of three approaches primarily used to identify it: evolutionary, comparative, or pre-suppositional.

The ***evolutionary approach*** considers biological/anatomical (material) and/or behavioral (activity) traits that appear to distinguish human ancestors in the hominid line from non-hominid primates. Among the biological/anatomical traits identified by this approach are bipedalism, cranial capacity, dentition, an opposable thumb, a lowered larynx, a developed Broca's area of the brain, the presence of a frameshift mutation in the MYH 16 (myosin heavy chain type 16) gene, and the structure of the ASPM (abnormal spindle-like microcephaly) associated gene. The last two of these are especially interesting applications of molecular/cellular biological studies to problems in human evolution and offer possible explanations for *Homo sapiens'* large and complex cerebral cortex.

Hansell Stedman and his coworkers at the University of Pennsylvania have reported evidence that a muscle protein localized exclusively to the jaw muscle of primates was inactivated by a mutation occurring in the hominid line about 2.4 million years ago, just shortly before a dramatic increase in the cranial capacity of *Homo erectus* that occurred about 2 million years ago. Stedman hypothesizes that inactivation of this gene resulted in a sudden and dramatic decrease in jaw muscle mass, relieving powerful forces that had been exerted on the brain case at the muscle insertion points. With less force on the brain case, the way may have been opened for the evolution of a larger, more gracile cranium whose increased volume became filled by cerebral cortex material. This finding is of special interest since a consensus has developed that certain behavioral traits associated with humanness have as their basis a species-specific development and functioning of the cerebral cortex.

Bruce Lahn and his colleagues at the University of Chicago have reported what one journalist has proclaimed as "the gene that made us human" (Evans et al., 2003; Zorich, 2004). The ASPM (abnormal spindle-like microcephaly associated) gene, when mutated in humans, results in microcephaly, a condition characterized by an abnormally small cerebral cortex (Bond et al., 2002; 2003). The gene is also present in other primates and non-primate mammals, but in humans the specific structure of the gene seems to have been under selective pressure to produce a protein whose function results in a human sized cerebral cortex (Evans, et al., 2003). Although the specific action of the protein product of the human ASPM gene is not fully understood, the function and locality of expression of homologous genes in developing Drosophila and mice has led to the suggestion that is may be involved in regulating prenatal cell division in the developing cerebral cortex (Evans et al., 2003).

Among the behavioral traits that an evolutionary approach has identified for humanness are tool use/making, fire use/building, foresight, speech, language, culture, a "killer" instinct, cooperation within social groups, religion, art, and altruism. Whether each of these is a uniquely human trait is controversial, but a discussion of those arguments is not necessary unless one of the ambiguous criteria like tool use or language is selected as a definitive marker for personhood. Since I do not do that, we can move on to the other two approaches.

The ***comparative approach*** focuses on differences between modern humans and other contemporary species. Within this approach I categorize traits as being either biological, behavioral, or metaphysical in nature.

Modern cell biology has also made a contribution here. That the cellular basis for humanity's uniqueness may have been found is implied by the title of a lead article appearing in the New York Times' *Science Times*, "Humanity? Maybe It's in the Wiring" (Blakeslee, 2003). The article reports the finding by John Allman and his colleagues at the California Institute of Technology that giant, cigar-shaped neurons called spindle cells occurring primarily in the right frontoinsular cortex may be responsible for processing information used to respond to complex, socially emotional situations associated with feelings like romance, deception, and embarrassment. Humans have 5-40 times as many of these cells than do the living great apes, the the only other species known to possess spindle cells (Allman, et al., 2003).

Behavioral based traits considered by some to place us apart from other contemporary animals include the ability to empathize or "othermindedness," our possession of non-momentary interests, emotion, art, a capacity for beliefs or propositional attitudes, intentionality, an awareness that we are subjects of mental states, problem-solving ability, or a moral sense (Doran, 1989).

Due to their abstruseness, I have placed two human distinguishing traits in the metaphysical category. The first of these is ensoulment in the sense as first proposed by Aristotle. Although one now rarely sees Aristotle cited in the context of human soul acquisition, I mention his ideas here because of the great influence they had on later Christian thinking. Aristotle proposed that during early development, humans sequentially acquire three types of souls, a vegetative soul which makes us alive, a sensitive soul which allows for animal-like sentience, and a rational soul which makes us human. Aristotle believed that the rational soul appeared in the fetus at about 40 days after conception. For Aristotle, who of course did not know about eggs and sperm, conception was the time at which the semen encounters menstrual blood, thereby imparting life to it. As it turns out, were this event actually to occur, its timing would not be far off from the moment of coalescence of the genomes of male and female gametes into one zygote nucleus, the marker now used by biologists for "fertilization." The second abstruse, human-defining trait is consciousness. It is difficult to find clear and concise definitions of what is meant by human consciousness as distinct from animal consciousness, but it is sometimes described as having a sense of self with an existence moving through time and an interest in the continuation of that existence (Kuhse and Singer, 1986; Tooley, 1983).

With the ***presuppositional approach*** it is presumed at the start that humans are deserving of dignity and that this assumption requires no justification. The questions then become, "When during development does this dignity kick in, and once conferred, can it be lost?" Criteria for dignified humanness that I view as presuppositional include theologically based ensoulment, individuation, the onset of electroencephalogram (EEG) detected brain waves, viability, and birth.

Regarding ensoulment, it is interesting to note that in the 13th century, St. Thomas Aquinas concurred with Aristotle that ensoulment occurred at 40 days of development, but only for male fetuses. Strangely, Aquinas believed ensoulment of females was delayed until 90 days after conception. Presently, the official Vatican position is that all human embryos from conception onward ought to be treated as though they have been ensouled by God and possess full moral status.

Individuation is a developmental event marking the point beyond which one and only one individual can result from subsequent embryogenesis and fetal development. This event occurs at the so-called primitive streak stage of development about 14 days after fertilization, the point beyond which the embryo can no longer spontaneously split to form identical twins. Salesian priest, theologian, and philosopher, Norman M. Ford, has suggested that the embryo be given full moral status at the primitive streak stage because of the phenomenon of individuation (Ford, 1988).

Viability is the criterion for personhood cited in the 1973 U.S. Supreme Court decision in the Roe vs. Wade case and is set at the end of the second trimester of pregnancy. Coincidently, this is also a time marked by adult-like patterns of EEG activity (Morowitz and Trefil, 1992) and a dramatic increase in the rate of synapse formation between neurons of the cerebral cortex (Purpura, 1975; Rakic et al., 1986).

The above listing contains only some of the bewildering array of criteria that have been suggested for marks of human uniqueness or claiming special moral status for human beings among other living creatures. Examining this list with the issue of personhood raised by modern biotechnologies in mind, I found it difficult to commit to any one or even a cluster of the criteria as a satisfying marker for personhood. Many are no longer considered human-specific, and others have become so controversial as to preclude reasonable hope for their consensual international acceptance. It was then that I thought of an essay that my colleagues and I have assigned for many years to our students in an interdisciplinary history course. The essay is titled *Oration on the Dignity of Man.* It was written by a 23-year-old philosopher of the Italian Renaissance named Giovanni Pico. He is better known as Pico della Mirandola because of his northern Italian village of origin, Mirandola.

Pico della Mirandola (1463-1494)

Pico's view of human nature can be very useful to us today as we move into the uncertain ethical world of 21st century biotechnology. In fact, it is the essence of human nature that Pico describes in his *Oration, our capacity for choice-making*, that I propose using as a basis for personhood when faced with certain dilemmas about the ethical use of modern biotechnologies.

It is legitimate to ask why I chose Pico as an authority on human nature rather than one of a score of other philosophers who have written since Pico on the question of human nature and personhood. Primarily, I chose Pico because his view emerges from a diligent and respectful study of virtually all of the philosophical, theological, literary, and mystical traditions of humankind knowable to him. It is inclusive thinking like this that is needed if we are to reach a consensus about how to behave in today's biotechnological world.

How Pico came to write his famous essay is an interesting story. He was obsessed with understanding the diverse paths humankind has taken toward wisdom and self-understanding. As a teenager, he began arming himself with the tools needed to gain such understanding. These included a reading knowledge of Greek, Latin, Hebrew, Arabic, and Aramaic, and facility with canon law. He used these tools to teach himself about the pagan philosophies of ancient Greece and Rome, Neoplatonism, the writings of the Greek and Latin Church fathers, 13th and 14th century scholasticism, Averroism, the Hermetic and Orphic texts, and Jewish philosophy, theology, science, and mysticism.

His lifelong project was to identify the threads of truth coursing through each of the world's diverse traditions and to weave these into a unified synthesis of human insight and wisdom spanning two millennia and representing all of the religious and philosophical thought known to the West. His ultimate objective was to foster peace between the world's traditions by reconciling their insights, one with another.

The major outcome of these studies was the formulation of 900 theses (Farmer, 2003) which Pico proposed to defend in Rome during the winter of 1486-1487 against any and all philosophers, theologians, or other scholars willing to debate them. Leaving few scholarly disciplines untouched, the subjects represented by the propositions included metaphysics, moral philosophy, astrology, physics, numerology, theology, magic, epistemology, physiology, and several others. This extraordinary debate was to be held before the college of cardinals with Pope Innocent VIII presiding as judge. Although the debate never took place, the reason being another story in itself, Pico did prepare a speech to open the debate. It is that speech that we now know as the essay, *Oration on the Dignity of Man* (Pico, 1486). In Pico's *Oration* is this famous paragraph that states his view on human nature. In it God is speaking to Adam in the Garden of Eden, explaining to him how he differs from all other creatures.

We have given to thee, Adam, no fixed seat, no form of thy own, no gift peculiarly thine, that thou mayest feel as thine own, have as thine own, possess as thine own the seat, the form, the gifts which thou thyself shall desire. A limited **nature** *in other creatures is confined within the laws written down by Us. In conformity with thy free judgment, in whose hands I have placed thee, thou art confined by no bounds; and thou wilt fix limits of nature for thyself...Neither heavenly nor earthly, neither mortal nor immortal have We made thee. Thou, like a judge appointed for being honorable, art the molder and maker of thyself; thou mayest sculpt thyself into whatever shape thou dost prefer. Thou canst grow downward into the lower natures which are brutes. Thou canst again grow upward from thy soul's reason into the higher natures which are divine. (Translation by Charles Glenn Wallis)*

Here we have a Renaissance humanist and world philosopher promoting the notion that humans are co-creators of themselves. There is little doubt that Pico had the Christian God in mind as the other artisan in co-creation. But, in my view, whether God or natural selection is placed as the co-creator opposite humankind in its own creation is not what is important in Pico's thought. What is important is that we recognize ourselves as equal, if not major, partners in co-creation. Both the species and each individual have been endowed with a capacity for choice-making-the former some 100,000 years ago, and the later fairly early in life. How we use that capacity to sculpt ourselves as a species and as individuals is up to us. That is what Pico is telling us. And just what kind of choices does Pico have in mind when proposing that *choice-making* distinguishes us from all other creatures? I feel confident that it is not the kind of choice a humming bird makes when it visits red flowers and not white flowers, or the "decision" of a Baltimore oriole to nest in the high branches of an oak rather than on the ground. Those are instinctual acts, "confined within the laws written down by Us," and not really choices at all. The human-specific choices attributed to Adam by Pico are moral choices derived from "thy soul's reason." These are behavioral choices we make that effect, among other things, our own and others' quality of life and the stability and beauty of the planet itself.

From Pico's view that a capacity for choice-making is at the core of human nature, I derive the following principle: *Our use of biotechnology ought to respect and protect the choice-making capacity of human beings and of humankind.* How can this principle be applied to the issue of the moral status of the human blastocyst, the problem at hand for each of the three biotechnologies described at the beginning of this essay?

Applying the Pico Principle to 21st Century Biotechnologies

Acceptance of the capacity for choice-making as a useful criterion for personhood requires asking what attributes a human being must acquire in order to possess a choice-making capacity. To answer that question, I suggest the following abilities as necessary components of a moral choice-making capacity: 1) gathering sensory data, 2) storing those data, 3) selectively retrieving data, 4) analyzing data to imagine outcomes for various paths of action, and 5) applying reason, emotion, and empathy to choose the desired outcome.

When does this constellation of capacities develop? One thing that can be said with certainty is that all of these abilities do not develop at once. In fact, based on current information from the disciplines of human developmental biology and psychology, it appears that the biological hardware necessary for having at least a capacity to exercise these five abilities at some point in time is assembled during a period beginning at about 5 weeks after conception and extending for about 10 years into postnatal development. For example, sensory neurons from the olfactory apparatus first establish synapses in the developing brain at 5 weeks into prenatal development (Larsen, 2001), marking the first establishment of the hardware required for gathering some sensory data. Spindle cells of the prefrontal cortex implicated in data storage and retrieval begin appearing at about 4 months into development, and the proliferation of cells that form the cerebral cortex also begins at about this time, presumably under the control of ASPM gene activity. Data analysis requires communication between neurons in the cerebral cortex, and the intra-cortical synapses needed to mediate this are forming at an exponential rate between weeks 25 and 32 of prenatal development (Morowitz & Trefil, 1992). A fully functional brain requires that its nerve axons be myelinated. Myelination begins during the second trimester of prenatal development, occurs at its most rapid rate after birth, and is not completed until the child is about 10 years old (Morowitz & Trefil, 1992). Awareness that one has a future is needed in order to apply foresight to the decision-making process, and that awareness is thought not to begin until about two years after birth. "Other-mindedness," or the capacity for empathy occurs even later during the 3rd of 4th year of postnatal life.

So, if a capacity for choice-making is taken as a useful criterion for personhood, and if that capacity emerges gradually between 5 weeks of prenatal development and 10 years of postnatal life, what can be concluded about personhood and the moral status of the human embryo? I offer the following: 1) at the least, a nascent choice-making capacity is required for conferring personhood on a human being, and 2) prior to 5 weeks of development, the embryo cannot qualify for personhood.

These conclusions may appear very minimal and of questionable value since they do not specify a beginning point for personhood; however, in the context of the three biotechnologies described earlier, they are very useful. They allow a decision to be made about the moral status of the human blastocyst and therefore about the ethical status of stem cell research, therapeutic cloning, and pre-implantation biopsy. Since not even a nascent choice-making capacity is present prior to 5 weeks of prenatal life, the use of the 5-day old blastocyst in these technologies does not violate the dignity of personhood.

This is not to say that other ethical issues are unimportant. Indeed, many other ethical issues associated with these biotechnologies would remain to be resolved even if a consensus could be reached on the personhood issue. What should be the source of blastocysts for research? Of eggs for therapeutic cloning? Who shall benefit the most from the development of these technologies into actual clinical procedures? What will be the cost for bringing the technologies into the clinic? Can the cost be justified when millions of persons worldwide experience malnourishment and starvation and when three children die each minute from malaria, all under circumstances that could benefit from monies applied to research and other activities aimed at improving the human condition? Still, if the present analysis helps to resolve the personhood problem for early embryos, emotional and intellectual energies may be freed to devote to addressing these additional issues. Finally, although my analysis of personhood and the moral status of the human embryo are vulnerable to criticisms which space prevents me from addressing here, I must nevertheless acknowledge their existence.

Problems Remaining to be Addressed

Three problems that need addressing in order to undergird the value of this analysis of personhood for human embryos are 1) the so-called "is-ought" dichotomy and the associated "naturalistic fallacy," 2) the question of free will for human activity, and 3) the pitfalls of arguing for personhood on the basis of potentiality.

The *"is-ought" dichotomy*, the formulation of which is usually credited to David Hume, asserts that it is not possible to logically derive a statement of moral obligation from an empirical observation about nature. Those who claim otherwise are often accused of a failure of logic called the *naturalistic fallacy*. The "is" of this dichotomy for the present analysis is that choice-making is identified as a species-specific marker for human nature. The "ought" is the claim that the choice-making trait should be protected, honored, and preserved. In other words, just because humans are moral choice-makers, why does it follow that this is a trait to be preserved and that beings possessing it deserve the dignity of personhood and continued existence? This question needs answering.

Obviously, placing high value on human choice-making capacity presumes the existence of *free will* for the ultimate expression of that capacity. Therefore, arguments for a strongly deterministic universe and genetic determinism must be addressed for "choice-making" to be taken seriously as a human trait that ought to be protected and preserved.

Finally, by identifying the acquisition of moral "choice-making capacity" as a developmental process occurring over more than 10 years, I leave myself open to the criticism that an argument for conferring personhood on human beings younger than 10 years old must be an *argument from potential*. The pitfalls of an argument based on potentiality have been described by English bioethicist, John Harris (1998), who points out the absurdities to which this argument leads. Thus, not only would the single-celled conceptus be a person, but so too the unfertilized egg which may be stimulated to develop parthenogenetically, and also virtually any one of our body cells in the hands of an adept cloning biotechnician. Although I have not concluded when personhood ought to be conferred, only when it is not present, I admit to an unwillingness to say that a 9-year-old child (or even a newly born infant) is not a person. This may mean that one or more incipient levels of personhood and their moral status may need to be defined for human beings within the 10-plus year long period of development for choice-making capacity. The same applies to the end period of life when choice-making components may be *lost* gradually over an extended period of time.

To conclude, I turn to another familiar figure of the Italian Renaissance, Michelangelo Buonarroti (1475-1564), and his masterpiece *The David* now standing in the Academy in Florence, Italy. In a PBS film on Florence and the Renaissance, Bill Moyers had this to say about *The David* and the legacy of 15th century humankind's decision to grasp control of its own fate:

> *The heroic ideal of David was the ultimate expression of Florentine optimism - their belief in the divinity of the human being. Created in the image of God, now Man was creating images of himself. Contained in the marble was the mirror of the soul. We needed only to free it as Michelangelo had liberated David from the block. But what does it bring, this gift of freedom? Certainly the ability to dream and the power to achieve. But perhaps, as Michelangelo had seen, it also leaves us standing alone - to make and face our fate.*

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A Conceptual Analysis of Selectionism: Part I

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A. Introduction

Overview

Many behavior analysts have noted similarities or parallels between Darwinian natural selection in biological evolution and selection by consequences in the ontogenetic evolution of behavior and in cultural evolution. Examples, in alphabetical order, are Alessi (1992), Delprato and Midgley (1992), Donahoe (2003), Glenn (2003), Glenn, Ellis, and Greenspoon (1992), Palmer and Donahoe (1992), and Skinner (1974, chap. 3). Some of them have interpreted the similarities or parallels as arising from a common underlying philosophy they call "selectionism," but I give a different interpretation in this paper. Briefly, my interpretation is that, first, biological, behavioral, and cultural selectionism are theories rather than philosophies; second, these theories are similar in many ways because each of them is consistent with the world view (Pepper,1942) called contextualism; and third, the theories refer to different empirical domains, and therefore the relations among them are analogical, or metaphorical, rather than literal. Another preliminary point is that due to space limitation, I will not analyze cultural selectionism at all and will not give complete analyses of natural selection and behavioral selection by consequences. Also, I will say very little about respondent conditioning, even though John Donahoe's "unified reinforcement theory" implies that many of the same things could be said about both kinds of conditioning (Donahoe, 2003, and references he cited). Finally, and again because of space limitation, I have divided the paper into two parts that are about equally long and that are published separately.

Modeling

The easiest way to show how the biological and behavioral theories are similar and different is to use one of them as a metaphorical model of the other. A model is generally not useful unless its domain has already been worked out better than the domain being modeled. Therefore, I will use the biological theory as the model, not to imply that the behavioral domain is reducible to the biological domain, but because the biological theory is more detailed and has more widespread empirical grounding than the behavioral theory. The theories are actually related only by analogies, not by homologies.

Another point about modeling is that the model and the modeled refer to different empirical domains and therefore not every feature of the model has an analogy in the modeled. Specifically, models usually include (a) features that are matched to features of the domain being modeled, (b) features that need not be matched but perhaps can be, and (c) features that must not be matched. Hesse (1966, p. 8) called these sets of features (a) the "positive analogy," (b) the "neutral analogy," and (c) the "negative analogy." The point is that models can be useful even if completely exhaustive mapping is not possible. Another point is that models are likely to be more useful, the more the positive analogy; more deployable, the more the neutral analogy that can be transformed into positive analogy; and more misleading, the more the negative analogy. A final point is that ignoring the neutral analogy is not the same as what Husserl called *bracketing*, or *disconnecting* (1913/1931, Sections 31-32, pp. 107-111). These terms mean that a domain, a thesis, a feature, or whatever, is accepted as valid but is barred from consideration both in itself and in its ramifications. This was the stance taken by classical stimulus-response learning theorists when they ignored mental behaviors on the argument that they could not deal scientifically with these behaviors until the laws of simple learning had been worked out.

B. Natural Selection in Biological Evolution

Overview of Modern Darwinian Theory

The basic premise in modern Darwinian theory is that individuals live, compete, reproduce, and die (Gould, 2002, p. 620). The competition is for environmental resources that are required for survival, or for obtaining mates, or for increasing the number of offspring that survive, and so forth; but in all cases some individuals may have an advantage in the competition because of inheritable variations in their physical structures or in the functioning of their physical structures. No matter how tiny the advantage, these individuals produce more offspring that survive and therefore contribute more of their genes to the next generation than individuals that do not have the advantageous structures or functions. This is the essence of natural selection; but it can be analyzed into 15 principles that are relevant in this paper. They are listed below as an advance organizer. Principles 1 through 6 are discussed in this part of the paper and Principles 7 through 15 are discussed in Part II. In the discussions, I also indicate analogues in behavioral selection by consequences and, sometimes, the whole field of behavior analysis.

Fifteen Principles of Natural Selection

1. Both necessity and chance affect natural selection, and therefore also affect evolution.
2. The unit in natural selection is the individual organism.
3. Competition occurs because environmental resources are limited.
4. Natural selection is selection of the fittest.
5. In the strict Darwinian sense, "the fittest" means producing the most offspring.
6. Adaptation underlies fitness.
7. Natural selection is an outcome rather than a force or process.
8. The environment causes and controls natural selection.
9. Natural selection requires that variations occur.

10. Natural selection requires that some variations have an advantage in the competition.
11. Natural selection requires that the advantageous variations are inheritable.
12. Variations can occur at any age of an individual, and if some variations are advantageous, they can be selected unless their later effects are disadvantageous.
13. Evolution is gradual and slow.
14. Natural selection can be positive or negative.
15. The losers of the competition eventually die out, but they can leave a legacy.

C. Discussion of First Six Darwinian Principles

1. Natural Selection and Evolution Involve Both Necessity and Chance

a. *The Darwinian principle*. Gould (2002, p. 1333) rejected "quantified predictability" as the benchmark of science because its use classifies natural history, including Darwinism, as an inferior science, and this classification is incorrect because natural history is actually a *different* science rather than an inferior one. It is different because it is based on historical explanation and gives true chance a role, not only with respect to random assortment of parental genes to offspring and random mutations of genes, but also with respect to random assortment of environmental variations to individual organisms. Mayr (2001, pp. 119-120, 141, 281) had the same view, accepting chance causality but also saying that characteristics of remote ancestors can sometimes be predicted from characteristics of present species, and the predictions are sometimes confirmed in the fossil record (p. 25).

Another point is that although Gould said that evolutionary change can potentially be in any direction, Darwin (1896, Vol. 1, pp. 106-107) said that some directions which might have been favorable might be unavailable for natural selection because the individuals that could have begun a particular direction, chance not to survive. Chance has not only this eliminative role but also a positive role, in the production of variations. For example, chance variations in environmental conditions can lead to variations in phenotypes, some of which are advantageous and will be promoted in natural selection and others of which are disadvantageous and will be eliminated.

In the mechanistic and organismic world views that Pepper (1942) described, chance is a name given to antecedent causes that are unknown; but in the contextualistic world view, chance can be a true cause. In this respect, and many others that I do not discuss herein, Darwinism is consistent with contextualism.

***b. Analogue in selection by consequences*.** Analogously, both chance and necessity affect behavioral selection by consequences and therefore also behavioral ontogeny. For example, Skinner (1974, pp. 113-115) gave chance a role in "creativity" and response selection; and the research literature on selection by consequences includes many instances of successful prediction. In these respects, and many others, behavior analysis and selection by consequences are consistent with contextualism (e.g., see chapters in Hayes, Barnes-Holmes, & Roche, 2001; Hayes, Hayes, Reese, & Sarbin, 1993). However, the predictions that Mayr mentioned are actually postdictions, and the analogue in behavior analysis--etiology--is often ignored, especially in behavior therapy. This analogy is neutral rather than negative; therefore, it may indicate a fruitful line of behavioral research.

2. Individual Organism Is Unit of Selection

a. *The Darwinian principle*. In mainstream modern Darwinism, the thing that is directly selected in natural selection is the individual organism. It is not any aggregation of organisms--not a group, a tribe, a species, a genus, or any other kind of aggregation. This point is clarified by noting that aggregations cannot interact with the environment except in a metaphorical sense. A mob as such does not do anything; the individuals in the mob do things. The unit of selection is also not any part of the individual organism--not a gene, DNA, a polypeptide, an organ, a trait, or any other part. This point is clarified by a distinction made between "selection of" and "selection for" (Mayr, 2001, p. 126; 2004). Mayr (2001) gave sickle cell anemia as an example: The underlying gene is recessive and therefore the disorder appears in recessive homozygotes, but in heterozygotes the phenotype that is expressed protects against malaria. Therefore, in malarial regions, the processes underlying natural selection result directly in selection of individuals whose genotype includes the relevant gene, and they result indirectly in selection for the sickle cell gene.

Darwin sometimes talked about competition between races within a species (e.g., 1896, Vol. 1, pp. 92-93), but he specified that the competitors are the individual "organic beings" (p. 94). Dobzhansky (1951, p. 77), Lewontin (2000, p. 76), and Mayr (2001, pp. 126-128) also said that the individual organism is the unit of selection; but others have said that the gene is the unit. Gould (2002, p. 615) rejected conceptions of the gene as the unit, arguing that the causal agent and unit of selection is an "interactor," which must be an individual, and that genes are "replicators" rather than interactors.

Gould argued that the individuals that are interactors are not necessarily individual organisms, but can also be aggregations of individual organisms, such as groups, species, or genuses (p. 624, chap. 8), and Darwin himself sometimes referred to group selection (Gould, pp. 133-136). However, Darwin considered group selection to be an unattractive hypothesis and sought explanations in terms of selection at the level of the individual organism (Gould, pp. 129-132). As Gould put it, Darwin believed that "Nature knows no explicit principle of higher-level order" (p. 132), and although Gould argued for selection at higher levels, ranging from groups to clades, he acknowledged that selection at these levels is only a metaphor (p. 716). (A clade is a group of units, such as a group of species, that evolved from a common ancestor.)

A problem for the principle under consideration is how to explain the fact that cross-species mating usually produces sterile offspring. If selection occurred at the species level, the explanation could be that negative selection against producing fertile offspring prevents the emergence of a new cross-species source of competition. If selection occurs only at the level of the individual organism, the explanation is that cross-species sterility emerged not because it was selected but because it was a by-product of other, directly selected phenotypic differences between species, such as differences in the reproductive structures and functioning (see Sun, Ting, & Wu, 2004).

b. *Analogues in selection by consequences*. The analogous unit of selection in selection by consequences is a concrete behavior that instantiates a particular operant. This analogy has several implications. Glenn et al. (1992) showed that the operant is analogous to the species; but as Skinner (1953, pp. 91-95) said, concrete behaviors can be consequated but operants themselves cannot. The concrete behaviors are variable--in topography, for example--and the only property they have in common may be that they affect the environment in the same way. Therefore, the reinforcement history of an operant is dispersed across the reinforcement histories of a number of physically different behaviors, just as the evolutionary history of a species is dispersed across the evolutionary histories of a number of physically different individual organisms.

Glenn et al. and other behavior analysts such as Donahoe and colleagues (Donahoe, 2003; Palmer & Donahoe, 1992) endorsed a distinction by Ernst Mayr between the concept of a class in essentialist thinking and the concept of a taxon in population thinking, which respectively characterize the creationist versus Darwinian theories of evolution. Glenn et al. quoted Mayr's saying that "A taxon is a concrete zoological or botanical object" (Glenn et al., 1992, p. 1334, citing Mayr, 1982, p. 253). Actually, though, a taxon is not a concrete object of any kind. If it were concrete, I could see it somewhere other than as a word on a piece of paper. A taxon such as a species or an operant is a class, and even if it is a functional class--such as a response class in behaviorism--it is an abstraction. The operant is a functional class--a class of behaviors that have the same effect on the environment--and I can see a specific behavior and its effect on the environment, even though I cannot see the operant as such.

Selection by consequences also has an analogy to cross-species sterility as a by-product of other, directly selected differences. The analogue is response generalization, which according to Stokes and Baer (1977) does not occur spontaneously but must be learned. According to the analogy, generalization does not occur spontaneously, not because of a natural anti-generalization law but because learning does not *require* generalization.

3. Competition is Pervasive

a. *The Darwinian principle*. Darwin said that because resources are limited, "Of all individuals born, only a few can survive" (1896, Vol. 1, p.76) and therefore the individuals that are born must compete for the resources or die prematurely. Of course, plants, nonhuman animals, and probably most humans do not *choose* to compete rather than die, just as hydrogen does not *choose* to combine with oxygen to produce water. These are facts of nature. Another fact is that individuals that have an advantage in the competition are more likely to survive than other individuals. The advantage can be very slight; as Darwin said, "A grain in the balance may determine which individuals shall live, and which shall die" (Vol. 2, p. 278).

Darwin (Vol. 1, p. 79) said that the competition can be between individuals of different species, individuals of different races within the same species, or individuals of the same race within the same species, and that the competition--he said "struggle"--"will almost invariably be most severe between the individuals of the same species, for they frequent the same districts, require the same food, and are exposed to the same dangers. In the case of varieties [that is, races] of the same species, the struggle will generally be almost equally severe" (p. 80). Darwin also said that the competition can be between an individual and its environmental conditions, indicating that in general, competition is a "struggle" for survival and does not necessarily require more than one individual at a given place and time.

b. *Analogue in selection by consequences*. The behavioral analogue of Darwinian competition is competition between behaviors, but the "competition" is usually between a behavior and its environment rather than between two behaviors. The kinds of behavioral competition most often studied seem to be approach-avoidance, approach-approach, and avoidance-avoidance conflict.

Approach-avoidance conflict is between behaviors that instantiate different operants, on the assumption that avoidance is not merely nonapproach. Therefore, this kind of conflict is closely analogous to Darwinian competition between individuals of different species. In Darwinism these individuals do not need to be in the same place at the same time; analogously, in selection by consequences the behaviors do not need to occur simultaneously or, in a laboratory setting, in the same session. The consequence for the behavior that is performed--which can be called the winner of the competition--is either positive reinforcement or avoidance of punishment. Therefore, the consequence of winning the conflict is analogous to Darwinian survival.

The conditions that prevail on a given occasion of approach-approach conflict lead to competition between either (a) instantiations of two different but highly similar operants, analogous to individuals of different races within the same species, or (b) two instantiations of the same operant, analogous to individuals of the same race and same species. A given operant includes a class of discriminative stimuli, a behavior class, and a class of consequent stimuli. The competing behaviors differ most importantly in their specific discriminative stimuli, but may also differ in the specific movements that actualize them (see Lee, 1992) and may differ in their specific consequent stimuli. Therefore, the choice between alternatives (a) and (b) probably depends mainly on whether the discriminative stimuli are from the same class. In any case, the winner gets reinforced, and the Darwinian analogues are the same as in approach-avoidance conflict.

The same analysis applies to avoidance-avoidance conflict, and I would guess that if the words "approach" and "avoidance" are interpreted metaphorically, the analysis applies to any kind of response competition.

4. The Fittest Are Selected

a. *The Darwinian principle*. Darwin (1896, Vol. 1, p. 77) said that the phrases "natural selection" and "survival of the fittest" are synonymous, but he also said that "survival of the fittest" is the more accurate phrase. Actually, it is problematic in two important ways. First, "the fittest" does not mean the best in any absolute or ultimate sense and it means more than is implied in saying that survival of the fittest means only survival of those individuals that in fact survive. It means survival of individuals that are the fittest in the sense that they are the best *available* for natural selection. Second, the phrase is incomplete because natural selection requires not just survival but survival and reproduction (Holsinger, 2002, p. 1291). In fact, failure to survive makes reproduction impossible, and therefore the principle could be called "reproduction of the fittest." However, this phrase is problematic because it may imply an outside agent that does the reproducing. The phrase "natural selection" has a similar problem: It may imply an outside agent that does the selecting. Also, as Darwin (p. 99) commented, "selection" incorrectly implies a conscious choice.

b. Analogue in selection by consequences. The analogue of Darwinian natural selection--or survival of the fittest, reproduction of the fittest, or selection of the fittest--is selection by consequences. The concrete behavior that gets reinforced is the one that is the fittest in the sense that it occurs first, or requires the least energy, or has whatever other property that leads most closely to satisfaction of the environmental demands. Environmental demands are analogues of what geneticists call "selection pressures," especially because both are abstract concepts and not causal agents. For example, the environmental demands in a Skinner box actually include (among other things) an amount of pressure sufficient to move the lever a certain distance; and the selection pressure exerted by predators on prey is actually an individual organism being chased and/or nonmortally wounded by another individual organism.

5. Strictly, Fitness Means Producing Viable Offspring

a. ***The Darwinian principle.*** The individuals that have the edge in the Darwinian competition are said to be more "fit" or better "adapted" than the other individuals. I will discuss Darwinian adaptation in Section C.6. Darwinian *fitness* means producing offspring that are viable, and therefore it leads to contributing genes to the next generation. With respect to natural selection it means producing more viable offspring than other individuals in the same population, and therefore contributing more genes to the next generation.

b. ***Analogue in selection by consequences.*** As indicated in Section C.4.b, in a behavioral competition, the concrete behavior that is reinforced is the one that is fittest in the sense that it has the most of whatever property leads closest to satisfaction of the environmental demands. The property might be, for example, speed or energy efficiency. In the strict sense in Darwinism, fitness refers to only one property, production of viable offspring. At one level, the reason fitness has only this property is that it is the only property that is necessary and sufficient for the occurrence of evolution. At another level, fitness has only this property because it is a consequence of survival, which is a consequence of an individual's physical structure or functioning that most closely adapts to the correct selection pressures. Therefore, when analyzed in general terms fitness in selection by consequences is analogous to Darwinian fitness in the strict sense.

6. Adaptation Underlies Fitness

a. ***The Darwinian principle.*** Adaptation means having traits--physical structures and/or functioning--that facilitate survival of an individual in the current environment for enough time to allow the individual to reach reproductive maturity and to reproduce, and to allow offspring to become independent of parental protection. The production of viable offspring constitutes fitness; therefore, enhanced fitness is an effect of adaptation-enhancing traits. The effect can be direct or indirect. An example of a direct effect of an adaptive physical structure in a bisexual plant is physical separation between the male and female parts such that the fertilizing pollen is more likely to come from another plant than from the same plant. An example of an indirect effect of adaptive functioning in an animal is chicks that scurry away from the hen and into concealment in response to particular clucks by the hen (Darwin, 1896, Vol. 1, p. 329).

Most geneticists say that the characteristic selected in natural selection is *fitness*, but it cannot be because fitness is not a phenotype, it is a result of phenotypes (see Section C.2.a and Part II Section B.7.a). For the same reason, *adaptation* cannot be the characteristic that is selected. Rather, the selected phenotype is either an aspect of physical structure or an aspect of functioning, specifically an aspect that results in better adaptation and therefore greater fitness. An implication is that although adaptation and fitness are *strengthened* when natural selection occurs, the strengthening is a by-product of selection.

b. ***Analogue in selection by consequences.*** The behavioral analogue of Darwinian adaptation can be inferred from the analogue of Darwinian fitness discussed in Section C.5.b. Behavioral adaptation means performing a concrete behavior that meets the environmental requirements sufficiently well to be reinforced.

Staddon (2003) noted that analogously to the strengthening versus selection distinction in Darwinism, reinforcement does not directly *strengthen* behavior, it directly *selects* behavior. According to this analogy, an animal trainer does not shape a specific behavior by modifying its properties to accord ever more closely with the desired behavior, but rather reinforces a specific behavior until it occurs reliably, then uses differential reinforcement to select another specific behavior that the trainer considers to be closer to the desired behavior, continuing this process until the desired behavior itself occurs reliably.

D. Summary of Part I

1. Both necessity and chance affect natural selection and evolution, and analogously affect behavioral selection by consequences and behavioral ontogeny.

2. The unit in natural selection is the individual organism. Analogously, the unit in selection by consequences is a specific concrete behavior.

3. In Darwinian theory, competition between individual organisms, or between an individual organism and its environment, occurs because environmental resources are limited. The analogue in selection by consequences is that different concrete behaviors "compete" for reinforcement or avoidance of punishment.

4. Natural selection is selection of the fittest. The behavioral analogues of natural selection and "the fittest" are selection by consequences and the concrete behavior that most closely satisfies the criteria for reinforceability.

5. In the strict Darwinian sense, "the fittest" are the individual organisms that produce the most offspring. The analogue in selection by consequences is that the reinforced behavior is the one that most closely satisfies the criteria for reinforceability.

6. In Darwinism, adaptation underlies fitness. The behavioral analogue of adaptation is that at least one concrete behavior

meets the criteria for reinforceability sufficiently closely to be reinforced.

A final comment is that the other nine Darwinian principles listed in Section B.2, and their behavioral analogues, are discussed in Part II of this paper, to be published in the next issue of this journal. To conserve journal space, references are given only at the end of Part II.

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A Conceptual Analysis of Selectionism: Part II

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A. Introduction

Overview

The present paper is the second, concluding part of a paper begun in the preceding issue of this journal. The complete paper deals with 15 principles related to the modern Darwinian theory of natural selection, and analogies of these principles in behavioral selection by consequences. Six of the 15 principles were analyzed in Part I; the other nine are analyzed in the present paper. The references for both parts are given at the end of the present part.

B. The Fifteen Principles

The principles marked with an asterisk were discussed in Part I Section C; the others are discussed in Section B below. Subsections in both parts are indexed with the Arabic numerals given here.

*1. Both necessity and chance affect natural selection, and therefore also affect evolution.

*2. The unit in natural selection is the individual organism.

*3. Competition occurs because environmental resources are limited.

*4. Natural selection is selection of the fittest.

*5. In the strict Darwinian sense, "the fittest" means producing the most offspring.

*6. Adaptation underlies fitness.

7. Natural selection is an outcome rather than a force or process.

8. The environment causes and controls natural selection.

9. Natural selection requires that variations occur.

10. Natural selection requires that some variations have an advantage in the competition.

11. Natural selection requires that the advantageous variations are inheritable.

12. Variations can occur at any age of an individual, and if some variations are advantageous, they can be selected unless their later effects are disadvantageous.

13. Evolution is gradual and slow.

14. Natural selection can be positive or negative.

15. The losers of the competition eventually die out, but they can leave a legacy.

C. Discussion of Principles Seven through Fifteen

7. Natural Selection Is Not a Process

a. *The Darwinian principle.* Falconer (1981, p. 301) said, "The 'character' that natural selection selects for is *fitness*." This statement is misleading unless one keeps in mind the distinction between "selection of" and "selection for." Fitness is a trait; therefore, as indicated in Part I Section C.2.a, selection *for* fitness can occur but selection of fitness cannot. Another problem with the statement is that natural selection cannot select anything, because it is not a process. Granted, most geneticists and other scientists say that natural selection is a process, force, or power that causes evolution. Examples of geneticists are Darwin (1872, pp. 77, 102-103), Crow (1986, pp. 144-147), Gould (2002, pp. 139, 619, 627, 655), and Mayr (1992, p. 135; 2001, chap. 6); other scientists include Hogg (1999a, 1999b), Palmer and Donahoe (1992), and Staddon (2003). Actually, however, natural selection is only an outcome, as noted by Gould (2002, pp. 614-637), Mayr (2001, p. 281), Nagel (1977/1979, p., 301), and Skinner (1974, p. 37). Gould said it is useful for the bookkeeping of evolution but is not a cause of evolution; Nagel said it is "not literally an 'agent' that *does* anything"; and Skinner said, "[Natural] selection is a special kind of causality which is not properly represented as a force or pressure."

Evolution is also an outcome rather than a process, and therefore neither natural selection nor evolution can explain change (Nagel, 1977/1979). The processes that explain change are ones that lead to increased probability of survival and reproduction or, more precisely, processes by which "the carriers of different genotypes in a population contribute differentially to the gene pool of the succeeding generations" (Dobzhansky, 1951, p. 77).

b. *Analogue in selection by consequences.* The behavioral analogues of natural selection and evolution are selection by consequences and behavioral ontogeny. The fact that natural selection and evolution are outcomes does not undermine these analogies, because selection by consequences and behavioral ontogeny are also outcomes rather than processes. The actual behavioral processes are operant conditioning procedures, perhaps with additional inborn mechanisms that permit learning higher-order operants.

8. Environment Causes and Controls Natural Selection

a. *The Darwinian principle.* Gould (2002) said, "In natural selection, environment proposes and organisms dispose" (p. 163). More fully, the environment causes and controls natural selection, but individuals' phenotypes cause and control the actual accomplishment called natural selection (pp. 161-163).

b. *Analogue in selection by consequences.* Selection by consequences is closely analogous: The environment offers a behavior the opportunity to be consequated, but the opportunity is ineffective unless the behavior occurs.

9. Variation is Required

a. *The Darwinian principle.* The kind of variation that is relevant to natural selection refers to differences in degree of adaptation or, more precisely, differences in the physical structures or ways of functioning that result in adaptation. Darwin said that the source of variation is changes in "conditions of life" (1872, p. 3; 1896, Vol. 1, p. 100), which means changes in the environmental conditions that the physical structures or ways of functioning are adaptive to. Genetics theory adds mutations and recombination of genes as other sources (Mayr, 2001, pp. 279-280). Variation provides the substrate for natural selection--which also implies that variation is not the agent of change. In Aristotle's terms, variation is the material cause of evolution, and the processes that result in natural selection are the efficient causes. A consequence that Darwin emphasized is that variations must be small and evolution must be slow (see Section B.13). The reason, as Gould said (2002, p. 149), is that if variations are large and evolution is fast, the variations themselves are the efficient causes of evolution, and natural selection has only a mopping-up role of eliminating the less fit.

b. ***Analogue in selection by consequences.*** The behavioral analogue of Darwinian variation is behavioral variation, without which selection by consequences has nothing to select. The causes of behavioral variation include variations in the external and internal environment and, as Neuringer (e.g., 1986, 1992) has shown, effects of prior learning, which is also an environmental effect. Examples of relevant environmental variations include variations of discriminative stimuli, current establishing operations, and current setting events, all of which can be external or internal; exclusively internal variations in neural and physiological functions; and variations in prior learning, which are functionally internal.

10. Some Variations Must be Advantageous

a. ***The Darwinian principle.*** Natural selection requires not only that variations occur, but also that some variations are advantageous in the competition for resources, even if the advantageousness results from disadvantageousness of other variations. That is, some variations must be more adaptive than others, because if all of the existing variations are equally adaptive, pure chance determines which ones win the competition, and evolution cannot occur because the tiny steps cannot have a cumulative effect--they are not taken down the path started by the common ancestor.

b. ***Analogue in selection by consequences.*** The behavioral analogue of the Darwinian competitive advantage can be inferred from the analysis in Part I Section C.6.b: The specific concrete behaviors that better satisfy the environmental requirements are reinforced. The directionality of shaping is an analogue of the directionality that evolution has once a path has started.

11. Advantageous Variations Must be Inheritable

a. ***The Darwinian principle.*** Selection can occur if some variations are more adaptive than others, because the individuals exhibiting these variations will produce more viable offspring.

However, unless the adaptive variations are inheritable, the advantage that the parents have is not passed to the offspring, and evolution does not occur. Even if the advantageous trait is inheritable, evolution will stop in the first filial generation if the advantage is lost. The advantage can be lost in several ways. For example, mutation of a gene required for expression of the advantageous trait may result in expression of a different trait, including death of the offspring, and mutation of a previously irrelevant gene may create an epistatic interaction that changes expression of the genotype underlying the previously advantageous trait. The same effect can result from slippage in replication of DNA, physiological injuries, and chance environmental variations that influence how the relevant genotype is expressed. Changes in the environment can also make the trait no longer advantageous. However, these events do not undermine Darwinian theory; they only slow down evolution.

b. ***Analogue in selection by consequences.*** The behavioral analogue of inheritability is relative permanence of the effects of reinforcement and punishment. The relative permanence can be cut short, or at least hidden, by further shaping, differential conditioning, resurgence of instinctive behaviors, extinction procedures, and so forth; but selection by consequences still *generally* has relatively permanent effects, so the analogue is complete.

12. Selection Can Occur at Any Age

a. ***The Darwinian principle.*** Darwin (1986, Vol. 1, p. 105) said that natural selection can occur at any age of an individual; that the effects at a given age can affect traits at a later age, and that the effect on the later traits cannot be injurious because if it were, the species would eventually become extinct.

b. ***Analogue in selection by consequences.*** Selection by consequences can occur at any age, and the result affect behaviors at later ages if it constitutes a "behavioral cusp" in Rosales-Ruiz and Baer's (1997) sense, or functions as a precurrent behavior in a behavioral chain learned later, or is a step in a shaping procedure, or is part of a response class that is being learned and will later constitute an operant or a higher-order operant, and so forth. If the later effect is injurious, the selected behavior will be nonreinforced or punished, and therefore will become extinct. It has an injurious later effect if, for example, it prevents occurrence of a desirable later behavioral cusp, disrupts the behavioral chain, prevents occurrence of a better variant behavior in the shaping process, or is so prepotent that it blocks formation of a response class or blocks transitivity, symmetry, or other functions of an operant or a higher-order operant.

13. Evolution is Gradual and Slow

a. ***The Darwinian principle.*** Evolution is gradual, which means that it proceeds in tiny steps, some virtually undetectable (Darwin, 1896, Vol. 1, p. 131; Vol. 2, pp. 277-279). It therefore requires many generations--thousands or even tens of thousands--and it is consequently very slow. The gradualness principle is often challenged by creationists as implausible. A concrete illustration is that during the evolution of the long neck of giraffes, some individuals had necks that were a tiny bit longer, say a millimeter longer, than the necks of competing individuals, and the ones with the longer necks were naturally selected because they could reach a millimeter more tree leaves than the competitors. The creationist argument is that the extra millimeter of food would not be enough to increase the probability of survival. An answer is that giraffes take very many bites of food each day, and therefore the extra millimeter they get in many of their bites could add up to an appreciably bigger daily intake. A better example for the creationist argument might be that a millimeter increase in the length of protopeacocks' tails would be undetectable by protopeahens, thus giving the longer tails no adaptive advantage. An answer is that the assumed limit on protopeahens' perceptual abilities is not--and cannot be--supported by any observational evidence, but that Darwinian theory and the fact that peacocks now have long tails provide inferential support for assuming that protopeahens indeed detected a millimeter increase in tail length.

b. ***Analogue in selection by consequences.*** In studies of schedules of reinforcement, the characteristic cumulative curves emerge gradually and slowly, analogous to Darwinian evolution even though the size of the steps and the slowness are scaled differently. Other effects of learning that emerge gradually and slowly include relational frames and other higher-order operants, discriminative responding, and some kinds of shaping.

However, in applied behavior analysis the hallmark is relatively rapid change--instead of years of psychiatric sessions, or even more years of psychoanalytic sessions, behavior therapy can eliminate phobias and many other undesired behaviors in a few sessions. Conditioning with punishment procedures can also be extremely rapid. Taste aversions can be learned in one or two trials, perhaps via Pavlovian aversive conditioning, and in the Watson and Rayner (1920) study with "Little Albert," an operant response was suppressed after only two trials with a punishment contingency. The first experimental session with Albert consisted of two trials on which his reaching toward a rat was followed immediately by a loud sound; and when the rat was presented on a test trial a week later, Albert withheld the reaching response.

Therefore, selection by consequences is sometimes analogous to natural selection in being gradual and slow, and sometimes it is not at all analogous because it is saltatory and fast. Maybe the analogue for the latter cases is biological extinction resulting from natural catastrophes--a principle that I do not discuss in this paper.

14. Positive and Negative Selection Occur

a. ***The Darwinian principle.*** Both positive and negative selection occurs, respectively preserving advantageous variations and eliminating disadvantageous ones (Darwin, 1896, Vol. 1, p. 98; Gould, 2002, p. 139; Holsinger, 2002). However, positive selection can occur only if at least one variation is advantageous, and negative selection can occur only if at least one is disadvantageous. Also, as indicated in the analysis in Part I Section C.2.a, the unit of selection is the individual organism rather than the advantageous or disadvantageous trait; therefore, positive and negative selection cannot simultaneously affect the same individual.

b. ***Analogue in selection by consequences.*** Reinforcement procedures are analogous to positive natural selection, and punishment and extinction procedures are analogous to negative natural selection. Both kinds of procedure are used in differential conditioning, discriminative learning, conditional discrimination, and certain kinds of multiple schedules, but they are not administered simultaneously. This fact supports the analogies to positive and negative natural selection. The analogies would not be close if the behavior of the individual, which is a specific concrete behavior, is *simultaneously* reinforced and punished. Approach-avoidance and other response conflicts would not be examples, because they involve different concrete behaviors (Part I Section C.2.b). However, an example in research with pigeons is performance of a key-peck that results in simultaneous delivery of grain and electric shock.

15. Losers May Leave a Legacy

a. ***The Darwinian principle.*** When the inherited tiny variations accumulate to a sufficient extent, the selected individuals constitute a new species and the old species becomes extinct because the few individuals that are left in it do not compete effectively with individuals in the new species. However, the new species is in the same line of descent as the old one, and therefore the genome of the new species includes some of the genes in the genome of the old one and the other genomes in the line of descent. Some of these carryover genes are expressed as similar traits, and therefore result in family resemblances across the successive species. Other carryover genes are suppressed in most of the within-species variations somewhere in the succession, but are expressed in some of the other within-species variations. The latter traits are called reversions to older forms (Darwin, 1896, Vol. 1, pp. 194-203).

b. ***Analogue in selection by consequences.*** As Donahoe (2003) pointed out, a behavioral analogue of Darwinian reversions is that behaviors which were previously acquired and then extinguished may reappear sequentially during extinction.

D. Summary of Part II

7. Natural selection and evolution are outcomes rather than processes. Exactly analogously, selection by consequences and ontogeny are outcomes rather than processes.

8. The environment causes and controls potential natural selection, but individuals' phenotypes cause and control the actual accomplishments. Analogously, the environment causes and controls potential selection by consequences, but the potential is actualized only if appropriate concrete behaviors occur.

9. Natural selection requires variations in physical structures or ways of functioning, because otherwise it has nothing to select. Selection by consequences requires behavioral variations for the analogous reason.

10. Natural selection requires that variations differ in adaptiveness, because otherwise chance determines which organisms win the competition for resources. The behavioral analogue is that specific behaviors vary in how well they satisfy the criteria for reinforceability.

11. Evolution requires that advantageous variations are inheritable, because otherwise natural selection does not yield evolution. Analogously, effects of selection by consequences must be relatively permanent because otherwise chance rather than reinforcement history determines the course of behavioral ontogeny.

12. Natural selection can occur at any age provided that the trait selected for is not injurious at a later age. Analogously, behavioral change can occur at any age, but behavioral ontogeny requires that early-learned behaviors do not interfere with desired later learning.

13. Evolution is gradual and slow. Some kinds of selection by consequences are also gradual and slow, but others are saltatory and fast, especially with punishment procedures. Effects of

punishment procedures may be analogous to extinctions resulting from natural catastrophes.

14. Advantageous traits are preserved in positive natural selection; disadvantageous traits are suppressed in negative natural selection. The behavioral analogues are reinforcement procedures versus punishment and extinction procedures.

15. Traits suppressed during evolution may reappear later as "reversions." The behavioral analogue is "resurgence" of behaviors during extinction.

E. Conclusion

Behavioral selection by consequences is analogous in many ways to Darwinian natural selection. Some of the analogies are so obvious that they do not further the understanding of behavioral selection by consequences, but some seem less obvious and they may provide some useful new ways to look at behavioral selection by consequences. A point that must be emphasized, however, is that the relation between selection by consequences and natural selection is metaphorical; that is, the correspondences are analogies rather than homologies.

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Acquisition of New-Stage Behavior

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Acquisition of new stage behavior (stage transition) was an important aspect of Piaget's (1954) theory. If there are steps during acquisition, why might there be and what might they be? Is change gradual or quantal? Although these questions raise important issues about the nature of development, little research has been undertaken, at least among American psychologists. The reason for this seems to be the controversy surrounding Piaget's notions of stage and stage change. Here Hierarchical Complexity's Treatment of Stage Transition is presented which addresses all the above. Examples of ways of inducing stage change are reviewed.

To overcome the huge gap between lower-stage behavior and higher-stage behavior, Piaget suggested two processes: assimilation of new behaviors and new performances to the present stage; and accommodation of new behaviors to the higher-stage performance. The ***stage of performance*** is the highest-order-of-complexity task performed correctly (Commons & Miller, 2001; Commons & Pekker, submitted; Commons, Trudeau, et. al. 1998). The model of hierarchical complexity (MHC) shows that at each higher order of complexity there is a new, more abstract "layer" of actions added that organizes the previous component actions in a nonarbitrary way. Note that stage of performance on any given task will correspond to the order of hierarchical complexity of the task itself. In both the case of assimilation and of accommodation, we argue that the laws of learning apply. Different forms of instruction produce different combinations of assimilation and accommodation. Assimilation is the acquisition of more skill at the current stage. Accommodation is the acquisition of a skill at the next stage. The general finding (Binder, 2000; Rosales-Ruiz, 2000) is that the more solid the performance at lower stage behaviors, the more easily new-stage behavior may be acquired.

We very briefly describe five general ways of advancing stage change:

(1) The didactic method of teaching about higher-stage behaviors.

(2) The Piagetian notion of immersion, the use of contradictions and use of reflective abstraction (Campbell, 1993). There are a wide range of programs and variation on this theme. (See Brendel, Kolbert, & Foster, 2002; Lovell, 2002; McAuliffe, 2002).

(3) The use of reinforcement for correct answers and outcomes.

(4) The use of support or demand (Arlin,1975; Commons & Richards, 1995; Fischer et al., 1984; Gewirtz, 1969; and Vygotsky 1962; 1966.

(5) The use of direct instruction and charted performance as feedback (Binder & Watkins, 1990).

Didactic teaching has many variants. The most common is show-and-tell. At the high-school level and above, this is referred to as lecture. Preaching goes back to the time of Moses and before. Historically, in many Western colleges and universities, a major purpose of lectures was to train clergy. Thus, lectures seem to have been derived in form from sermons. Information is imparted by speaking to the multitude. Other forms of this technique include the viewing of films, videotapes, DVDs, or the use of other electronic one-way media, such as listening to audio tapes. Sometimes a lecture may be followed by a discussion section, which may include a more detailed lecture with some possibility for students to pose questions and comments.

A second form of didactic teaching related to lectures is the use of reading material. Not surprisingly, it is more effective. It allows a student to self-pace, review and highlight. Also, reading is a much more active process for the student than listening. In the order of activity, show and tell is the least active, followed by listening, and reading, which is the most active of the means so far reviewed. Reading can be easily modified to allow the student to be much more engaged in the material, as exemplified by problem sets and programmed instruction. This includes the use of flash cards in paper or computer form.

In the Piagetian notion of immersion, people work in environments in which materials for learning and development, and problems are present. They may construct and solve problems with the materials. There is interaction among the actions of the person and the outcomes produced by changes in the environment (including the social environment). Such immersion works well for children and adults who already care about contradictions in academic-like settings. Contradiction arises when ones own actions and reasons do not match what is being said in what one is reading. In everyday settings, it arises when one's actions fail to produce the predicted results. In dialectical theories of stage change of which Piaget's theory is one of the first, contradiction leads people to adopt an opposite same stage behavior or a complementary same stage behavior. But when people find out that these behaviors produces contradictions as well, they will, in most cases, alternate back and forth between the positive and alternative same stage behavior. Finally, after they realize that alternating between behaviors still produces contradictions, they attempt to organize the behaviors together in arbitrary ways. The process of reinforcement will eventually select those organizations of behavior that work and do not produce contradictions.

Children who do not find contradiction in academic realms punishing or feel that their actions lack reinforcement (less motivated) do not necessarily change stage of performance very readily under these conditions (Commons & Miller, 1998). As described by Commons and Miller (1998), in one experiment, children earned points by performing the following task correctly. In this task, they had to figure out which of four possible ingredients would clean a stained piece of cloth. They were given six episodes in which the cloth came out clean three of the times, and dirty three of the times. The children's points from the ten test episodes were then pooled for each of their different teams. Each team competed with each other to earn the highest number of points. These competitions for points led 75% of fifth- and sixth-grade students tested (who mostly scored concrete stage) to acquire formal operations on a number of Piagetian tasks. A concrete performance consisted of using combinations of variables or matching a few variables from one or two episodes to predict how the cloth would come out. A formal operational performance consisted of finding which variable consistently predicted whether the cloth would come out clean or dirty using all the episodes. Note that they were given no instruction or support, so this is an example of immersion, but with extrinsic reinforcement. Extrinsic contingent reinforcement may be needed in some settings to ensure that immersion will generally succeed.

Fischer (personal communication) reported that various forms of support lead to acceleration of the acquisition of new-stage behavior. Support might consist of providing examples or prompts for the correct response. This acceleration is probably due to the fact that such supports reduce the required task demands by exactly one order of hierarchical complexity. By definition, support assists performance.

The question is, could support assist performance in increments less than multiples of one stage? The proof that difficulty (but not the order of the task) is reduced by a multiple of one stage is not complicated, and is the following. There cannot be intermediate stage performances between stages because there are no intermediate order tasks nor intermediate behaviors. No matter how hard people look, they have never found any. One of the easiest ways to see why this is so is to try to find a behavior that is in-between solving addition and multiplication problems on the one hand and long multiplication on the other hand. Try to find some intermediate stage action between those two actions and long multiplication. Of course one can do chains of addition and chains of multiplication, which is more difficult than adding or multiplying a single pair of numbers. But those chains are still at the same stage. Solving simple addition problems (e.g. 2 + 3 = ?) and solving simple multiplication problems (e.g. 2 x 4 = ?) are same stage behaviors. Solving problems that require distribution such as long multiplication problems (e.g. 2 x (3 + 4) = ?) is a behavior of the next higher stage. When a person combines the behaviors of solving simple addition and simple multiplication problems to solve a long multiplication problem, s/he reaches the higher stage. Yet in a transition from the lower stage to the higher stage, people do perform behaviors that are between the stages because there are no intermediates between solving simple addition and multiplication problems and solving long multiplication problems requiring distribution. Perhaps they would first attempt to solve a long multiplication problem by solving chains of addition, but this behavior is in the same stage as solving simple addition problems.

Some behaviors at the same stage do have intermediates. For example, crawling and walking are at the same stage. This is because they both require a similar stage of the coordination of perception and motor control. So there are intermediate behaviors such as walking while holding on to a supporting object. The stage of performance by definition is the highest order task performed correctly (Commons, et. al. 1998; Commons & Miller 2001) This makes it possible to perform the higher-stage tasks. Repeated performances at the higher stage are reinforced and therefore acquired.

Finally, fields such as Precision Teaching offer training of new stage actions. Two basic notions in Precision Teaching are those of elements (components) and compounds (combinations of elements). Here we apply the acquisition of compounds to address the problem of stage transition. Higher-stage behaviors are the compounds that combine their components--the lower-stage behaviors. But not all compounds are higher stage, only those that organized lower stage actions in a non-arbitrary fashion. Precision teachers train individuals on the elements or components to fluency, and only later train individuals to combine these elements (Graf & Lindsley, 2002). Fluency training on the elemental behaviors consists of repetition until an individual is able to perform at an extremely rapid rate. In this type of training, the rate at which a student completes a task is charted. The teacher then makes decisions about the effectiveness of current instructional interactions based on the charted performances. The teacher compares the obtained rates to performance on the same task by experts or people of equivalent standing. Graphical cusps may be observed during acquisition (Rosales-Ruiz & Baer, 1997).

When the rate of behavior reaches a maximum, most closely matching the rate of an expert, the behavior is deemed to be *fluent*. Even moderate numbers of errors in performance may have long disappeared when rates of behavior increase greatly. If the behavior is over-learned to the extent that very little effort or special attention is required, then the performance is deemed *automatic*. Fluency training on the components seems to increase the speed at which compounds are acquired from components. The implication of this work is that Precision Teaching in behavior analysis helps provide an empirical account of development.

The example of developing the use of the distributive property is expanded to illustrate the effectiveness of fluency training in Precision Teaching. The example shows how one could move rapidly from the primary stage behavior of using simple single operation arithmetic to using distributive properties. A student is trained with flash cards to predict the correct answer to such primary stage problems such as 2 + 3 = ? The problems are written on one side of the card. On the other side is the answer 5. For a one minute session, students do as many of these problems as possible with the instruction to go as fast as possible. The number of problems completed is then charted on log-linear paper. Each session, the number of problems completed increases. On log-linear paper, the increase looks like a straight line. Finally the asymptotic performance is reached. In a similar fashion, the students learn from speeded practice simple multiplication problems such as 4 x 5 = ? These two elemental or component actions are then integrated into a distributive problem. The student learns to calculate the answer to 4(2 + 3) as 4(2) + 4(3) = 8 + 12 = 20. The students generally learn distributive problems more quickly because they are fluent in simple addition and multiplication problems.

During the relatively rapid acquisition of the compound, concrete-stage behavior of using distributive methods, one might observe the following steps. At step 1, either addition or multiplication is tried. At step 2, whether addition or multiplication is tried changes with each example. At Step 3, substep 0, both multiplication and addition are tried in a disorganized fashion, for example 4 is multiplied by 3 but not by 2. At substep 1, multiplication of at least the first term is tried and then the results added, for example 4(2) + 3 = 11. There can be variations on this but basically, multiplication is carried out first, addition second but not necessarily on the right terms and variables. At substep 2, the order and variables are correctly chosen but there may be a failure to add or to simplify, for example 4(2) = 8, 4(3) = 12. Finally at step 4, the multiplicand is distributed across the terms connected by the addition sign, +, 4(2) + 4(3) = 8 + 12. Then the resulting products are added, 8 + 12 = 20. Because the multiplication and the addition are almost automatic, the concrete stage distributive ordering may be rapidly acquired.

Speed and Limits of Stage Transition

If we start with the assumption that the sequential increase in hierarchical complexity of tasks is linear, then there are at least four questions regarding the speed and limits of acquisition. The first question is, why does the speed of acquisition decrease over the life span as the order of complexity of required actions increase? Second, if acquisition were linear, as it might be for machines, what might be an equation for an overall first approximation of that acquisition? Third, are the acquisition curves for animals (including humans) and machines similar? And last, do the acquisition times explain the limits as to the highest stage attained?

Assume that the difficulty is equal for all transitions between task performances on task differing by one order of hierarchical complexity (or as some might say, to increase the stage of performance by one). This is the simplest assumption. If it is wrong, it could be rejected by data showing otherwise. This does not imply that there are not increasing times between acquisitions of next stage behavior, and in fact, there are. The underlying causes of developmental stage transition and its limits is not to be decided here. It could be some combination of neural development and environmental history (e.g. Elman, 1993). There are a number of models that have been proposed (e.g. Hartelman, van der Maas & Molenaar, 1998; Molenaar & van der Maas, 2000; Saskia, Olthof & Boom, 2000; van Geert, 1998). In gross form, it could be related to age and education. Because stage change at any stage may be equally difficult, the variable of stage of development may not be predictive of difficulty.

For the general case, let T = time to attain a given stage of action, ΔT is the change in time, Δstage is the change in stage. The *learning cycle time* is the amount of time it takes to acquire a new stage behavior:

Learning cycle time = ΔT/stage

Then the amount of time it takes to train a machine is:

I = k

Time to Train = Σ (learning cycle time for stage k)

I = 1

If acquisition were linear then,

Time to train = learning cycle time * number of such cycles to retain.

But we know that in humans as well as in most other animals, learning time increases with stage of the required performance (e.g. Armon, 1984; Armon & Dawson, 1997). This is part of what sets the limit for the highest stage that can be acquired.

Another process that also partially sets the limits of stage transition is that at some point in an organism's life, the rate of loss of skills, knowledge, understanding, judgment, problem solving and the like surpasses the rate of acquisition (Baltes & Graf, 1997). The newest work on adulthood and aging suggests the rate of loss only accelerates precipitously in the last year or so before death of very active and engaged people. Put more simply, time runs out. It is also suggested that the upper limit for a particular individual seems almost completely heritable. Evidence is provided by the lack of variation as adulthood progresses among identical twins reared apart who have been given training. Before training begins the twins may be performing at different levels. However, giving both twins training causes acceleration in the lower level performing twin but not in the other twin, which suggests the existence of a biologically determined learning ceiling. If there was no ceiling, both twins would have improved (Bouchard, 1995; 1997).

This discussion may make it sound as if, under ideal conditions, there is nothing in the stage transition theory we have presented that necessitates an upper limit on stage transition for a population. This may be true even if those who are slower or environmentally challenged learners may progress to their maximum because they have reached their upper limit within their life span. The current formulation includes 15 orders of complexity. This may allow us to determine the upper limit for human beings. There have been an increasing number of informal empirical reports in Precision Teaching, that posit that there is a limit to the number of times a series of elements can be turned into a combination (Binder, personal communication). These reports in the form of training studies have shown that at a given age, there are limits to how much training is effective in bringing about change. This can be seen anecdotally in graduate education. Whereas it is probably true that most graduate instruction does not even come close to optimal instructional methods, we also suspect that no matter how much training people have received, some never move beyond the systematic stage in their problem solving. According to the formulation of limits given here, they have reached their biological limit.

Solving the Most Highly Hierarchically Complex Problems: A Matter of Biological Limits, Educational Experiences, or Both?

Theorizing in psychology has always had an inherent tension as to the achievable developmental ends of individuals as well as organizations and what is actually found. Whereas some individuals are observed to develop skill at the highest orders of hierarchical complexity, others do not appear to do so (Kegan, 1995). How skillful in a developmental sense someone is can influence how effective they are in a number of situations. Skinner (1948), in Walden II, expressed this tension most fully, going back and forth between the need for a philosopher king in a semi-fascist system, and a system of personal choice based on variable proclivities and preferences of individuals. In the end, the issue has not been resolved. Semi-fascist systems represent the dying gasps of the systematic stage. Unfettered choice such as direct voting on laws would also be systematic stage. Even if there are many possible integrations of systems that are high on leadership and direction on one hand and individual choice on the other, there are no unique solutions (Sonnert & Commons,

1994) Kegan and Lahey (2001), Morris (1993), Demick and Miller (1993) discuss some adult developmental alternatives to Skinner's formulations. Recent advances in the study of positive adult development provide a beginning look at this issue. Data shows individuals could potentially solve problems of one order more complex than the ones they currently do without any further training (e. g. Colby & Kohlberg, 1987). This is found to be true even for individuals who hold seemingly complex professional jobs. Even though contingencies exist that might reinforce more hierarchically complex behavior, the contingencies fail. What is it that might limit the proclivities of individuals? Why does just one more order of complexity seem possible? In addition to the biological limits, the lack of appropriate training or education is also a cause of lack of development.

Conclusion

The acquisition of new stage behavior (stage transition) was an important aspect of Piaget's (1954) theory of stage and stage change. Our approach expanded upon Piaget's suggestion of steps during acquisition. Applying the Model of Hierarchical Complexity and the quantal nature of stages generates a description of stage change as the increasingly rapid alternation of last-stage behavior. It was suggested that alternation of alternative lower stage behaviors increased in rate until they were essentially smashed together and then organized into a new stage behavior. This alternation can be described by the steps and substeps. A variety of ways of inducing and measuring stage change were reviewed. Empirical field tests of the newer means of intervention are needed to establish what methods work best with which people and under what circumstances. Many methods of producing change work well in pilot studies, but do not replicate well. The problem is like with many interventions, one wants to mix methods. But to produce clean policy research, only the type of intervention may be varied. One might also notice the possibility that different interventions have different secondary effects. Direct instruction might not promote independence and reflection if it were the only method used for the entire program of education. But in the real world there are always mixtures. From present data, and relatively simple skills, Direct Instruction with Precision Teaching probably works the best. But discovery methods seem necessary to produce creativity in adults because there cannot be support by outsiders on key issues requiring creativity. Otherwise, the problems would have been previously solved and there would be no need for creativity.

Table 1. Stage Transition Steps and Substeps

Table 1a. Deconstruction in the Transition Steps

Step	Sub-step	Relation	Name	Dialectical Form
0 (4)		a = a' with b'	Temporary equilibrium point (thesis)	Previous stage synthesis does not solve all tasks. (Deconstruction Begins) Extinction Process
1		b	Negation or complementation (antithesis)	Negation or complementation, Inversion, or alternate thesis. Subject forms a second synthesis of previous stage actions). (antithesis)
2		a or b	Relativism (alternation of thesis and antithesis)	Relativism. Alternates among thesis and antithesis. The schemes coexist, but there no coordination of them). (alternation of thesis and antithesis)

Table 1b. Construction in the Transition Steps

3		a and b	Smash (attempts at synthesis)	The following substeps transitions in synthesis.
	1		Hits and Excess False Alarms and Misses	Elements from a and b are included in a non-systematic, non-coordinated manner. Incorporates various subsets of all the possible elements.
	2		Hit and Excess False Alarms	Incorporates subsets producing hits at stage n. Basis for exclusion not sharp. Over generalization
	3		Correct Rejections and Excess Misses	Incorporates subsets that produce correct rejections at stage n. Produces misses. Basis for inclusion not sharp. Under generalization
4(0)	4	a with b	New temporary equilibrium (synthesis and new thesis)	New temporary equilibrium (synthesis and new thesis)

Table 2. Behaviors may form classes. Stimuli may be placed into classes both functionally and analytically.

Order of Hierarchical Complexity	Name	Example
0	Calculatory	Simple Machine Arithmetic on 0's and 1's
1	Sensory & Motor	Either seeing circles, squares, etc. or instead, touching them. O ■
2	Circular Sensory-motor	Reaching and grasping a circle or square. O ■
3	Sensory-motor	A class of filled in squares may be formed ■ ■ ■ ■ ■
4	Nominal	That class may be named, "Squares"
5	Sentential	The numbers, 1, 2, 3, 4, 5 may be said in order
6	Pre-operational	The objects in row 5 may be counted. The last count called 5, five, cinco, etc * * * * * ■ ■ ■ ■ ■ O O O O O ■ / ○ □ □
7	Primary	There are behaviors that act on such classes that we call simple arithmetic operations 1 + 3 = 4 5 + 15 = 20 5(4) = 20 5(3) = 15 5(1) = 5
8	Concrete	There are behaviors that order the simple arithmetic behaviors when multiplying a sum by a number. Such distributive behaviors require the simple arithmetic behavior as a prerequisite, not just a precursor 5(1 + 3) = 5(1) + 5(3) = 5 + 15 = 20
9	Abstract	All the forms of five in the five rows in the example are equivalent in value, x = 5. Forming class based on abstract feature
10	Formal	The general left hand distributive relation is x * (y + z) = (x * y) + (x * z)
11	Systematic	The right hand distribution law is not true for numbers but is true for proportions and sets. x + (y * z) = (x * y) + (x * z) x □ (y □ z) = (x □ y) □ (x □ z)
12	Meta-systematic	The system of propositional logic and elementary set theory are isomorphic x & (y or z) = (x & y) or (x & z) Logic x □ (y □ z) = (x □ y) □ (x □ z) Sets T(False) □ φ Empty set T(True) □ Ω Universal set

Symbols

& = and
] = is equivalent to
' = intersection (overlap, elements in common)
≤ = union (total elements)
T = Transformation of
N = Empty set (no elements)
Σ = Universal set (all the elements there can be)
(Ex) = There exists some element x
(x) = For all x
(Hx) = The action on element x

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In Search of Contingency Learning: Something Old, Something New, Something Borrowed

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Adaptive switches can bring desired environmental events, such as cool air from a fan or music from a favorite radio station under the control of people with profound motor and communication deficits. A number of investigators have reported difficulties, however, in assessing whether people supported with switch-device configurations show cause-and-effect or contingency learning. Without expensive computer interfaces, analysis of switch-use is limited severely by inadequacies in commercially available adaptive equipment. Automated augmentations of typical switch-device configurations are described herein that provide data essential to accurate conclusions regarding the volitional nature of switch use. Case study examples of the importance of duration measures of responding and real-time data collection are provided. Relevance of this technology for identification of reinforcer preference hierarchies, field-based infant research, and treatment of challenging behavior are addressed.

Key words: adaptive switches, profound multiple disabilities, cause-and-effect learning, contingency learning, response variability, bin analyses, cumulative records

In Search of Contingency Learning: Something Old, Something New, Something Borrowed

Adaptive switches often are employed in educational and activity programs serving children and adults with profound multiple disabilities (Reid, Phillips, & Green, 1991). Adaptive switch programs often are directed at establishing communication skills such as signaling for attention, requesting, and choice making (Kennedy & Haring, 1993; Wacker, Wiggins, Fowler, & Berg, 1988). For others, the programs focus on establishing personal control of leisure-oriented materials or appliances, such as audio tape players, fans, vibrators, mechanical toys, and computer-delivered entertainment (Crawford & Schuster, 1993; Realon, Favell, & Dayvault, 1988; Saunders et al., 2001).

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Adaptive switches most commonly employed in such programs are constructed by housing a small electro-mechanical switch, or microswitch, in a user interface designed to make closure of the switch relatively effortless. Commercially manufactured microswitches, including pressure-sensitive disks, joysticks, mercury filled tubes and motion detectors, are available from a number of vendors. Switches can be used to toggle power on and off from both alternating current (AC) and direct current (DC) sources.

Adaptive switch programs usually are adopted and employed when efforts to establish more typical communication and environmental-control repertoires have failed. The individuals enrolled in switch programs often have severe motor skill deficits, with limitations in range of motion, grasp and release, coordination, and strength. Indeed, a common challenge to establishing a switch program is to identify a single physical movement that appears to be volitional and that also occurs with sufficient force and distance to displace a switch interface. Motor movement assessment also must address positioning and postural issues in the nonambulatory. Deafness, low vision, uncontrolled seizures, postural discomfort, multiple medications, frequent illnesses and other medical conditions characterize many individuals who might benefit from switch programs. Thus, individuals considered for microswitch supports frequently present with characteristics that interact to make interpretation of their switch responding difficult. These individuals are at risk of having switch supports discontinued or provided inconsistently because their switch use is perceived to be involuntary and therefore not functional.

Most data-based programs that employ adaptive switches usually employ a method of assessing whether switch use implies learning. In the present context, learning refers to establishment of differential responding across different response-event contingencies in adaptive switch configurations. Across disciplines other than behavior analysis, the descriptive phrase for differential responding is usually cause-and-effect learning, contingency learning (Gewirtz, 1997), or contingency awareness (Watson, 1966). In a typical test for contingency learning, an individual is exposed first to conditions in which responses to the switch do not produce an arranged outcome (no-activation condition). No-activation conditions are alternated with activation conditions in which responses produce an arranged outcome, such as music. Comparison of activation and no-activation conditions have been made across short consecutive periods (e.g., 5 min) within a session (Schweigert, 1989; Schweigert & Rowland, 1992), across single days with several short sessions per day (Dunst, Cushing, & Vance, 1985) and across several evaluation periods (e.g., 5-10 days) (e.g., Realon, Favell, & Lowerre, 1990; Schweigert, 1989; Saunders et al., 2001; Wacker et al., 1988).

In a review of studies of switch use in persons with disabilities, Lancioni, O'Reilly, and Basili (2001) reported that some participants did not show differential responding across no-activation and activation conditions. Participants either failed to show condition-related changes in responding (Dewson & Whiteley, 1987; Realon, Favell, & Dayvault, 1988; Ivancic & Bailey, 1996; Leatherby, Gast, Wolery, & Collins, 1992) or showed such highly variable responding across conditions that conclusions about contingency learning were equivocal (Leatherby et al., 1992; Ivancic et al., 1996). Discovering why contingency learning is not shown is complicated. Some switches provide sensory feedback (e.g., clicks, sudden displacement) that could compete with scheduled consequences (e.g., music). Response effort and fatigue, satiation, insufficient exposure to the contingencies and other factors also must be considered in data interpretation. This paper summarizes and presents illustrative data from our ongoing research on adaptive switch use by individuals with profound disabilities. The purpose of the paper is to introduce the reader to the data collection and analysis methods that have emerged to support this research. The methods have potential applications to clinical and field-based research in areas such as the treatment of aberrant behavior, infant learning, and self-monitoring of medication effects and side effects.

Method and Results

Participants

The individuals currently supported and studied in our work consist of about 120 individuals with severe to profound multiple disabilities, receiving services either in a skilled nursing facility or in community program offering vocational training, life enrichment and other supports in residential and day locations. Generally, these individuals present with an absence of language and other forms of communication, few coordinated movements, and suspected but difficult-to-measure sensory impairments. Profound mental retardation is inferred in nearly all but most are untestable with standardized instruments. Nearly all are nonambulatory. All require pervasive and extensive supports. A review of clinical records revealed that, prior to the institution of their switch programs, evidence of operant learning from formal programming was rare. Table 1 shows characteristics of the 9 participants whose data are discussed below.

Rate versus Duration Measurement

More than half of the individuals tested in our program of switch research initially showed little or no differences between activation and no-activation test phases. Our initial tests, conducted in the regularly scheduled daily recreation and leisure activity periods, relied on commercially available switch interfaces. Consequently, counts of switch closures were the only data we could collect with automated methods. To calculate rates of responding, session duration was measured with clocks or stopwatches and the automated counts were divided by session duration. The results of this limited methodology were disappointing. In most cases very low rates or highly variable rates of responding were recorded. Further, tests for contingency learning did not often provide conclusive data.

Table 1. Description of Participants

Participant	Age	Sensory impairment	Motor impairment	Other medical issues
Diane	58		severe bilateral spastic quadriplegia	scoliosis hydrocephaly seizure disorder
Robert	61	vision impairment	spastic quadriplegia	kyposcoliosis seizure disorder
Karen	29	blind: optic atrophy	spastic quadriplegia	kyposcoliosis microcephaly seizure disorder
Charles	37	blind: optic atrophy chorioretinitis	spastic quadriplegia	thorocolumbar rotoscoliosis
William	61	visual impairment	spastic quadriplegia	seizure disorder dysphagia
Mary	50	blind: retrolental fibroplasia	spastic quadriplegia choreoathetosis	encephalopathy hyperkeratosis of hands tardive dyskinesia
Ann	40	mild vision impairment	spastic quadriplegia	developmental aphasia
Tom	49	visual impairment	spastic paraplegia	seizure disorder
Alice	24		unsteady gait due to lymphedema	

When we changed to a homemade interface that permitted measurement of response duration, conclusions about contingency learning by our participants quickly changed (Saunders et al., 2001). The interface or data recorder was a 17.5 x 12 x 5 cm metal box housing a counter, timer, and other electronic components, shown in Figure 1, (Questad & Cullinen, 1987). All components were purchased through an electronics supply catalog. The box was connected in line between a participant's switch and a leisure device or appliance selected as a potential reinforcer. When the switch was depressed, concurrently the counter advanced one digit, the timer was activated, and the leisure device was activated. Device activation continued and the timer advanced digitally in increments of one-tenth of a minute until the switch was released. The total number and total duration of switch closures were recorded from the display panels located on the side of the box.

For the tests of contingency learning, the switch, leisure device, and data recorder were positioned physically in reference to the individual in the same way each activity period. When individuals were seated for activity periods, hand-depressed switches and the data recorder were located either on the individual's wheelchair tray or on a table in front of the individual's wheelchair. The switch was taped or affixed with Velcro® to the surface of the table or wheelchair tray top, as were all wires. Switches that operated with a head movement were attached to the back of the wheelchair using either a Velcro® strap or a special switch mount. Most leisure devices and the data recorder were located in front of the individual either on the table or wheelchair tray. When vibrators were the leisure devices, they were located in contact with the individual's body (e.g., vibrating pads are placed on upper legs; tube vibrators, around the neck). When an individual was positioned in bed for the activity period, the switch was clipped to the pillow or bed covers and wires were covered with a strip of cloth. Recorders and leisure devices other than vibrators were usually placed on a bedside table or shelf.

Table 2. Description of Switch Configuration

Participant	Type of switch	Position of switch	Leisure item activated	Position of participant
Diane	Big Red®	on wheel-chair tray	radio	sitting in wheelchair
Robert	Bass (Don Johnston, Inc.[4])	on wheel-chair tray	radio	sitting in wheelchair
Karen	Spec® (Ablenet, Inc.[2])	on pillow next to head	radio	prone in bed
Charles	Jelly Bean® (Ablenet, Inc.[2])	on wheel-chair head-rest	audio tape player	sitting in wheelchair
William	Pal Pad (Adaptivations Inc.[1])	on wheel-chair tray	audio tape player	sitting in wheelchair
Mary	Ellipse switch (Don Johnston[3])	on wheel-chair tray	tube vibrator	sitting in wheelchair
Ann	Pal Pad	on wheel-chair tray	vibrating pillow in lap	sitting in wheelchair
Tom	Multi-Sensory Center (Enabling Devices[4])	on table	vibration	sitting in chair
Alice	Pal Pad	on table	music	sitting in chair

Note.

[1]Adaptivations, Inc,. 2225 West 50th Street, Suite 100, Sioux Falls, SD 57105

[2]Ablenet, Inc., 1081 Tenth Avenue S.E., Minneapolis, MN 55414-1312

[3]Don Johnston, Inc., 26799 West Commerce Drive, Volo, IL 60073

[4]Enabling Devices, 385 Warburton Avenue, Hastings-on Hudson, NY 10706

At the start of each leisure activity period, the individual was prompted verbally and physically assisted to close the switch one time to activate the device. No further prompts were provided for the remainder of the activity period. At the end of the activity period, the time was recorded and the cumulative number of switch closures *and cumulative* duration of switch closures were transcribed from the readouts on the data recorder. The switch-closure count was transformed to rate. Total duration was transformed to "percent of activity period." Data were collected 3-4 times per week in activity periods of 45 min each. Recently, the data recorder shown in Figure 1 was replaced with a recorder with additional features, shown in Figure 2. The new recorder, manufactured specifically for this research by the University of Washington's Scientific Instruments Department, automatically records the length of the test period in addition to the total duration of responding and the number of responses. The new recorder also permits switch closures to either turn on a device or turn off a device that is already active or on.

Figure 3 shows results from Diane's tests for contingency learning in the top panels, with rate data plotted on the left and duration data (percent of activity period) plotted on the right. Table 2 provides information on Diane's switch, switch position, her position, and the leisure device she controlled (and similar information for the other participants).

Figure 1. Drawing of an early prototype of a data recorder for evaluation of adaptive switch use.

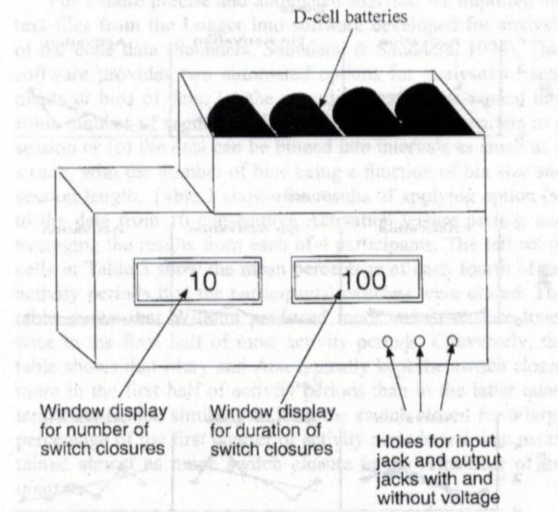


Figure 2. Drawing of the current data recorder. This unit displays switch closures, cumulative duration of switch closures, and cumulative duration of the session in the three LCD display windows labeled as a-c. Input/output jacks allow switches to activate a device, deactivate a device, or activate one device and deactivate a second device concurrently. The unit also has output for updating the HOBO® Logger regarding the state of the adaptive switch.

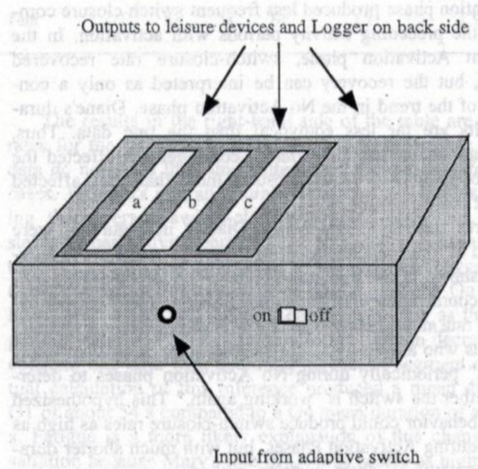
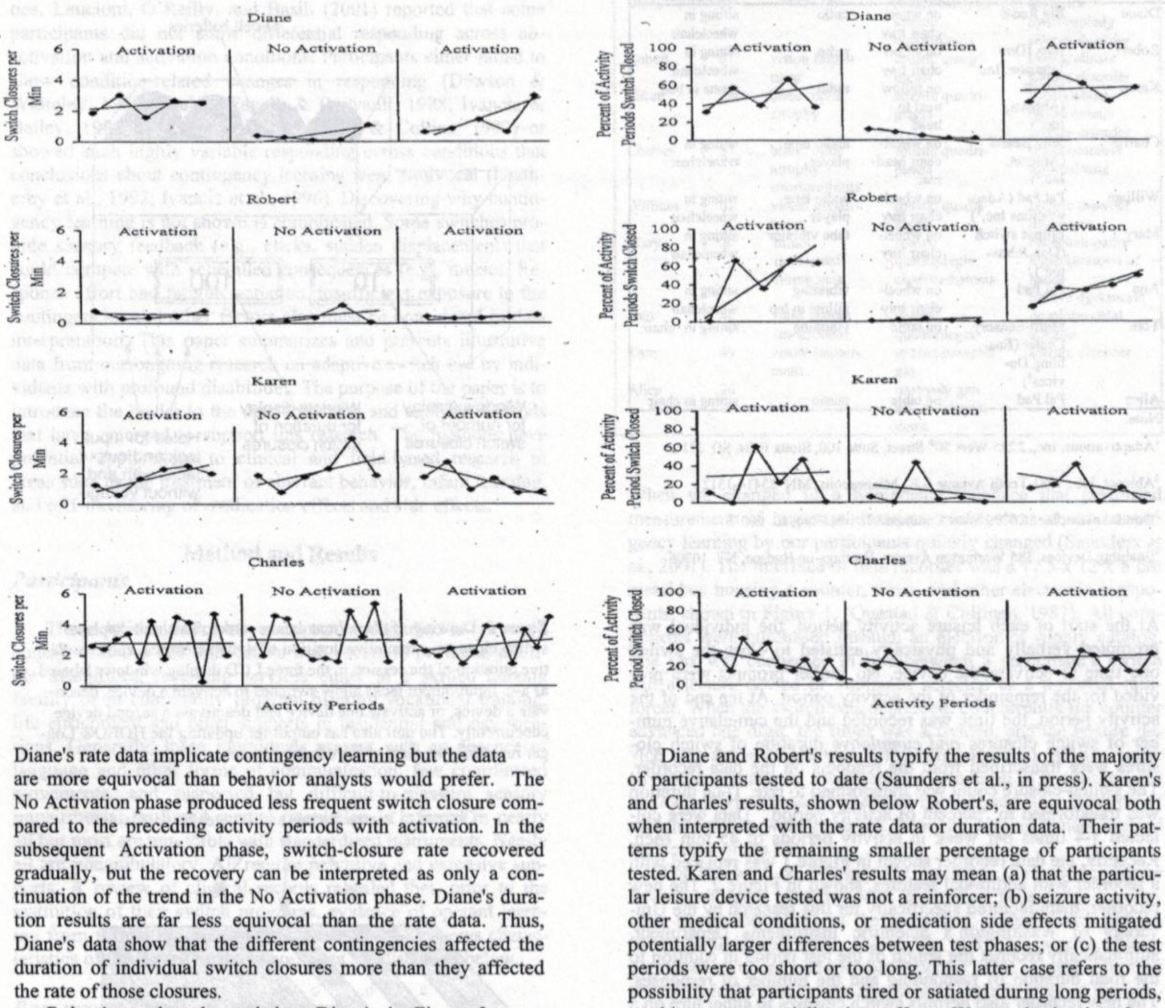


Figure 3. Graphs of rate switch closure and percent of session with switch closed (total duration) for 4 participants across multi-session tests for contingency learning.



Diane's rate data implicate contingency learning but the data are more equivocal than behavior analysts would prefer. The No Activation phase produced less frequent switch closure compared to the preceding activity periods with activation. In the subsequent Activation phase, switch-closure rate recovered gradually, but the recovery can be interpreted as only a continuation of the trend in the No Activation phase. Diane's duration results are far less equivocal than the rate data. Thus, Diane's data show that the different contingencies affected the duration of individual switch closures more than they affected the rate of those closures.

Robert's results, shown below Diane's in Figure 3, were comprised of totally inconclusive rate data. In contrast, the duration data shown in the right-hand panel provide convincing evidence of contingency learning as did Diane's. This contrast between the rate and duration results is not necessarily unexpected. Individuals who are motivated to activate their device are likely to "check" periodically during No Activation phases to determine whether the switch is "working again." This hypothesized checking behavior could produce switch-closure rates as high as observed during Activation Phases, but with much shorter durations. Alternatively, short duration responses might be maintained in the No Activation phase by sensory feedback from switch closures, as mentioned above.

Diane and Robert's results typify the results of the majority of participants tested to date (Saunders et al., in press). Karen's and Charles' results, shown below Robert's, are equivocal both when interpreted with the rate data or duration data. Their patterns typify the remaining smaller percentage of participants tested. Karen and Charles' results may mean (a) that the particular leisure device tested was not a reinforcer; (b) seizure activity, other medical conditions, or medication side effects mitigated potentially larger differences between test phases; or (c) the test periods were too short or too long. This latter case refers to the possibility that participants tired or satiated during long periods, washing out potentially clear effects. Were only the data from the first 5 min of each period analyzed, for example, contingency learning might have been shown. Alternatively, each may have had to learn the contingency anew each day. Thus, only the latter portion of each test period should be compared

Bin Analyses

To conduct analyses of specific portions of test periods the experimenter must either stop the tests at predetermined points, record the results, reset the counters, and restart the test or collect data throughout with real-time methods. In previous research requiring real time data, we employed bar code data collection technology (e.g., R. Saunders, Saunders, Brewer, &

Roach, 1996; M. Saunders, Saunders, & Marquis, 1998). Bar code systems require continuous observation by a human observer, however. In search of a methodology that did not require continuous observation, we found that the Onset Computer Corporation manufactures a variety of devices for continuous automated real time data collection. Some of their devices are used in climate and weather research. For our work, we borrowed from their technology by acquiring HOBO® State Loggers, HOBO® Shuttles and BoxCar ® Pro software.

HOBO® State Logger. The Logger is a plastic unit measuring approximately 4 x 6 x 1 cm. A CR-2032 lithium battery that provides enough power to operate for approximately 1 year of continuous use powers the unit. The Logger records switch closures in real time via input through a miniplug into its side. Thus, switch closures that activated participants' leisure devices could also be recorded with the Logger. The output from the Logger is a date and time stamped text file showing each change in the state of the switch--open versus closed. The Logger can store 2000 changes in state before its contents must be uploaded to a computer and its memory emptied.

HOBO® Shuttle. The Shuttle is a unit approximately 9 x 6 x 2 cm designed for uploading the contents of Loggers in the field. The Shuttle can store the contents of 200 Loggers before its contents must be uploaded to a computer. When the Shuttle empties the memory of a Logger, it re-initializes the Logger with the correct time and date and insures that its program is operational. The program operating in the Logger and the Shuttle is provided via BoxCar ® Pro software.

Figure 4. Schematic of the set up of a data recorder, Logger, adaptive switch, and leisure device.

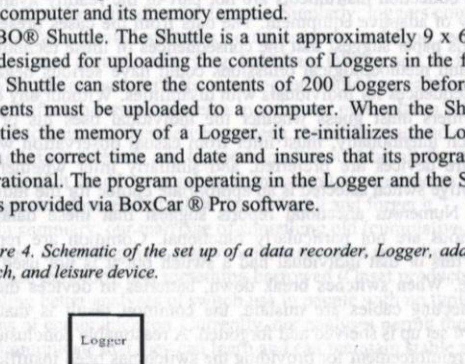


Figure 4 shows a schematic of the new recorder, a switch, a Logger, and a leisure device in the typical configuration. With this configuration, data have been collected and analyses begun to test our hypothesis that some participants do not respond consistently across their rather lengthy leisure activity periods. Following an activity period in which data are collected with this configuration, the BoxCar® Pro software produces summary statis*tics* (e.g., total number of closures) and can produce an on-screen depiction of the responding that occurred. The data are presented in the same form produced by event recorders, often common to animal laboratories. A continuous horizontal line depicts a switch in the open state and switch closures as vertical deviations from that line. The deviations are maintained as long as the switch is closed. Variations in response rate and response duration within the entire activity period can be detected with careful visual inspection of the event record.

For a more precise and automated analysis, we imported the text files from the Logger into software developed for analysis of bar code data (Saunders, Saunders, & Saunders, 1994). This software provides two automated options for analyses of segments or bins of data: (a) the recorded data can be binned into some number of segments of equal length, such as quarters of a session or (b) the data can be binned into intervals as small as 5 s each, with the number of bins being a function of bin size and session length. Table 3 shows the results of applying option (a) to the data from 10 consecutive Activation leisure periods and averaging the results from each of 4 participants. The left set of cells in Table 3 show the mean percentage of each fourth of the activity periods that the participants' switches were closed. The table shows that William produced more switch closure timewise in the final half of most activity periods. Conversely, the table shows that Mary and Ann typically kept the switch closed more in the first half of activity periods than in the latter quarters. Tom tended similarly to keep the switch closed for a large percentage of the first quarter of activity periods and then maintained almost as much switch closure in the remainder of the quarters.

Table 3. Percent of Time Closing the Switch and Rate of Switch Closures in Each Quarter of a Session

Participant	Percent				Rate per min			
	Q 1	Q 2	Q 3	Q 4	Q1	Q2	Q3	Q4
William	9	8	23	16	0.4	0.3	0.8	0.6
Mary	72	60	40	33	0.8	0.5	0.7	0.7
Ann	21	26	14	11	3.0	2.1	1.3	1.3
Tom	71	53	54	64	1.2	1.2	1.5	1.0

The results in the right-hand side of the table are the mean rates for the quarters of the same 10 activity periods. The rate data do not yield the same pattern as the duration data in some cases. William's rate and duration patterns are similar, suggesting that average switch-closure duration remained relatively stable across activity periods (i.e., percentages and rate change together in the same directions). Ann's data also suggest a relatively consistent average duration across quarters. On the other hand, Mary's rate and duration data suggest that as the activity periods progressed, her average closure duration decreased (i.e., constant rate data with declining percent-of-segment data). Actual calculation of this inference produced a mean duration in Q1 of about 54 s compared to a Q4 mean duration of about 28.5 s. Fatigue is a more likely explanation of this change than is satiation because Mary's rate in Q4 was nearly as high as in Q1. Tom's rate and duration data reveal no particular interaction. Thus, for individuals whose whole-session data are ambiguous, bin analyses can lead the experimenter to closer examination of particular periods of responding.

Cumulative Records

One method for closer examination of responding is the production of cumulative records (e.g., Ferster & Skinner, 1957), a technique rarely seen in reports of applied research today. We produced cumulative records from the HOBO® text files by binning a session or session segment into small intervals of time and calculating the percent of each interval that the switch was closed and the number of closures per interval (option b, above). These data were exported to an Excel® spreadsheet wherein an embedded formula was used to transform the data into a series of cumulative sums.

Figure 5. Cumulative records of within-session tests of contingency learning with Alice from consecutive 20-s bins of data. In the upper graph, the arrow labeled "a" points to a burst of responses in the first 20-s interval, arrow labeled "b" points to a single response lasting several intervals, and the arrow labeled "c" points to s series of intervals with several responses in each.

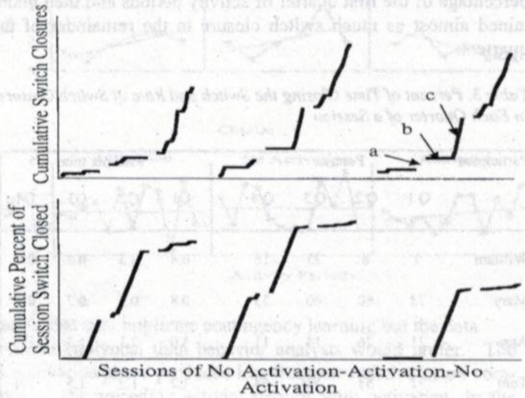


Figure 5 shows cumulative graphs for three contingency learning test sessions for Alice. Each 15-min test session was comprised of three 5-min phases. In these test sessions, Alice's tape player for listening to music was present on the table in front of her throughout each session. The tape player was not connected to the switch, however, in the first and third 5 min of each session.

The experimenter demonstrated what the switch did or did not do at the beginning of each 5-min phase by assisting Alice to make one switch closure. No prompts occurred thereafter. The cumulative records in the figure highlight the strengths of this form of analysis. First, the data show that learning occurred across test sessions. In particular, by the third session, the duration data (lower graph) show the pattern expected if learning occurred: The switch was closed nearly throughout the Activation phase, but was closed only briefly in the No Activation phases. The upper graph of cumulative responses shows a consistent pattern of low rate responding in the first No Activation phase followed by an increase during the Activation phase and even higher rate responding in the second No Activation phase. The data from the two graphs together can be interpreted as follows: Responding was not reinforced in the first phase; thus, response rates were low and long-duration responses extinguished across sessions. Responding was reinforced in the second phase, but high rates of responding are counter-productive if one desires continuous music; thus, rates remained modest and individual switch closures were relatively lengthy. In the third phase, high rate responding with very brief switch closures probably represents a schedule-history effect: Brief-duration, high-rate responding was an efficient method of "checking" to see if the music connection has been restored.

Discussion

Many clinicians, teachers, and care staff provide adaptive switches to individuals with profound multiple disabilities so they may control leisure devices. There is scant guidance from published research, however, on how to measure switch performances and evaluate the results. Most likely this is because data collection instruments are not part of the readily available array of adaptive equipment. The data from the cases presented in this paper suggest that the consequences of these technological and methodological omissions could have serious negative consequences for individuals with disabilities. Without any data, providers must guess whether the individual uses his or her switch intentionally, must infer from casual observation which leisure devices are preferred, and similarly infer whether the adaptive switch selected is an appropriate choice for the individual. Numerous anecdotal reports suggest that these data-less methods are not particularly functional. Common are reports that this or that individual had a switch but it is not used any more. When switches break down, batteries in devices die, or connecting cables are mislaid, the common result is that the entire set up is shelved and forgotten. A reasonable conclusion is that reinforcement for providing the switch has been insufficient to establish motivation for replacement and repair.

In the not-too-distant past, automated data collection of switch use would have required relay racks full of snap leads, bulky cumulative or 6-pen event recorders, and expensive timers. Clearly, classrooms, bedrooms, and living rooms are not places for these instruments. Microcircuitry and microprocessors are rapidly changing the possibilities, with emerging opportunities for behavior analysts. In the context of adaptive switches, for example, numerous areas need attention from professionals skilled in data analysis. In the current program climate, assessment of reinforcer preferences and provision of choice opportunities are hot topics. Field-based empirical evaluation of reinforcer preference is possible with equipment such as we described. Perhaps no better measure of preference can be found than comparison of the slopes of cumulative rate and duration. Another opportunity is evaluation of functional vision and hearing. Responding shown to be under the control of leisure devices with auditory or visual output can be tested for resistance to extinction as the auditory or visual output of the leisure devices is systematically altered (e.g. volume lowered). Alternatively, switch responding could be brought under the control of conditional auditory or visual stimuli. For example, the switch could be placed on a lighted tray and switch use scheduled to produce an outcome only when the light tray is turned on. Systematic modification of the brightness or color of the light tray could reveal some parameters of the individual's functional vision.

Field-based treatments or research on aberrant behavior, such as self-injury and severe tantrums, also could benefit from this technology. With a toggle switch or pressure switch attached to a belt or belt loop and a Logger in a pocket, parents, teachers, and care staff could obtain real-time records that permit measurement of rate and duration, as well as time-based scatter plots of target behaviors. Onset and duration of symptoms of medication side effects, epileptic seizures, and other health-related events could be measured accurately and easily. Similarly, medical patients could monitor and self-report the onset and duration of medical symptoms or medication side effects with this technology. Possibilities such as these in applied treatment settings appear endless.

Researchers interested in infant development might find this technology useful also. Placing a HOBO® in line between a crib-mounted kick panel and a mobile, for example, would permit real-time recording of play behavior without an experimenter or parent present. Indeed, several days of recording could occur between experimenter visits to upload the data to a Shuttle® and re-initialize the Logger. Similarly, loggers coupled with sound-activated switches could produce real-time records of onset and duration of crying, babbling, talking and so forth. Pressure plates, each with its own Logger, could be positioned to record infant movement patterns in cribs and other places infants are left to entertain themselves or sleep. As interesting and exciting as infant research can be, perhaps it would be all the more exciting if it could be conducted in natural environments with inexpensive devices that allow one to "set it and forget it."

In summary, our marriage of something old (cumulative records), something new (a device for automated recording of response duration), and something borrowed (Onset products) is enabling better analyses of switch use in people with no typical means of communication. Currently, our analyses permit them to communicate that they can learn and can maintain stable patterns of responding for some idiosyncratic period of time. The communication of that fundamental information should now enable us to establish a hierarchy of reinforcer preferences. If we find a hierarchy, we should be able to enable choice behavior (e.g., press the switch for device A and release the switch for device B) or even requesting (e.g., press the switch for device A and release the switch for a prolonged period to request device B in place of device A). This methodology may benefit not only our current population, but also, potentially, victims of stroke, traumatic brain injury, and neurological disease.

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The Evolution of Verbal Behavior in Children

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There is growing evidence of a developmental trajectory for key verbal capabilities. The evidence comes from research guided by Skinner's (1957) theory of verbal behavior and the accomplishment of schools based entirely on scientific practices. The broad verbal developmental fractures include: listener, speaker, speaker-listener exchanges with others, speaker as own listener (self-talk conversational units and naming), reader, writer, writer as own reader, and advanced verbal mediation. Many of the capabilities, and their subcomponents identified in the research, are higher order operants or relational frames. Our research first identified missing verbal capabilities in children, which, in turn, led to the identification and induction of pre and co-requisite repertoires. Once the missing verbal capabilities were induced in children who had been missing them, the children subsequently acquired repertoires that had not been possible for us to teach previously. We speculate on the relation of these capabilities or fractures in verbal function to linguistic, neuroscientific, cognitive and anthropological suppositions concerned with the evolution of language function in the individual's lifespan, as well as, the evolution of verbal function in the species.

The Evolution of Verbal Behavior in Children

Complex language is one of the unique repertoires of the human species. Others include teaching and certain "types of imitation" (Premack, 2004), although these too may be pre or co-requisites for certain functional uses of language. Over the last 40 years linguists have contributed theories and evidence about the structure of language (Chomsky, 1959; Chomsky & Place, 2000, MacCorquodale, 1970; Pinker, 1999). Neuroscientists have identified neurological correlates associated with some aspects of language (Deacon, 1979; Holden, 2004). Behavior analysts have focused on the source of and controlling variables for the function of language as behavior per se (Catania, Mathews, & Shimoff, 1990; Greer & Ross, 2004; Michael, 1984; Skinner, 1957).

More recently, scholars have come to view human language as a product of evolution; "Linguists and neuroscientists armed with new types of data are moving beyond the nonevolutionary paradigm once suggested by Noam Chomsky and tackling the origins of speech head-on." (Culottes & Brooks-Hanson, 2004, p. 1315). This work focuses on the evolution of both non-oral motor and oral components of speech (Deacon, 1997; Holden, 2004), although some arguments are characterized necessarily more by theory than data.

Despite the evidence that primates and pigeons can be taught certain features of verbal behavior (Epstein, Lanza, & Skinner, 1980; Premack & Premack; 2003; Savage-Rum Baugh, Rumbaugh, & Boysen, 1978), the speaker as own listener repertoire makes complex verbal behavior possible and this may be what is most unique about human verbal functions (Barnes-Holmes, Barnes-Holmes, & Cullinan, 2001; Lodhi & Greer, 1989; Horne & Lowe, 1996). Some suggest that oral communication evolved from clicking sounds to speech sounds, and they site the extant clicking languages (Pennisi, 2004). It is likely that sign language and gesture predated both vocal forms; but it is the evolution of the spoken and auditory components of language that are seen as critical to the evolution of language. Some of these include changes in the anatomy of the jaw—modern humans have more flexible jaws than did Neanderthals. Also, the location of the larynx relative to the trachea is different for humans, and this anatomical feature made it possible for the modern human to emit a wider range of speech sounds (Deacon, 1997). The combination of these anatomical changes together with the identification of separate, but proximate, sites in the brain for speaking, listening, and imitation seem part of what made spoken language possible (Deacon, 1997). The presence of these anatomical and physiological properties made it possible for the evolution of verbal functions through the process of cultural selection (Catania, 2001). The functional effects of speech sounds acquired by their consequences are provided within the verbal community. This latter focus is what constitutes the subject matter of the study of verbal behavior.

The new foci on language, as an evolved anatomical and physiological capacity, does not necessarily suggest the existence of a universal grammar; nor, in fact, does it eliminate the possibility of an evolved universal grammar. Some of the linguistic neuropsychological searches for an evolved universal grammar now follows the PET and MRI trails for discovering blood flow associated with the speech and hearing centers in the brain (Holden, 2004). Interesting and as important as this work may be, little of that work, if any, is devoted to the function of language as behavior per se. Nor is it concerned with the biological or cultural evolution of verbal function in our species or in the lifespan of the individual, although anthropological linguists point to functions as the initial source. Only the research associated with Skinner's (1957) theory of verbal behavior as behavior per se, and expansions of the theory by contemporary behavior analysts, provides the means for analyzing how cultural selection gave rise to the function of language (Greer, 2002; Greer & Ross, in press; Hayes, Barnes-Holmes, & Roche, 2000; Lowe, Horne, Harris, & Randle, 2002). Currently, the linguistic, neuropsychological work, and the behavior analytic foci remain separate sciences, though they need not remain so (Catania, 1998).

From Theory to Research

Although Skinner's work is often described as a theory, there is now a body of research supporting and expanding the theory. While a large portion of the literature on verbal behavior has been theoretical, we have identified over 88 experiments devoted to testing the theory, not including the significant body of related work in relational frame theory that includes at least an equal number of studies (Hayes et al., 2000). In our program of research in verbal behavior, we have completed approximately 44 experiments and a number of replications. Our particular research program was occasioned by our efforts to develop schools that provide all of the components of education based solely on teaching and schooling as a scientific endeavor. While the existing work in the entire corpus of behavior analysis provided a strong foundation for a science of schooling, much was still missing. Cognitive psychology offered a plethora of theories and findings, and when they were germane to our efforts, these findings proved to be operationally synonymous to those identified in behavior analysis. However Skinner's (1957) Verbal Behavior showed the way for a research program to fill in much of what was missing in a manner that allowed us to operationalize complex cognitive repertoires.

In our commitment to a thoroughgoing scientific approach to schooling, we needed functional curricula that identified repertoires of verbal operants or higher order operants. Our efforts involved using the pre-existing conceptual and applied verbal behavior research, identifying the needs of children who were missing certain repertoires, and identifying the validity of untested components of Skinner's theory through new experiments done by others and us. Through this process, we have been able to meet real educational needs, or at least the most pressing needs—the recognition of which were missing in the existing science of behavior or cognitive psychology. Of course, these educational voids were also apparent in normative practices in education based on pre-scientific approaches that treat teaching as an art. We needed findings that worked in the day-to-day operation of our schools, if we were to educate the "whole child." Along the way, we discovered some interesting aspects of verbal behavior that may prove useful to a behavioral developmental psychology (Baer, 1970; Bijou & Baer, 1978; Gewirtz, Baer, Roth, 1958; Gewirtz & Pelaez-Nogueras, 1991).

Repertoires of Verbal Behavior for Instructional Purposes

First, applications of the research findings in verbal behavior in our CABAS schools led to the categorization of children for instructional purposes according to levels of verbal behavior that we extrapolated from Skinner's analysis of the different components of verbal behavior (Greer, 2002). [1] While traditional diagnoses, or developmental constructs are useful for some inquiries, they are not very useful for instructional purposes. However, the identification of the functional verbal capabilities of children that we extrapolated from Skinner's work was very helpful. Skinner described the different verbal repertoires of the speaker and the relation of the speaker and listener in terms of typically developing individuals. These repertoires seemed to constitute what individuals need to possess if they are to function verbally, and those verbal functions provided operational descriptions for most of the complex educational goals that had been prescribed by educational departments throughout the western world (Greer & Keohane, 2004). For educational purposes, the categories or stages provided us with behavioral functions for a curriculum for listening, speaking, reading, writing, and the combinations of these that made up complex cognitive functions.

The verbal categorization proved useful in: (a) determining the ratio of instructors to students that would produce the best outcomes for the students (Table 1), (b) identifying what existing tactics from the research worked for children with and without particular verbal capabilities (See Greer, 2002, Chapters 5 and 6), what specific repertoires children could be taught given what each child initially brought to the table, and a curricula composed of functional repertoires for complex human behavior.

Most importantly, the categories identified specific verbal capabilities we needed to teach, if we were to make real progress with our children. The categories provided a continuum of instructional sequences that provided a functional approach to cognitive academic repertoires, and the recasting of state and international educational standards into functional repertoires of operants or higher order operants rather than structural categories alone (Greer, 1987, 2002; Greer & McCorkle, 2003). Each of the major verbal categories also identified levels of learner independence (i.e., operational definitions of autonomy) as well as what we argue are valid measures of socialization. Table 1 lists the verbal stages as we have related them to independence and social function.

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[1] For information on and the evidence base for teaching as a science in CABAS schools and the CABASÒ system see Greer (2002), Greer, Keohane, & Healy (2002), Selinski, Greer, & Lodhi (1991), and www.cabas.org. The findings of the research we describe have has been replicated extensively with children and adolescents in CABASÒ Schools in the USA, Ireland, Argentina and England and we believe they are robust. A book that describes the verbal behavior research and procedures in detail is in progress for publication in 2006 (Greer & Ross, in progress).

Table 1. Evolution of Verbal Milestones and Independence

Verbal Milestones	Effects on Independent Functioning
1) Pre Listener Status	Humans without listener repertoires are entirely dependent on others for their lives. Interdependency is not possible. Entrance to the social community is not possible.
2) Listener Status	Humans with basic listener literacy can perform verbally governed behavior (e.g., come here, stop, eat). They can comply with instructions, track tasks (e.g., do this, now do this), and avoid deleterious consequences while gaining habilitative responses. The individual is still dependent, but direct physical or visual contact can be replaced somewhat by indirect verbal governance. Contributions to the well-being of society become possible since some interdependency is feasible and the child enters the social community.
3) Speaker Status	Humans who are speakers and who are in the in the presence of a listener can govern consequences in their environment by using another individual to mediate the contingencies (e.g., eat now, toilet, coat, help). They emit mands and tacts and relevant autoclitics to govern others. This is a significant step toward controlling the contingencies by the speaker. The culture benefits proportionately and the capacity to be part of the social community is greatly expanded.
4) Speaker Listener Exchanges with Others (Sequelics and Conversational Units)	a) Sequelics. Humans with this repertoire can responds as a listener-speaker to intraverbals, including impure tacts and impure mands. Individuals can respond to questions for mand or tact functions or to intraverbals that do not have mand or tact functions. The individual can respond as a speaker to verbal antecedents and can answer the queries of others such as: What hurts? What do you want? What's that? What do you see, hear or feel? One is reinforced as a listener with a speaker response. b) Conversational Units. Humans with this repertoire carry on conversational units in which they are reinforced as both speaker and listener. The individual engages in interlocking verbal operants of speaker and listener. The individual is reinforced both as a listener for sensory extensions as well as a speaker.
5) Speaker as Own Listener Status Say Do Conversational Units Naming	a) Say and Do. Individuals with this repertoire can function as a listener to their own verbal behavior (e.g., first I do this, then I do that), reconstructing the verbal behavior given by another or eventually constructing verbal speaker-listener behavior). At this stage, the person achieves significant independence. The level of independence is dependent on the level of the person's listener sophistication. b) Self-talk. When a human functions as a reinforced listener and speaker within the same skin they have one of the repertoires of speaker-as-own-listener. The early evidence of this function is self-talk; young children emit such repertoires when playing with toys, for example (Lodhi & Greer, 1990). c) Naming. When an individual hears something as a listener and can use it as a speaker without direct instruction or can learn something as a speaker and use it as a listener without direct instruction, the individual has another repertoire of speaker as own listener. This stage provides the means to expand forms and functions through incidental exposure.
6) Reader Status	Humans who have reading repertoires can supply useful, entertaining, and necessary responses to setting events and environmental contingencies that are obtainable by written text. The reader may use the verbal material without the time constraints controlling the speaker-listener relationship. The advice of the writer is under greater reader control than the advice of a speaker for a listener; that is, one is not limited by time or distance. Advice is accessible as needed independent of the presence of a speaker.
7) Writer Status	A competent writer may control environmental contingencies through the mediation of a reader across seconds or centuries in the immediate vicinity of a reader on a remote continent. This stage represents an expansion of the speaker repertoires such that a listener need not be present at the time or at the same location as the writer.
8) Writer as Own Reader: The Self-Editing Status	As writers increase their ability to read their own writing from the perspective of the eventual audience, writers grow increasingly independent of frequent reliance on prosthetic audiences (e.g., teachers, supervisors, colleagues). A more finished and more effective behavior-evoking repertoire provides the writer with wide-ranging control over environmental contingencies such that time and distance can be virtually eliminated. Writing can be geared to different audiences without immediate responses from the target audience
9) Verbal Mediation for Solving Problems:	A sophisticated self-editor under the verbal expertise associated with formal approaches to problem solving (e.g., methods of science, logic, authority) can solve complex and new problems in progressively independent fashion. The characterization of the problem is done with precise verbal descriptions. The verbal descriptions occasion other verbal behavior that can in turn direct the action of the person to solve the particular problem. A particular verbal community (i.e., a discipline) is based on verbal expertise tied to the environment and modes of inquiry are made possible.

Much of our work as teacher scientists is devoted to experimentally identifying prerequisite or co-requisite repertoires needed by each child to progress. Once these were identified, we used or developed scientifically based tactics for moving a child with the lack of a particular verbal capability from one level of verbal capability to the next level in the continuum. When we found it necessary, and were able to teach the missing repertoires, the children made logarithmic increases in learning. As evidence accumulated with individual children and experiments, we also began to identify critical subcomponents of the verbal capabilities. Table 2 lists the verbal capabilities and the components and prerequisites that we are beginning to identify. As we began to identify more subcomponents, we worked our way inductively to the identification of the components within the verbal capabilities suggested by Skinner. The quest led serendipitously to increased attention on the listener and speaker as own listener repertoires, a focus that began to be evident in the work of others as well (Catania, Mathews, & Shimoff, 1990; Hayes, Barnes-Holmes, & Roche, 2000; Horne & Lowe, 1996).

Table 2. Verbal Milestones and Components

Pre-listener Components: Does the Child Have These Capabilities?

Visual tracking
Capacity for "sameness" across senses
Basic compliance based on visual contexts and the teacher or parent as a source of reinforcement

Listener: Does the Child Have These Capabilities?

Conditioned reinforcement for voices
Discrimination between words and sounds that are not words
Auditory matching of words
Generalized auditory matching of words
Basic listener literacy with non-speaker responses
Visual discrimination instruction to occasion instruction in naming
Naming
Observational naming and observational learning prerequisites
Reinforcement as a Listener (Listener reinforced by the effect the speaker has on extending the listener's sensory experience)
Listening to one's own speaking
Listening to one's own textual responses
Listening and changing perspectives: Mine, yours, here, there, empathy

Speaker: Does the Child Have These Capabilities?

Vocalizations
Parroting (Pre-echoic vocalizations with point to point correspondence)
Basic Echoic-to-mand function (consequence in and out of sight)
Echoic-to-tact function (generalized reinforcement control)
(Faulty echoics of echolalia and palillalia related to faulty stimulus control or establishing operation control that needs to be repaired through instruction)
Mands and tacts with basic adjective-object pairs developed as autoclitic frames
Transformation of establishing operations across mands and tacts
Impure mands (mands under multiple control)
Impure tacts (tacts under multiple control)
Tacts and mands emerging from incidental experience (naming and the speaker repertoires)
Comparatives: smaller/larger, shorter/longer, taller/shorter, warmer/colder in mand and tact functions
Specificity: in/on/under/beside/above/below, inside/outside as mand and tact functions
"Wh" questions in mand and tact functions

Speaker Listener Exchanges with Others: Does the Child Have These Capabilities?

Sequelics as speaker
Sequelics as listener-speaker
Conversational units (joint speaker and listener control)

Speaker as Own Listener: Does the Child Have These Capabilities?

Basic naming from the speaker perspective
Observational naming from the speaker perspective
Verbal governance of own speaker responses (say and do correspondence)
Conversational units in self-talk

Early Reader Repertoires: Does the Child Have These Capabilities?

Conditioned reinforcement for observing books
Textual responses: see word-say word at adequate rate improved by prior conditioning of print stimuli as conditioned reinforcement for observing
Match printed word, spoken word by others and self and printed word, spoken word and picture/object, printed word and picture/action
Responds as listener to own textual responding

Writer Repertoires: Does the Child Have These Capabilities?

Effortless component motor skills of printing or typing
Transformation of spelling across written and oral spelling and other joint stimulus control
Writes to affect the behavior of a reader for technical functions (mand, tact, autoclitic functions)
Transformation of stimulus function for metaphoric functions (word used metaphorically)
Writes to affect the emotions of a reader for aesthetic functions (mand, tact, autoclitic functions as well as simile and metaphor for prose, poetry, and drama and meter and rhyme scheme for poetry)

Writer as Own Reader (Self-Editing): Does the Child Have These Capabilities?

Is verbally governed by own writing for revision functions (finds discrepancies between what she reads and what she has written)
Verbally governs a technical audience by reading what is written as would the target audience (editing without assistance from others)
Verbally governs an aesthetic audience as a function of reading what is written as would the target audience (editing without assistance from others)

Verbal Mediation for Solving Problems: Does the Child Have These Capabilities?

Is verbally governed by print to perform simple operations
Is verbally governed by print to learn new stimulus control and multiple step operations
Is verbally governed by print to perform complex verbally mediated algorithms. (The characterization of the problem is done with precise verbal descriptions. The verbal descriptions occasion other verbal behavior that can in turn direct the action of the person to solve the particular problem. A particular verbal community, or discipline, is based on verbal expertise tied to the environment and modes of inquiry are made possible.)

It was evident that without the expertise to move children with language delays through a sequence of ever more sophisticated verbal capabilities, we could make only minimal progress with our children. As we began to identify ways to provide missing capabilities, the children began to make substantial gains. As the magnitude of the differences became apparent in what the children were capable of learning following the attainment of missing repertoires, we came to consider the possibility that these verbal repertoires represented developmental verbal capabilities.

We have shown that certain environmental experiences evoked the capabilities for our children. However, we are mindful that providing particular prerequisite repertoires that are effective in evoking more sophisticated verbal capabilities in children with language disabilities or language delays does not necessarily demonstrate that the prerequisites are component stages in all children's verbal or cognitive development. While Gilic (2004) demonstrated that typically developing 2-year old children develop naming through the same experiences that produced changes in our children with verbal delays, others can argue effectively that typically developing children do not require specially arranged environmental events to evoke new verbal capabilities. A definitive rejoinder to this criticism awaits further research, as does the theory that incidental experiences are not required. See Pinker (1999) for the argument that such experiences are unnecessary.

Milestones of the Development of Verbal Function: Fundamental Speaker and Listener Repertoires

Our rudimentary classifications of children's verbal development adhered to Skinner's (1957, 1992) focus on the verbal function of language as distinguished from a structural or linguistic focus. Skinner focused on antecedent and consequent effects of language for the individual as a means of identifying function, as distinguished from structure (Catania, 1998). Eventually, his theory led to a research program devoted to the experimental analyses of verbal behavior with humans. In a recent paper (Greer, & Ross, in press) and a book in progress (Greer & Ross, in progress), we have suggested that this research effort might be best described as verbal behavior analysis, often without distinction between its basic or applied focus. We have incorporated the listener role in our work, in addition to the speaker functions. While Skinner's self-avowed focus was the speaker, a careful reading of Verbal Behavior (Skinner, 1957/1992, 1989) suggests much of his work necessarily incorporated the behavior of the listener vis-à-vis the speaker (e.g., the source of reinforcement for the listener). Our research on the role of the listener was necessitated by the problems encountered in teaching children and adolescents with language delays, of both native and environmental origin, to achieve increasingly complex cognitive repertoires of behavior. Without a listener repertoire many of our children could not truly enter the verbal community. We needed to provide the listener roles that were missing and that were required if the repertoires of the speaker were to advance. Skinner made the point that a complete understanding of verbal behavior required the inclusion of the role of the listener (See the appendix to the reprint edition of Verbal Behavior, published by the B. F. Skinner Foundation, 1992, pp.461-470). Moreover, new research and theories based on Skinner's work have led to a more complete theory of verbal behavior that incorporates the role of the listener repertoire.

These include, but are not limited to: Research done by relational frame theorists (Barnes-Holmes, Barnes-Holmes, & Cullinan, 1999); Hayes, Barnes-Holmes, & Roche, B. (2000), Naming research by Horne and Lowe and their colleagues (Horne & Lowe, 1996); Lowe, Horne, Harris, & Randle (2002); Research on auditory matching and echoics (Chavez-Brown & Greer, 2004); Research on the development of naming (Greer, Stolfi, Chavez-Brown, & Rivera-Valdez, 2004); Research on conversational units and speaker-as-own-listener (Donley & Greer, 1993; Lodhi & Greer, 1989), and Research on learn units (Greer & McDonough, 1999).

Our levels of verbal capability incorporate the listener as part of our verbal behavior scheme. The broad categories that we have identified to date are: (a) the pre listener stage (the child is dependent on visual cues, or, indeed, they may not even be under the control of visual stimuli), (b) the listener stage (the child is verbally governed as in doing as others say) (c) the speaker stage (the child emits mands, tacts, autoclitics, intraverbal operants), (d1) the stage of rotating speaker-listener verbal episodes with others (the child emits conversational units and related components of learn units in interlocking operants between individuals), (d2) the speaker-as-own listener stage (the child engages in self talk, naming, speaker-as-own-listener editing function, and say-do correspondence), (e) reader (the child emits textual responding, textual responding as a listener and emergent joint stimulus control, and the child is verbally governed by text), (f) the writer stage (the child verbally governs the behavior of a reader for aesthetic and technical effects), (g) writer-as-own reader (the child reads and revises writing based on a target audience), and uses verbal mediation to solve problems (the child solves problems by performing operations form text or speech). Each of these has critical subcomponents and the subcomponents of the categories that we have identified to date are shown in Table 2.

The Listener Repertoire

In the verbal community a pre listener is totally dependent on others for her care, nourishment, and very survival. Pre-listeners often learn to respond to a visual and tactile environment; but if they do not come under the control of the auditory properties of speech they remain pre-listeners. For example, in certain situations they learn to sit when certain visual cues are present. It is often not the spoken stimuli such as "sit still, "look at me," or "do this" to which they respond, but rather certain instructional sequences or unintentional visual cues given by teachers and caretakers. They do no respond to, or differentiate among, the auditory properties of speech as stimuli that evoke specific responses. When the basic listener repertoire is missing, children cannot progress beyond visual or other non-auditory stimulus control. However, substantial gains accrue when children achieve the listener capability, as we shall describe.

Auditory Matching. It is increasingly apparent, that children need to match word sounds with word sounds as a basic step in learning to discriminate between words, and even distinguish words from non-word sounds. While most infants acquire auditory matching with apparent ease; some children do not acquire this repertoire incidentally. Chavez-Brown & Greer (2003) and Chavez-Brown (2004) taught children who could not emit vocal verbal behavior or whose vocal speech was flawed to match pictures first using BigMackÒ buttons as a pre training procedure to teach them to use the apparatus to learn to match words. The teacher touched a single button in front of her that had a picture on it and she touched each of the two buttons the students had in front of them (one with the target picture and one with a foil picture). Then the students responded by touching one of the two buttons in front of them that matched the picture touched by the teacher. Once the children mastered the visual matching task, as a means to introduce them to the apparatus, we removed the pictures and taught them to match the sound generated by the teacher's button (the buttons produced individual pre-recorded words or sounds). At this second stage one of the students' buttons had a sound and one of their buttons had no sound. Once they mastered matching the words contrasted with no sound buttons, they matched words with non-word sounds as foils, and then they matched particular words contrasted with different words. Finally, they learned generalized matching for words produced by pushing the buttons (i.e., novel word sets). Our findings showed that children, who had never vocalized before, began to approximate or emit echoic responses under mand and tact establishing operations as they mastered generalized word matching. Moreover, a second set of children, who had only approximations (i.e., faulty articulations), learned full echoics that graduated to independent mands and tacts. This matching repertoire may be an early and necessary step in the acquisition of speaking and may also be key to more advanced listening. See also correlations between auditory matching and the emissions of verbal operants identified by Marion et al. (2003) that suggested the auditory matching research we described above.

The Emersion of Basic Listener Literacy. When children have "auditory word matching" they can be taught the discriminative function necessary to become verbally governed. In the past few years, we found that children without listener repertoires reached a learning plateau and were no longer making progress in instruction beyond extensions of visual matching. We believe that children around the world who have these deficits are not making progress in early and intensive behavioral interventions. These children require inordinate numbers of instructional presentations, or learn units, and still do not make progress on repertoires that require verbal functions that are the very basic building blocks of learning. In an attempt to help these children become listeners, we developed an intervention that we call listener emersion (Greer, Stolfi, Chavez-Brown, & Rivera-Valdez, 2004.). During listener emersion, we suspend all of the children's instructional programs and provide intensive instruction in responding to the discriminative acoustical properties of speech. This instruction continues until children's listener responses are fluent.[2]

In the listener emersion procedure, children learned to respond to words spoken in person by a variety of individual voices as well as to voices recorded on tapes and other sources. By fluent, we mean that the children learned to respond to four or more sets composed of five instructions such as "point to ___," "match ___", "do this," "stand up," and "turn around." The children also learned not to respond to nonsensical, impossible, or non-word vowel-consonant combinations that are inserted into the program as part of each set. These sets were presented in a counterbalanced format with criterion set at 100% accuracy. Next the children learned to complete the tasks at specified rates of accurate responding ranging from 12 to 30 per minute. Finally, they learned to respond to audio taped, mobile phone, or computer generated instructions across a variety of adult voices. Once the children's basic listener literacy emerged (i.e., the children met the listener emersion criteria), we compared the numbers of learn units required by each student to meet major instructional goals both before and after listener emersion. After acquiring the basic listener literacy, the numbers of instructional trials or learn units that they required to achieve instructional objectives across the range of their instruction decreased from four to ten times what had been required prior to their obtaining basic listener literacy.

The Speaker Stage

Acquisition of Rudimentary Speaker Operants. In the late eighties, we identified procedures for inducing first instances of vocal speech that proved more effective than the operant shap-

[2] We chose the term listener emersion because it seemed particularly appropriate. The Oxford English Dictionary 2nd Edition describes one usage of the term emersion as follows, "The action of coming out or issuing (from concealment or confinement). Somewhat rare." (OED, p. 177) Thus, once a child has acquired the listener repertoire, the child may be said to have come out of confinement to a pre listener status. They have acquired an essential component of what is necessary to progress along the verbal behavior continuum.

ing of spoken words as linguistic requests (Williams & Greer, 1989). That is, rather than teaching parts of words as vowel consonant blends, that had been the existing behavioral procedure (Lovaas, 1977), we arranged the basic establishing operations and obtained true mands and tacts using echoic-to-mand and echoic-to-tact procedures (Williams & Greer, 1989). Once true verbal operants were taught, the children used "spontaneous speech." The children came under the relevant establishing operations and antecedent stimuli (Michael, 1982, 1984, 1993) associated with mand and tact operants and related autoclitics, rather than verbal antecedents such as, "What do you want?" They did not require intraverbal prompts as a means of teaching pure tacts. In another procedure Sundberg, Endicott, and Eighenheer (2000) evoked the emission of impure tacts and the emission of impure tacts and mands; these are necessary repertoires as well.

While children who do not speak can be taught verbal behavior through the use of signs, pictures, or electronic speaking devices, speech is simply more useful. Speech works in the community at large. When we are unable teach speech, we too, use these substitutes, although there are few children that we cannot now teach to speak. The second choice for topography for us is electronic speaking devices because such devices supply the possibilities for speaker as own listener. The importance of speech becomes apparent when we reach the critical verbal repertoires of speaker as own listener and reader.

Although the use of the above procedures significantly increased the numbers of children we could teach vocal verbal operants to, there were still some children we could not teach to speak. While we could teach these children to use substitute topographies for speech, the development of speech is critical for subsequent verbal capabilities. For those children who did not learn to speak using our basic echoic-to-mand and echoic-to-tact procedures (Williams & Greer, 1989), we , and others, designed and tested several tactics to induce first instances of speech. We taught children who had acquired fluent generalized imitation, but who could not speak, to perform chains of generalized imitation of large and small movement responses at a rate of approximately 30 correct per minute at 100% accuracy. These children were then deprived of preferred items for varying periods of time and were only able to obtain the items contingent on speech under conditions in which they first performed a rapid chain of generalized imitation (moving from large motor movements to fine motor movements related to touching their lips and tongue). As soon as the last motor movement step in the teaching chain was completed we offered the item under deprivation as we spoke its name. After several presentations as described, the children spoke their first echoic mands.

Some of these children were as old as nine years of age and their first words were not separate phonemes but were mands like "baseball card, coke, or popcorn." Once the echoic to mand was induced for a single word or words, other echoic responses were made possible and their independent mand repertoire was expanded. Follow-ups performed years after these children spoke their first words showed that they maintained and expanded their mand and eventually tact repertoires extensively (Ross & Greer, 2003). We currently think that the procedure acted to induce joint stimulus control across the two independent behaviors of imitating and echoing (see Skinner, 1957 for the important distinction between imitation and echoic responding).

In an extension of this work, Tsiouri & Greer (2003) found that the same procedure could be used to develop tact repertoires, where the establishing operation was deprivation of generalized reinforcers. See Skinner (1957, page 229) for a source for the establishing operations for the tact. Moreover, tacts and mands could be evoked in tandem fashion where emission of the tact operants resulted in an opportunity to mand as a result of using the tandem procedures developed in Williams & Greer (1989).

The establishing operation is key to the development of these rudimentary operants (Michael, 1982, 1984, 1993). There appear to be three tested establishing operation tactics: (a) the interrupted chain (Sundberg, Loeb, Hale & Eighenheer (2001/2002), the incidental teaching procedure in which the incidental establishing operations opportunities are captured (Hart & Risely, 1975), and the momentary deprivation procedure (Williams & Greer, 1989). Schwartz (1994) compared the three procedures and found them equally effective but that the momentary deprivation procedure resulted in slightly greater maintenance and required significantly less time. It is suggested that more powerful results may accrue if each of these establishing operations are taught in a multiple exemplar fashion providing the child with a range of establishing operations for controlling the emission of rudimentary operants. Still other establishing operation tactics are needed like the identification of establishing operations for tacts described in Tsiouri and Greer (2003). Also, see Sundberg, et al. (2001/2002) for mand establishing operations. Indeed what is characterized in the literature as "naturalistic language" interventions are essentially suggestions for capturing establishing operations (G. McDuff, Krantz, M. McDuff, & McClannahan, 1988). The difficulty with relying solely on the capture of incidental establishing operations is that there are simply not enough opportunities to respond. There is now an abundance of tested tactics for evoking establishing operations in instructional sessions that can be used without waiting for the incidental occasion, although it is critical to capture the incidental opportunities.

From Parroting to Verbal Operants. The stimulus-stimulus pairing procedure of Sundberg, Michael, Partington and Sundberg (1996) evoked first instances of parroting of words as a source of automatic reinforcement. These investigators paired preferred events, such as tickling, while the experimenters said words and the children began to parrot the words or sounds. Moreover, the children emitted the words in free play suggesting that the saying of the words had acquired automatic reinforcement status. Yoon (1998) replicated the Sundberg et al. procedure, and after the parroting was present for her students, she used the echoic-mand tactic described above (Williams & Greer, 1989) to evoke true echoics that, in turn, became independent mands. Until the parroted words were under the echoic to mand contingencies, the children were simply parroting as defined by Skinner (1957); however, obtaining the parroting as an automatic reinforcer made the development of true echoics possible. The emission of the parroting response may be a crucial first step and may be as complex as acquiring stimulus transformation.[3] The children in these studies moved from the listener to

[3] It would seem that a certain history must transpire in order for a point-to-point correspondence between a word spoken by a parent and the repetition of the word by a child to qualify as an echoic operant rather than parroting. The child needs to say the word under the relevant dep-

the speaker stage as a result of the implementation of extraordinary instructional procedures (See Sundberg & Partington, 1998 for an assessment and curriculum). Once a child has acquired a speaker repertoire, the speaker-listener repertoire becomes possible. Speaker capabilities opened extraordinary new possibilities for these children, as they did for our ancestors in the combined evolution of phylogenic capabilities with capabilities evoked by cultural selection.

Transformation of Establishing Operations Across Mand and Tact Functions. Initially, learning one form (e.g., word or words) in a mand or tact function does not result in usage of the form in the untaught function without direct instruction (Lamarre & Holland, 1985; Ribes-Inesta, Gomar-Ruiz, & Rivas, 1975; Twyman, 1996). For example, a child may emit a word as a mand (e.g., "milk") under conditions of deprivation, such that the emission of "milk" results in the delivery of milk. But, the child cannot use the same form ("milk") under tact conditions (i.e., the emission of the word in the presence of the milk when the reinforcement is a social or other generalized reinforcement probability). While the independence of these two functions have been reliably replicated in young typically and non-typically developing children, at some point most children can use forms that they acquired initially as a mand and use the same forms as a tact, or vice versa. Some see this as evidence of something like a neurologically based universal grammar that makes such language phenomena possible (Pinker, 1999). Clearly, neural capacities must be present just as the acoustic nerve must be intact to hear. But, the unequivocal existence of a universal grammar does not necessarily follow; the source is at least as likely to lie in the contingencies of reinforcement and punishment and the capacity to be affected by these contingencies in the formation of relational frames/higher order operants. One example of the acquisition of a higher order operant is the acquisition of joint control of a form in either mand or tact functions after learning only one function. Although the mand and tact functions are initially independent at some point, a child can use a form in an untaught function without direct instruction.

Nuzzolo-Gomez and Greer (2004) found that children who could not use a form learned in a mand function as a tact, or vice versa, without direct instruction in the alternate function (Lamarre & Holland, 1985; Twyman, 1996a, 1996b), could be taught to do so when they were provided relevant multiple exemplar experiences across establishing operations for a subset of forms. Greer, Nirgudkar, & Park (2003) replicated these finding and we have used the procedure effectively with numerous children in CABAS schools. The new verbal capability doubled incidental or direct instructional outcomes.

Speaker Immersion. Even after the children we taught had acquired a number of rudimentary speaker operants, some did not use them as frequently as we would have liked. Speaking had emerged but it was not being used frequently, perhaps because the children had not received adequate opportunities of incidental establishing operations. We designed a procedure for evoking increases in speaker behavior that we called speaker immersion (Ross, 1995). Once we immersed the children, for whom the operants had already emerged, in instruction devoted to the continuous use of establishing operations requiring speaking responses for all reinforcement throughout the day, the children's use of verbal operants dramatically increased as they learned to maximize gain with minimal effort. The children learned that it is easier and more efficient to get things done by speaking than by emitting responses that require much more energy.

rivation conditions associated with the mand or the tact and then have that echoic evolve into either a mand or a tact. Once at least one of these events transpires, the parroting can move to an echoic. While more sophisticated operants and higher order operants or relational frames are basic to many sophisticated aspects of verbal behavior, the move from parroting is probably just as complex. The acquisition of echoing is the fundamental speech component of verbal functioning. One wonders how long, and under what conditions, it took for the echoic repertoire to evolve in our species. To evoke true echoics in children who have never spoken is probably one of the major accomplishments of the behavioral sciences. Indeed, the procedures we now use in verbal behavior analysis to induce first instances of vocal verbal operants have never been tried with primates, nor have these procedures been used to induce parroting. However, procedures for inducing parroting and echoics and other first instances of vocal verbal behavior have been successful in developing functional vocal verbal behavior in individuals who probably would have never spoken without these procedures. Amazing! There are even more fundamental components underlying even these response capabilities and aspects of observation show rich potential (Premack, 2004).

Milestones of Speaker and Listener Episodes: Interlocking Verbal Operants Between Individuals

Verbal Episodes Between Individuals

Verbal behavior is social, as Skinner proclaimed, and perhaps one cannot be truly social without verbal behavior. A major developmental stage for children is the acquisition of the repertoire of exchanging speaker and listener roles with others—what Skinner (1957) called verbal episodes. A marker and a measure of one type of verbal episode is the conversational unit, while another type of verbal episode is a learn unit. We developed these measures as indices of interlocking verbal operants. No account of verbal behavior can be complete without the incorporation of interlocking verbal operants.

Epstein, Lanza, and Skinner (1980) demonstrated verbal episodes between two pigeons. We argue that they demonstrated a particular kind of interlocking verbal operant that we identify as a learn unit. In that study, after extensive training, the researchers had two pigeons, Jack and Jill, respond as both speaker and listener in exchanges that simulated verbal episodes between individuals. Each pigeon responded as both speaker and listener and they exchanged roles under the relevant discriminative stimuli as well as under the conditions of reinforcement provided by each other's speaker and listener responses (a procedure also used in part by Savage-Rumbaugh, Rumbaugh, & Boysen, 1978). The pigeon that began the episode, the teacher pigeon, controlled the reinforcement in the same way that teachers deliver effective instruction (Greer & McDonough, 1999). That is, the teacher pigeon had to observe the responses of the student pigeon, judge its accuracy, and consequate the student pigeon's response. Premack (2004) noted that the lack of this kind of teaching observation in primates is one of the repertoires that are unique to humans. In the Epstein et al. study, special contingencies were arranged in adjacent operant chambers to evoke or simulate the teaching repertoire. Note that the pigeon that served as a student did not emit the reciprocal observation that we argue needs to be present in a verbal episode that we characterize as a conversational unit. In a conversational unit both parties must observe, judge, and consequate each other's verbal behavior.

Conversational Units

We used the determination of verbal episodes as measures in studies by Becker (1989), Donley & Greer (1993), and Chu (1998) as well as related research by Lodhi & Greer (1989). However, the units of verbal episodes in these studies involved both individuals initiating episodes that involved reciprocal observation accruing from reinforcement as a speaker and as a listener. We called these episodes conversational units. In the first step of a conversational unit, a speaker responds to the presence of a listener with a speaker operant that is then reinforced by the listener. This verbal interaction is what Vargas (1982) identified as a sequelic. Next, the listener assumes a speaker role under the control of the initial speaker. That is, the listener function results in the extension of sensory experiences from the speaker to the listener as evidenced by the speaker response from the individual who was the initial listener. The initial speaker then functions as a listener who must be reinforced in a listener function (i.e., the initial listener as speaker extends the sensory capacities of the initial speaker as a listener). A new unit begins when either party emits another speaker operant. Interestingly, in the cases of children with diagnoses like autism, we can now teach them the sequelic speaker function in fairly straightforward fashion using procedures described above. However, these children often have little interest in what the speaker has to say. The reinforcement function for listening is absent. We are currently working on this problem.

Conversational units are essential markers of and measures of social behavior and, we argue, their presence is a critical developmental milestone in the evolution of verbal behavior. By arranging natural establishing operations, Donley and Greer (1993) induced first instances of conversation between several severely delayed adolescents who had never before been known to emit conversation with their peers. Coming under the contingencies of reinforcement related to the exchange of roles of listener and speaker is the basic component of being social. Chu (1998) found that embedding mand operant training within a social skills package led to first instances of, and prolonged use of, conversational units between children with autism and their typically developing peers. Moreover, the use of conversational units resulted in the extinction of assaultive behavior between the siblings extending Carr and Durand's (1985) finding.

Learn Units

Learn units are verbal episodes in which the teacher, or preprogrammed teaching device (Emurian, Hu, Wang & Durham, 2000), controls the onset of the interactions, the nature of the interactions, and most of the sources of reinforcement for the student. The teacher bases her responses on the behavior of the student by reinforcing correct responses or correcting incorrect responses. The interactions provided in the Epstein et al. (1980) and the Savage-Rumbaugh et al. (1978) studies are learn units rather than conversational units as we described above. (See Greer, 2002, Chapter 2, for a thorough discussion of the learn unit and Greer & McDonough, 1999 for a review of the research).

Milestone of Speaker as Own Listener: Verbal Episodes "Within the Skin"

As Skinner pointed out, the speaker may function as her own listener as in the case of "self-talk." Lodhi and Greer empirically identified speaker as own listener in young typically developing children who engaged in self-talk while playing alone (Lodhi & Greer, 1989). This appears to be an early, if not the first, identification of conversational units in self-talk emitted by individuals under controlled experimental conditions. The developmental literature is replete with research on self-talk and its importance, but until the functional components defining self-talk were identified, self-talk remained essentially a topographical measure because the speaker and listener functions were not identified. It is very likely that speaker as own listener types of learn units are detectable also, although we have not formally tested for them except in our studies on print control that resulted in students acquiring self administration of learn units (Marsico, 1998).

We agree with Horne and Lowe (1996) that a speaker as own listener interchange occurs in the phenomenon that they identified as naming. Naming occurs when an individual hears a speaker emit a tact, and that listener experience allows the individual to emit the tact speaker function without direct instruction and further to respond as a listener without direct instruction. Horne and Lowe (1996) identified the phenomenon with typically developing children. Naming is a basic capability that allows children to acquire verbal functions by observation. It is a bidirectional speaker listener episode. But what if the child does not have the repertoire? For example, matching, pointing to (both listener responses, although the point- to is a pure listener response), tacting, and responding intraverbally to multiple controls for the same stimulus (the speaker response as an impure tact) are commonly independent at early instructional stages. This is the case because, although the stimulus is the same, the behaviors are very different. The child learns to point to red but does not tact (i.e., does not say "red" in the presence of red objects, or tacts and does not intraverbally respond to "What color?"). This, of course, is a phenomenon not understood well by linguists because they operate on the assumption that understanding is an automatic given—a human example of generative verbal behavior, if you will. It is a source of many problems in learning for typically developing and non-typically developing children, as well as college students who demonstrate differences in their responses to multiple-choice questions (selection responding) versus their responses to short answer or essay questions (production responding). At some point, children can learn a match or point-to response and can emit a tact or intraverbal response without direct training. This is not, however, automatic for some children. Thus, if naming were not in a childs' repertoire, could it be taught?

Induction of One Component of Naming. Greer, Stolfi, Chavez-Brown, & Rivera-Valdes (2004) found that one could isolate experimentally a particular instructional history that led to naming for children who did not initially have the repertoire. After demonstrating that the children did not have the repertoire for tacts, we provided a multiple exemplar instructional intervention with a subset of stimuli involving rotating match, point-to, tact, and intraverbal responding to stimuli until the children could accurately do all of the responses to the subset. We then returned to the initial set and a novel set as well and showed that the untaught speaker listener repertoires had emerged.

These data suggested that the acquisition of naming, or one component of naming (i.e., going from listener to speaker) could be induced with multiple exemplar experiences. Naming is a generative verbal repertoire that Catania (1998) has called a "higher order operant." The Relational Frame Theorists described this particular higher order operant as an incidence of transformation of stimulus function (Hayes, Barnes-Holmes, & Roche, 2000). Skinner referred to the phenomenon as responding in different media to the same stimulus (i.e., thematic grouping) and Relational Frame Theorists provided feasible environmental sources for this and related phenomena (i.e., multiple exemplar experiences). That is, a particular response to a single stimulus or category of stimuli when learned either as a listener repertoire or as a speaker repertoire is immediately available to the individual as a response without direct instruction once the individual has stimulus transformation across speaker and listener. We found that the naming repertoire emerged as a function of specific instructional experiences. This represents another case of the emergence of generative verbal behavior that is traceable to environmental circumstances. Fiorile (2004) replicated this finding. Naming also represents the acquisition of one of the speaker as own listener stages. When children have acquired it, they have new verbal capabilities. Other types of generative behavior are traceable to multiple exemplar experiences, as we will discuss later.

Induction of Untaught Irregular and Regular Past Tense Responding. Still another case of speaker as own listener repertoires probably occurs in the emission of verb endings colloquially often associated with the cliché "kids say the darnedest things" (Pinker, 1992). We recently found that we could evoke untaught correct usage of regular and incorrect but "spontaneous" emission of irregular verbs (i.e., "he singed last night") as a result of multiple exemplar instruction with young children with developmental disabilities who could not emit either regular or irregular novel past tense forms without direct instruction (Greer & Yuan, 2004). The children learned to emit novel regular past tense forms without direct instruction and this abstraction was extended to irregular verbs. That is they emitted incorrect irregular forms such as "he singed" as do young typically developing children. In a related study, Speckman (2004) found that multiple exemplar experiences also resulted in the emission of untaught suffixes as autoclitic frames for tacts. However, it is important to recognize that Pinker (1999) says the fact that children begin to use the correct irregular forms at some point, rather than the incorrect forms, without any direct instruction is a more important capability. We suspect that multiple experiences could induce this capability too, although this research remains to be done.

Milestones of Reading, Writing, Self-Editing: Extensions of the Speaker and Listener Repertoires

Reading

Reading involves textually responding (seeing a printed word and saying the word), matching various responses to the text as comprehension (printed stimulus to picture or actions, the spoken sound and all of the permutations of this relationship) (Sidman, 1994). At first glance, the reader stage appears to be simply an extension of the listener repertoire; however, on closer scrutiny, reading is necessarily an advanced speaker as own listener repertoire because the reader must hear what is read. Reading consists of speaker-listener relationships under the control of print stimuli, actions or pictures. Textually responding requires effortless rates of responding to print stimuli in order to "hear" the spoken word. After all, it was the Middle Ages before we began to read silently and many religious and other ancient cultural practices still adhere to ceremonies in which one person reads to an audience.

The capacity to hear what one reads is important because the acoustical physical properties of sound allow more "bits" to be transmitted by sound than is possible with signs. For example, children who are deaf from birth, have extreme difficulty developing reading comprehension beyond Grade 6 (R. Kretchmer, personal communication, October, 2003). There are special auditory properties of speech that allow a great deal of information or bits to be used for the benefits of the reader (aesthetic or functional), or at least this was the case before computers. Good phonetic instruction results in children textually emitting untaught combinations of morphemes and if those words are in their listener repertoire they comprehend (see Becker, 1992, for the relevant research on multiple exemplar instruction and the emission of textual responses to untaught morphemes). However, even if a child can textually emit an accurate response to the printed stimuli, if the listener comprehension is not present the child "will not understand" what she has read (i.e., be unable to match the sounds to a picture or action). One can read a foreign language aloud and have no idea about what one is saying. Thus, the listener component is key. For example, adolescents with multiple year delays in their reading achievement may not comprehend because they can not emit a textual response to a particular word or group of words, but once they hear a spoken version they immediately comprehend, because their listener vocabulary exceeds their textual repertoire. The listener component of reading is as important as the textual speaking component; thus, a reader must be a reader as own listener, so to speak.

There is still a more basic component of reading that we identify as conditioned reinforcement for observing print and pictures in books. Tsai & Greer (2003) found that when they conditioned books such that 2 and 3-year old children chose to look at such books in free time, with toys as alternate choices, these children required significantly fewer learn units to acquire textual responses. The book stimuli selected out the children's observing responses, and once the children were observing, they were already closer to acquiring print stimuli as discriminative stimuli for textual responses. Thus, an early predictor of children's success in textual responding appears to be the conditioned reinforcement for observing book stimuli. Conditioned reinforcement for books may constitute a new capability. We currently also believe that pre-listener children who do not orient toward speakers and who are having listening and speaking difficulties may need to have the unfamiliar and familiar voices of adults acquire conditioned stimulus control for observing. This too may be a crucial stage in the acquisition of listener repertoires.

Writing

Writing is a separate behavior from reading and like the repertoire of speaking, represents a movement up the verbal scale. But, writing from a functional verbal perspective requires that the writer affect the behavior of the reader; that is they must observe the effects of their writing and in turn modify their writing until the writing affects the behavior of the reader. In the case of technical writing, the writer must provide technical information that affects the readers behavior ranging from influencing a shopper through provision of a shopping list, to the provision of an algorithm that affects complex scientific decisions. Writing, as in the case of speaking, needs to be under the control of the relevant establishing operations, if the writing is to be truly verbal. In several experiments, we provided establishing operations for writing with students whose writing did not affect the behavior of the reader, using a tactic we call writer immersion. In its basic form all communication is done in written form for extended periods throughout the day. Written responses are revised until the reader responds as the writer requires. This procedure resulted in functionally effective writing, measured in effects on readers, and improvements in the structural components of writing (grammar, syntax, vocabulary, punctuation, spelling) (Gifaldi & Greer, 2003; Keohane, Greer, & Mariano-Lapidus, 2004; Jadlowski, 2000; Madho, 1997). The experience taught the students to write such that they read as the target readers, or target audience, would read. The editing experience appears to evoke writer as own reader outcomes of self-editing, not unlike speaker as own listener (Jadlowski, 2000). This repertoire then appears to be an advanced speaker as own listener stage—one that requires one to read what one writes from the perspective of the target audience whose behavior the writer seeks to influence. Thus, like the reader function, the writer function builds on the speaker as own listener. Some difficulties in writing and reading are probably traceable to missing components of the speaker, listener, or speaker as own listener components.

Complex Verbally Governed and Verbally Governing Behavior

Technical Writing. Another key component of the complex cognitive repertoires of individuals involves reading or being verbally governed by print for technical outcomes. Marsico (1998) found that teaching students to follow scripts under conditions that allowed the investigators to observe the control of the print over the students' responses resulted in students "learning to learn" new concepts in math and more complex reading repertoires by acquiring verbally governed responding from print sources. This repertoire allowed the students to be verbally governed by print. As this repertoire becomes more sophisticated it leads to the more complex repertoire of solving complex problems from algorithms as in the case of the following of decision protocols. Keohane (1997) and Nuzzolo-Gomez (2002) in separate experiments showed that teacher scientists could perform complex data decision steps using algorithms based on the verbal behavior of the science that resulted in significant improvements in the outcomes of the teachers' students. Verbal rules guided data analysis and tactical decisions that were implemented with the teachers' students. These studies are analyses of the verbal behavior of scientists and the verbal stimulus control involved in complex problem solving repertoires suggested by Skinner (1957). We argue that these studies investigated observable responses that are both verbal and nonverbal and that such responses are directly observed instances of thinking.

While neuroscientists could probably locate electrical activity in the brain associated with our putative thinking responses, it is only the behavior outside the skin that distinguishes the electrical activity as thinking as opposed to some other event that might be correlated with the activity. Verbal stimuli control the complex problem solving, not the electrical activity—the electrical activity, although interesting, maybe necessary, and important, but is not thinking per se. One might argue that the electrical activity is light in a black box; although we see within "the black box", we do not see outside of the black box. This is an interesting reversal of the black box puzzle. If the electrical activity were to begin before the relevant contingencies in the environment were to be in place, the problem in the environment would not be solved.

One of the key components in writing is the process of spelling. Spelling involves two different and initially independent responses-- saying the letters for a dictated word and writing the letters. At some point we do emit an untaught response after learning a single one of these behaviors (see Skinner, 1957, 1992, p.99). How does a single stimulus (i.e., hearing the word) come to control these two very different behavioral topographies of writing and orally saying the letters? Recently we found that for children who initially could not perform the untaught function, providing multiple exemplar instruction for a subset of words across the two responses under a single audited vocal stimulus resulted in these students acquiring the repertoire with novel stimuli (Greer, Yuan, & Gautreaux, 2004). Like transformation of establishing operations for mands and tacts, and transformation of stimulus functions across speaker and listener in naming, the transformation of writing and saying in the spelling repertoires is still another environmental source for generative verbal behavior as an overarching operant or a higher order operant (Catania, 1998; Hayes, Barnes-Holmes, & Roche, 2000). These repertoires consist of learned arbitrary relationships between listening, speaking, and writing. It is not far-fetched to infer that typically developing children acquire this joint stimulus control across independent responses as higher order operants or relational frames through multiple exemplar experiences that the rotation writing and saying opportunities occur through similar incidental experiences rather than with the programmed experiences we provided our children. Once the child has transformation of stimulus control over written and spoken spelling, only a single response need be taught.

In related research, Gautreaux, Keohane, & Greer (2003) found that multiple exemplar instruction also resulted in transformation of selection and production topographies in geometry.

That is, middle school children who could not go from multiple choice responding to the production or construction prior to the multiple exemplar instruction, did so after an instructional history was created by multiple exemplar instruction across a subset of selection and production experiences. This study highlighted the difficulties experienced by some older children that may be due to a lack of prior verbal instructional histories. The replacement of missing verbal capabilities is may be the key to solving instructional difficulties experienced later in life with more complex subjects. When an individual is missing a component capability, it is possible that the remediation of the difficulty only truly occurs when the missing capability is put in place.

Aesthetic Writing. In an earlier section, we described writing repertoires that were of a technical nature. Aesthetic writing has a different function than technical writing (Skinner, 1957). Aesthetic writing seeks to affect the emotions of the reader. To date, little empirical work has been accomplished with the aesthetic writing repertoire. A critical, if not the most basic component of aesthetic writing, is the writer's use of metaphors as extended tacts. Meincke, Keohane, Gifaldi, and Greer (2003) identified the emergence of novel metaphorical extensions resulting from multiple exemplar instruction. This effort points to the importance of isolating and experimentally analyzing experiential components of aesthetic writing and suggests the role of metaphorical comprehension in reading for aesthetic effects. This also suggests that rather than teaching the aesthetics of reading through literary analysis as an algorithm, a student should have the relevant metaphoric experiences and perhaps these may be pedagogically simulated. It is likely that these metaphoric experiences provide the basis for the aesthetic effects for the reader. In order for the exchange to occur, the target audience for the writer must have the repertoires necessary to respond to the emotional effects. Of course the analysis of aesthetic writing functions is probably more complex than the analysis of technical repertoires, but we believe empirical analyses like the one done by Meincke et al. (2003) are becoming increasingly feasible. If so, the aesthetic and functional writer and reader repertoire may be revealed as new stages of verbal behavior.

From Experimental Effects to a Theory of Verbal Development

We believe we have identified several verbal repertoires that are key in children's development of successively complex repertoires of verbal behavior. Providing several of these repertoires to children who did not have them allowed these students to advance in their cognitive, social, technical, and aesthetic capabilities. As a result of this work we were increasingly persuaded that these levels of verbal capabilities did, in fact, represent empirically identifiable developmental milestones.

For our children, the capabilities that they acquired were not tied to tautological relationships associated with age (Baer, 1970; Bijou & Baer, 1978; Morris, 2002). Age may simply provide a coincidental relation between experiences that bring about verbal capabilities and the probabilities of increased opportunities for those experiences. Hart and Risely (1996) showed that impoverished children who had no native disabilities, but who had significantly fewer language experiences than their more well off peers, demonstrated significant delays by the time they reached kindergarten. When children with these deficits in experience with language continued in schools that did, not or could not, compensate for their sparse vocabulary, these children were diagnosed as developmentally disabled by grade 4 four (Greenwood, Hart, Walker, & Risely, 1996). It is not too farfetched to suggest that absence of the kinds of experiences necessary to evoke higher order verbal operants that we have identified, may also be part of the contribution to these delays.

We suggest that the presence of incidental multiple exemplar experiences provide the wherewithal for most typically developing children to seamlessly acquire the verbal milestones we described, probably because they have both the environmental experiences and neural capabilities (Gillic, 2004). For children without native disabilities who lack multiple exemplar experiences (Hart & Risely, 1996), as well as children with native disabilities who lack the necessary verbal capabilities, intensive multiple exemplar instruction may induce missing repertoires (Nuzzolo-Gomez & Greer, 2004). Such experiences probably result in changes in behavior both within and outside of the skin. Indeed biological evidence suggests that, " DNA is both inherited and environmentally responsive." (Robinson, 2004, p. 397; also see Dugatkin, 1996 for research on the influence of the environment on changes in genetically programmed behavior affected by environmental events). What may be an arbitrary isolation of behavior beneath and outside the skin may dissolve with increased research in the environmental effects on both types of behavior.

Our induction of these repertories in children, who did not have them prior to instruction, suggests it is not just age (time) but particular experiences (i.e., environmental contingencies including contingencies that evoke higher order operants) that make certain types of verbal development possible, at least for the children that we studied. Intensive instruction magnified or exaggerated these experiences and provided our children the wherewithal to achieve new verbal capabilities. We speculate also that the inducement of these verbal capabilities in children who do not have them prior to special experiences, creates changes in neural activity. Of course, a test of this is the real challenge facing developmental neuroscience (Pinker, 1999). A joint analysis using the science of verbal behavior combined with instrumentation of the neurosciences might prove very useful in assisting children. Incidentally, such an analysis might also act to enrich academic debate towards more useful outcomes.

Tables 1 and 2 showed the levels of verbal functions for the pre-listener through the early reader stages in summary form. We described the evidence that has proved useful in our efforts to induce and expand progressively sophisticated verbal functions. The capabilities that we addressed were originally identified based on the responses of individual children; specifically, they were based on our empirical tests for the presence or absence of the repertoires for individual children. In our educational work, when a particular repertoire was missing, we applied the existing research based tactics to provide the child with the repertoire. When we encountered children for whom the existing tactics were not effective, we researched new tactics or investigated potential prerequisite repertoires and related experiences that appeared to be missing for the child. The searches for possible prerequisite repertoires led to the identification of several subcomponents which when taught, by providing subcomponent repertoires, led to the emergence of verbal capabilities that were not present prior to our having provided the prerequisite instructional experience.

We continue to locate other prerequisites and believe that there are many others that remain to be tapped. Examples of rudimentary verbal functions that have been identified in the research include: (a) the emergence of better acquisition rates across all instructional areas as a function of teaching basic fluent listening, (b) the induction of parroting and then echoics that led to independent mand and tact functions, and relevant autoclitics for children with no speech or other verbal functions, (c) transformation of establishing operations across the mand and tact function for children for whom a form taught in one function could not be used in an untaught function prior to multiple exemplar instruction, (d) the identification of interlocking speaker as own listener operants in self-talk with typically developing children (Lodhi & Greer, 1989), (e) induction of conversational units with children who had no history of peer conversational units (Donley & Greer, 1993), (f) the induction of naming in children who did not have naming prior to multiple exemplar instructional experience (Greer, Stolfi, Chavez-Brown, & Rivera, 2004), (g) the emission of untaught past tenses for regular and irregular verbs as a function of multiple exemplar instruction (Greer & Yuan, 2004), (h) the emission of untaught contractions, morphemes and suffix endings as a function of having children tutored using multiple exemplar experiences (i.e., observational learning through multiple exemplars) (Greer, Keohane, Meincke, Gautreaux, Chavez-Brown, & Yuan, 2004, Speckman, 2004)), (i) better acquisition rates for acquiring textual responses as a function of conditioning books as preferred stimuli for observing (Tsai & Greer, 2003), (j) and the induction or expansion of echoic responding as a function of the acquisition of generalized auditory matching (Chavez-Brown, 2004).

The more advanced writer, writer as own reader or self-editing milestones involve key complex cognitive repertoires. Research in this area includes: (a) teaching more effective writer effects on readers and structural responses of writing as a function of establishing operations for writing (Madho, 1997. Greer & Gifaldi, 2003), (b) the induction of rule governed or verbally governed responding and the effects on verbal stimulus control of algorithms (Keohane, 1997; Marsico, 1998; Nuzzolo, 2002), (c) the role of multiple exemplar instruction on the emergence of metaphors (Meincke et al., 2003), (d) transformation of stimulus function across vocal and written spelling responses (Greer, Yuan, & Gautreaux, 2004), and (e) the acquisition of joint stimulus control across selection and production topographies (Gautreaux, et al., 2003). These more complex repertoires, we argue, build on the presence of speaker as own listener capabilities.

While we are not ready to declare emphatically that the capabilities that we have identified experimentally, or by extrapolation from experiments, have been definitively identified as verbal developmental stages, the evidence to date shows that they are useful for instructional functions. Furthermore, they suggest natural fractures in the development of verbal function.[4]

For typically developing children, these fractures may occur as a result by brief experiences with exemplars. For some typically developing 2-year old children that we have studied, simply having a few experiences with exemplars going from listener to speaker, followed by single exemplars going from speaker to listener, resulted in bidirectional naming that they didn't have prior to those separate but juxtaposed experiences (Gilic, 2004). While our children with language delays required the rapid rotation across listener and speaker exemplars to induce naming, investigators have yet to document the emergence of naming independent of experiences like those we describe; that is, to demonstrate that they emerge independent of experiences like those we describe would require rigorous isolation from such experiences. Simply pointing to certain repertoires and claiming that they evolved without experience no longer seems credible.

Some of the research we described is not yet published and our references include papers presented at conferences or unpublished dissertations not yet submitted for publication. Thus, these are early days in our work on some of the stages. But it is important to note also that we have been on a quest for the last 20 years to remediate learning problems based on verbal behavior deficits in children with and without disabilities. The quest has moved forward based on progressively more complex strategic analyses as we stumbled on what we now believe may be developmental milestones in verbal behavior. We have replicated most of the effects we have identified with numerous children in our CABAS schools in the USA, England, and Ireland. Thus, we believe that the evidence is robust and we hope that it can be useful to behavior analysts, neuroscientists, and linguists interested in a thorough analysis of the evolution of verbal behavior.

We have also speculated on the cultural evolution of verbal functions for our species relative to our proposed verbal developmental scheme (i.e., the role of cultural selection). Of course theories on the evolution of language are so extensive that some linguistic societies have banned their proliferation; yet, anthropologists and linguists are now suggesting there is new evidence to support the evolution of language (Holden, 2004). Some linguistic anthropologists may find the evolution of cultural selection of verbal operants and higher order verbal operants useful. It is even possible that the capacity for higher order operants and relational frames constitutes that which has been attributed to a universal grammar. Speaker and listener responses could have evolved from basic verbal operants to interlocking speaker and listener responding between individuals and within the skin of individuals (self-talk and naming)—an evolution made possible by our anatomical and physiological capacities to acquire higher order operants combined with cultural selection. Moreover, reading and writing functions also probably evolved

[4] We use the term natural fracture to differentiate numerically scaled hypothetical relations from relations that are absolute natural events as in the determination of geological time by the identification of strata. To further illustrate our point, "receptive speech" is a hypothetical construct based on an analogy made between the computer "receiving inputs" to auditory speech events. It is an analogy not a behavior or response class. Measures of receptive behavior are scaled measures tied to that analogy as in test scores on receptive speech. However, listener behavior is composed of actual natural fractures (i.e., the child does or does not respond to spoken speech by another). In still another example, operants are natural fractures, whereas, an IQ is a scaled measure of a hypothetical construct. Moreover, acquisitions of higher order operants such as the acquisition of joint stimulus control for spelling are also natural fractures.

as an extension of the basic speaker and listener functions; without them reading and writing would not have been possible at least in the way it has evolved for the species.

The human species, at its current level of evolution, is basically verbal, but it was not always so. A verbal behavior could have arisen from nonverbal sources and its transmission from generation to generation would have been subject to influences which account for the multiplication of norms and controlling relations and the increasing effectiveness of verbal behavior as a whole. (Skinner, 1992, p.470)

Speaker/writer operants and listener/reader responses constitute an important, if not the most important, aspect of human behavior as adaptation to what is increasingly a verbal environment. Simply speaking, verbal behavior analysis is the most important subject of a science of behavior. We hope it is not too presumptuous of us to suggest that verbal behavior analysis can contribute to a developmental psychology that treats environmental contributions as seriously as it treats the non-environmental contributions. After all, biology has come to do so (Dugatkin, 1996; Robison, 2004).

While we can simulate human listener and human speaker functions with nonhuman species (Epstein, et al., 1980; Savage-Rumbaugh et al., 1978), the simulation of naming and other speaker as own listener functions with nonhuman species remains to be demonstrated. Premack (2004) argues from the data that nonhumans lack the capacity for recursion. "Recursion makes it possible for words in a sentence to be widely separated yet be dependent on one another." (Premack, 2004, p. 320). We suggest that recursion may have been made possible by the evolution of speaker as own listener capabilities in humans as a function of both neural capabilities and cultural selection. Premack (2204) also presents convincing evidence that teaching is a strictly human endeavor. "Unlike imitation, in which the novice observes the expert, the teacher observes the novice—and not only observes, but judges and modifies." (Premack, 2004, p. 320; D. Premack & A. Premack, 2003). This describes the interaction we have characterized as in what takes place in a learn unit. The conversational unit differs from the learn unit in that the conversational unit requires a reciprocal observation. Observational repertoires like those Premack (2004) described may be fundamental components that underlie and presage the evolution of nonverbal to verbal behavior.

Observational Learning

While observation has been studied as a phenomenon, few if any studies have sought the possible environmental source for observational learning. We argue that observational learning differs from other indirect effects on behavior in that observational learning results in the acquisition of new operants. Other types of observational effects on behavior result in the emission of operants that were already in the observer's repertoire. The kind of behavior changes identified by Bandura (1996) were most likely of the latter sort since the presence or absence of the operants were not determined prior to the observational experience. Imitation results from a history that reinforces correspondence between the imitator and a model's behavior.

Some children do not have observational learning. They have weak observational repertoires. In cases where observational learning has been missing, we have induced it by providing certain experiences. It also may be possible that all children do not have observational learning until they have certain experiences. In one study, we increased observational learning as a function of having individuals function as tutors using learn units that required tutors to reinforce or correct the responses of their tutees. It was the application of the learn unit per se, specifically the consequence component that produced the new observational repertoire (Greer, Keohane, Meincke, Gautreaux, Pereira, Chavez-Brown, & Yuan, 2004). In another case with children who did not learn by observing peers, we taught them to monitor learn unit responses of their peers and observational learning emerged (Greer, Pereira, & Yuan, 2004).

This observing phenomenon involves a kind of consequent benefit similar to what the listener gains —specifically the extension of sensory reinforcement. Perhaps the teaching capacity involving reinforcement of the observed behavior of the learner is related to particular listener capabilities, while the recursion phenomenon is related to the interlocking speaker-listener capability. It is the interlocking speaker-listener-as-own-listener functions that make the more sophisticated milestones of verbal function possible. These functions make possible thinking, problem solving, true social discourse, and the development of repertoires compellingly described in relational frame theory (Hayes, Barnes-Holmes, & Roche, 2000). Speech and, we argue, the compression of information made possible by auditory stimuli in the human species, makes possible the more advanced speaker as own listener or textual responder as own listener and perhaps by extension the phenomenon of recursion. Regardless of whether our interpretation of the evidence is compelling, the evidence does reveal that a more complete picture of verbal behavior is evolving and that the role of the listener, and particularly the interrelationship between speaker and listener, is key to further advances in our understanding of verbal functions and their development within the individual.

Verbal Behavior Analysis and the Neuroscience of Language

None of the work we have described, or related work in verbal behavior, obviates the role of genetically evolved brain functions as the neurology correlated with the presence of our suggested milestones of verbal behavior and the generative aspects of behavior cum language. The research in verbal behavior does not question, or eliminate, the importance or usefulness of neuropsychological researches. Alternately, the work in the neuroscience of language does not obviate the environmental verbal functions of language as behavior per se and as higher order operants that are increasingly identified in verbal behavior analysis. They are simply different sciences involved with different aspects of language. On the one hand, work in verbal behavior analysis is beginning to identify key environmental experiences in cultural selection and suggests how neuropsychology can make the journey from MRI analyses to real verbal function—behaving with language outside of the skin. On the other hand, the work in the neurosciences of language is beginning to identify the behavior beneath the skin. It is compelling to consider the mutual benefit of obtaining a more comprehensive understanding of language to consider relating the efforts. Most importantly, combining the evidence and types of inquiry from both fields can help us teach a few more children to be truly verbal.

Behavior analysts have simulated language functions in non-humans (Epstein et al., 1980; Savage-Rumbaugh et al., 1978) and comparative psychologists have identified differences between the verbal behavior of primates and the verbal behavior of humans (Premack, 2004). Non-human species have not demonstrated speaker as own listener. However, research in verbal behavior analysis has led to the acquisition of listener repertoires, speaker repertoires, speaker as own listener repertoires, and generative verbal behavior in humans who did not have those repertoires prior to special environmental experiences. Perhaps work in verbal behavior analysis with individuals who can acquire verbal repertoires as a result of special interventions provides a bridge. While our particular work is driven by applied concerns, it may have some relevance to the basic science of behavior and even comparative psychology. Hopefully, readers who are more knowledgeable about these issues than we, will excuse our large canvas on the grounds that we are but simple teacher scientists. However, to us, there are few establishing operations as compelling for the growth of a science than the need to save a few children.

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Author's Note:
We would like to dedicate this paper to the memory of B. F. Skinner who would have been 100 years old at the writing of this paper. His mentorship and encouragement to the first author served to motivate our efforts to master his complex book and engage in our experimental inquires. We are also indebted to others who kept verbal behavior alive in times when the critics were harsh and the audience was narrow. Among these are Jack Michael, Charles Catania, Ernest Vargas, Julie Vargas, Mark Sundberg, U. T. Place, Kurt Salzinger, Joe Spradlin, Joel Greenspoon, and the children we worked with who needed what verbal behavior could offer in order for them to become social and more cognitively capable individuals. While the audience remains narrow, we are confident that the effects of research in verbal behavior will select out a larger audience.

Correspondence Training, Rule Governance, Generalization, and Stimulus Control: Connections or Disconnections?

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Correspondence training has been investigated steadily since the early research of Risley and Hart (1968). The outcomes of correspondence training are of particular interest in this paper because the consequences provided for the exhibition of the target behavior are not provided immediately following the verbal response to the question or following the target behavior, but are provided at some time after the behavior has been exhibited. Despite a lack of definitive understanding regarding the functional properties that are responsible for their effectiveness, correspondence training procedures now have been investigated for two decades. It is concluded that the effectiveness of correspondence training procedures and their contribution to generalization of behavior change substantiates their importance in the field of applied behavior analysis.

Correspondence training is a set of procedures in which an individual states a behavior to be exhibited, usually in response to a question, and reinforcement is delivered if the behavior is subsequently exhibited. "Correspondence", then, is the agreement between the antecedent statement and the consequential action. It can be defined as the exhibition of the target response at a time and place distant from the initial statement and the successive provision of the reinforcer for "corresponding". Correspondence training has been investigated steadily since the early research of Risley and Hart (1968). Their seminal work demonstrated that young children could receive training that would result in correspondence between their antecedent verbalizations and the responses that follow. The outcomes of correspondence training are of particular interest because the consequences provided for the exhibition of the target behavior are not provided immediately following the verbal response to the question or following the target behavior, but are provided at some time after the behavior has been exhibited. In the Risley and Hart study, the interval between the statement made by the children, the exhibition of the target response, and the receipt of reinforcers was a minimum of several minutes' duration. In other correspondence training research, this interval has varied from several minutes to as much as a day.

The initial research of Risley and Hart sparked a plethora of investigation into correspondence training. These have included examining the clinical utility of correspondence training to resolve problems associated with attention deficit hyperactivity disorder (Paniagua, 1992; Paniagua & Black, 1990), low levels of peer-directed talk exhibited by language-delayed and socially withdrawn young children (Osnes, Guevremont, & Stokes, 1986; Osnes, Guevremont, & Stokes, 1987), school to home correspondence (Baer, Osnes, & Stokes, 1983), correspondence training as a maintenance-promoting strategy (Baer, Williams, Osnes, & Stokes, 1985) and inattentiveness in classroom settings by children with mental retardation (Keogh, Burgio, Whitman, & Johnson, 1983; Whitman, Scibak, Butler, Richter, & Johnson, 1982).

With the increasing frequency and sophistication of investigation into the area of correspondence training, questions have arisen. When correspondence occurs, what process is responsible? The only known answer apparent upon initial analysis is that correspondence is not a result of direct-acting contingencies (Malott, Malott, & Trojan, 2000). Direct-acting contingencies are those that provide reinforcement immediately following a response. Because the reinforcer is provided at a time distant from the exhibition of the response to the correspondence training question, reinforcement is not contingent on the target behavior. Instead, reinforcement is provided after a verbal acknowledgement that the individual corresponded ("you did what you said you would do, so you can pick from the Happy Sack" [Osnes, Guevremont, and Stokes, 1986]). Because of the time lag between the emission of the behavior and the delivery of reinforcement in correspondence training, direct-acting contingencies appear not to be responsible for the correspondence between saying and doing.

If direct-acting contingencies are not responsible for correspondence, what is? One explanation for the effects of correspondence training suggests the overt verbal behavior of an individual (i.e., statement of intent) becomes discriminative for the availability of reinforcement for correspondence. Lattal and Doepke (2001), in providing an animal homologue of human say-do correspondence, suggest that correspondence may be the result of conditional stimulus control. Through the use of reinforcement for correspondence and a corrective procedure (i.e., blackout) for noncorrespondence, Lattal and Doepke found that pigeons could be trained to emit identical responses across temporally distal components. Conversely, it has been argued that correspondence may be the product of rule governance (Ott & Osnes, unpublished thesis). A rule is simply a description of a contingency (e.g., "if I do X, then I'll get Y"; if I don't do X, I won't get Y"). Therefore, rule governance occurs when these descriptions of contingencies exert influence over behavior. Consequently, the effects resulting from correspondence training may have little to do with precursory verbal behavior (i.e., statement of intent) but instead may be related to the development of rules ("if I do what I said I would do, I will get a "goodie") that influence future non-verbal behavior.

To further examine this supposition, Deacon and Konarski (1987) assessed the effects of two experimental conditions on correspondence across two groups of participants. More specifically, one group of participants was provided reinforcement for engaging in a previously participant-selected activity (i.e., correspondence training). A second group was exposed to a reinforcement condition that did not require participants to provide a verbal statement with respect to their future behavior. That is, participants were provided reinforcement for engaging in a previously experimenter-selected behavior independent of participant's previous verbal statements. Deacon and Konarski found that both conditions resulted in an increase in correspondence. Furthermore, the authors noted that both conditions resulted in high levels of generalized correspondence following withdrawal of the aforementioned contingencies. Consequently, the authors concluded that correspondence may be a function of rule-governance and that participant verbalizations may serve no function in occasioning future behavior.

Correspondence Training

Describing the effects of correspondence training as the product of "rule governance" does little in tacting the relevant operant mechanism. That is, although there may be agreement that correspondence is related to rule governance, there is often disagreement related to the way in which rules affect correspondence. One stance is that rules serve a discriminative function signaling the availability of reinforcement or punishment. An indirect-acting reinforcement contingency is in effect – the consequence is received at a time distant from the target behavior and that behavior is strengthened.

Conversely, however, there are those who argue that influence exerted by rules over behavior is not related to the discriminative properties of rules but instead to their function altering properties. Schlinger (1993) suggests that if "rules" are nothing more than verbal discriminative stimuli, there is no need to investigate their effects because such investigations into stimulus control have already been performed. Also, classifying stimuli as discriminative merely because they precede a response and appear to be functionally related to it may be simplistic and misrepresentative of the operations that truly are responsible for the behavior. Blakely and Schlinger (1987) indicated that the function of verbal stimuli is not readily classifiable as discriminative but instead should be classified as "function altering", because the verbal stimuli do not evoke behavior as is the case with discriminative stimuli. Instead, function altering stimuli are those that alter the functions of other stimuli in a manner consistent with operant and respondent conditioning.

It has been hypothesized that a function altering stimulus (FAS) possesses formal properties: it must name at least two events, and may name more. It also is possible that only a single word can have function-altering effects. When hearing the word "tornado", the probability of seeking a protective area increases. The FAS (the verbal stimulus, "tornado") functions as a rule. Extending this conceptualization to correspondence training (CT) procedures, the CT question is a verbal stimulus that may alter the function of the response due to its history of having been paired with reinforcement. For example, when the teacher asks the student the question "What are you going to do today in class?", and in the past when she'd asked this question and the student had told her that she, the student, would do a lot of work, the teacher would give the student the Happy Sack if the student really had done a lot of work. Two events are named: being in class and doing a lot of work. Because of its history of operant conditioning, the question has altered the function of the response. It has acquired the function of a rule ("If I do what I said I would do, I get to have the Happy Sack.")

Similarly, Malott, Malott, and Trojan (2000) theorize that a rule statement functions as an establishing operation. Their theory, negating the role of indirect-acting contingencies, proposes that the rule statement establishes noncompliance with the rule as an aversive motivating condition. Thus, when a rule is present (e.g., "I'm going to do a lot of work today in class, and at some time I'll get the Happy Sack"), it may signal the presence of reinforcement in the environment, but the rule is two-pronged. The inverse of the rule "If I do a lot of work today in class, I'll get the Happy Sack" is "If I don't do a lot of work today in class, I won't get the Happy Sack". With the latter contingency, an aversive condition is present – noncompliance with the rule produces an aversive, "no reinforcement" condition. In order to escape the aversive condition (in this example, the response cost of not receiving access to the Happy Sack), the individual does what he said he would do – he does "a lot of work in class today". His performance occurs not to access reinforcement, but to escape the aversive condition that presents itself when noncompliance with the rule occurs. In this theory, it is a direct-acting contingency that is still responsible for compliance with the rule, escape from an aversive condition, not an "indirect-acting contingency, a contingency in which the outcome is too delayed to reinforce or punish the causal behavior" (Malott et al., 2000, P. 365). Therefore, rule governance is controlled by direct-acting contingencies, and an individual's behavior is not under the control of an indirect-acting contingency.

To illustrate, a story written by young Stokes (personal communication, 2003) provides a vivid account of a world created by the RuleMaker (RM) and the RuleMaker's cronies. The RM is responsible for the creation of rules that govern diverse activities that are inherent in the universe as it is known to humans, e.g., the force of gravity, the ability of birds to fly and the contrasting inability of humans to fly. The inevitable questioning by the humans occurs ("Why do we have to be controlled by gravity? If we weren't, we would have the ability to fly. Who invented these rules? We'd invent different rules."), and a tension and dissonance become present in the environment. This tension is responsible for a continuous quest by the humans to overrule the RM and free themselves.[1]

The research of Ott and Osnes (unpublished thesis) lends support to the view that the correspondence training question functions as a "rule" after a history of reinforcement for the

1 The authors would like to acknowledge the contribution of Logan Stokes to this discussion from the rules that have been imposed by the RM and his cronies. Of particular interest in the story is the promotion of the RM as the evil character, the "bad guy". Implicit in the story line is the notion that rules are inhibiting and restricting, and escape from rules created by the RM is a goal of the humans. Direct-acting contingencies, escape, are causing the humans' behavior.

exhibition of correspondence. In their study, the on-task behavior of elementary-aged children with severe behavior problems in their regular education classrooms came under the control of the correspondence training question. When asked what they would do in class each day, they responded, "I'm going to sit nicely, raise my hand to talk, and do my work". After the class session had ended, they were allowed to pick from the Happy Sack (Sulzer-Azaroff & Mayer, 1992). The time between the response to the question and the opportunity to pick from the Happy Sack varied from approximately 30 to 45 minutes. The research was designed specifically to control for the effect of the correspondence question alone, and to determine if the question might acquire the discriminative properties of a "rule". Previous correspondence training research had not provided a question (Q), only a condition prior to the correspondence training (CT) condition. The research of Ott and Osnes provided an examination of the question by providing the Q-only condition prior to and following the CT condition. In Q-only, no consequences other than acknowledgement were provided (e.g., "OK, go to class"). By so doing, it was possible to isolate the effect of the question and determine if a history of CT appeared to produce a discriminative stimulus function for the Q. The results showed that Q prior to CT had no effectiveness, but following CT, Q-only resulted in an increase in on-task behavior to the same levels that had occurred during CT. This research lends credible support to the plausibility that the question asked during correspondence training procedures can function as an SD for appropriate behavior. As such, it has assumed the function of a "rule". Ergo, it may be possible that rule governance is facilitated via correspondence training procedures.

Of additional interest to researchers has been the finding that manipulations of correspondence training procedures have resulted in generalized effects. For example, in an investigation of the effectiveness of indiscriminable contingencies as promoters of generalization, Stokes and Baer (1977); Stokes and Osnes (1989); and Guevremont, Osnes, and Stokes (1986) investigated the effects of a sequence of mixed procedures on the generalization and maintenance of correspondence training effects on young children's behaviors in play, group, and snack settings in a preschool. In the indiscriminable contingencies condition, a mixed sequence of contingencies was used: 1) positive consequences immediately following prompted vocalizations only; 2) positive reinforcement for correspondence; 3) days with no verbalizations when no consequences were provided; 4) delayed positive consequences for prompted verbalization but not for correspondence; and 5) days where no consequences were provided for either verbalizations or correspondence. The order of the sequence remained constant throughout the study, and was delivered on consecutive days. The results of the experiment indicated that behavior changes resulting from correspondence training generalized to nontarget settings in the preschool and at home, and maintenance of treatment effects occurred for a 6-month period following cessation of all experimental procedures.

In a thought-provoking discussion of the relationship among rules, culture, and fitness, Baum (1995) defines a rule as "a verbal discriminative stimulus produced by the behavior of a speaker under the stimulus control of a long-term contingency between the behavior and fitness. As a discriminative stimulus, the rule strengthens listener behavior that is reinforced in the short run by socially mediated contingencies, but which also enters into the long-term contingency that enhances the listener's fitness" (p. 1). Initially, the rule functions as a verbal discriminative stimulus, the utility of which is to influence a listener in some way. Also, however, the rule is reflective of a short-term contingency (direct-acting) because the listener's behavior may receive reinforcement from the speaker in an unknown way. A final purpose of the rule is its long-term effects that serve to perpetuate the culture in which both speaker and listener live and must survive indefinitely. Thus, a rule has the function of enhancing the overall fitness and durability of a culture. By projecting the concept of a rule onto the long-term milieu necessary for survival, Baum moves rules away from direct-acting and indirect-acting contingencies (rule governance) into long-term control. Therefore, rule governance is not indicative of the final plateau to which human behavior must ascend, but is only a step along the path. Cultural survival occurs when mere rule governance ceases and switches to long-term control. Baum refers to this as the ultimate contingency.

Juxtaposing Baum's conceptualization of rule-following, rule governance, and cultural fitness with the function of the statement made within the confines of a correspondence training framework, it is possible to surmise that the question initially functions as a discriminative stimulus for rule-following. Yet after a history of demonstrating correspondence and maintenance of its effects, rule governance may develop. According to Baum's conceptualization, only control by the long-term contingency results in cultural fitness. The question remains then: Can the apparent short-term effect of correspondence training on the development of rule governance be further advanced into the ultimate, long-term contingency? Is the "corresponder" simply echoing or imitating the behavior he has observed another individual exhibit for which reinforcement has been provided? If so, only the process of stimulus control is operational, not rule governance much less the ultimate contingency described by Baum. It is this contingency that involves fitness in the long term, that which involves the consequences of health, resources, relationships, and reproduction. Is it possible to envision a scenario in which the rule governance that appears to result from correspondence training may contribute to the decisions made by individuals about these four important spheres of long-term survival? Insofar as the effects of correspondence training are generalized and durable, such a scenario may be possible. Contrastingly, however, in the absence of generalization and maintenance (behavioral durability), there is no evidence of "rule governance". If rule governance is a precursor to Baum's ultimate contingency that is essential for cultural fitness, then without the generalization that correspondence training procedures appear to generate, the four important spheres of long-term survival remain unaffected.

Generalization and Stimulus Control

While observing that generalized outcomes have occurred as a result of correspondence training, it has not been determined experimentally why generalization occurs. Are these outcomes due to the establishment of rule control or rule governance (or the lack thereof)? Are the generalized effects merely due to weak stimulus control processes, and the failure to generalize reflecting strong stimulus control? What is the relationship between rule governance and stimulus control? In what ways are generalization and stimulus control linked? Ultimately, are all four areas (correspondence training, generalization, stimulus control, and rule governance) inextricably related as if they are members of the same response class?

To avoid the implication that the aforementioned areas are equivalent, a hierarchy may be offered. Stimulus control and generalization are integral components of the science of human behavior that have been subjected to proof through repeated experimentation, originally in laboratory settings and later in applied settings. Rule governance is a category of behavior that is controlled by "rules derived from the contingencies in the form of injunctions or descriptions which specify occasions, responses and consequences" (Skinner, 1969, p 160). Recent discussions have placed rule governance within the conceptualization of relational frame theory (RFT) (e.g., O'Hora, Barnes-Holmes, & Roche, 2001). RFT suggests an approach to rule governance in terms of the derived relations involved (Hayes, Gifford, & Hayes, 1998; Hayes & Hayes, 1989). Like the categories of stimulus control and generalization, rule governance has been investigated steadily in attempts to identify the controlling conditions under which it occurs. However, unlike stimulus control and generalization, rule governance and RFT lack the benefit of decades of empirical scrutiny to determine their places within the science of human behavior. In contrast to these three areas of human behavior, correspondence training is a set of procedures, nothing more and nothing less, which appears to have promise for the acquisition of behavior of social importance in the applied setting.

That having been clarified, a discussion of the relationship between these two fundamental components of the science of human behavior, stimulus control and generalization, is warranted. Kirby and Bickel (1988) provided a commendable effort to diminish the necessity of generalization as a functional category of behavior by arguing that all generalized effects are the result of stimulus control and reinforcement mechanisms. While not arguing against the necessity of producing generalized effects in our applied work, they propose a set of principles (that they interestingly refer to as rules), to better understand the variables responsible in the production of generalized effects. The premise of their discussion is that "the apparent spread of effect is a function of discrete and incompletely understood stimulus control relations" (Kirby & Bickel, 1988, p 116).

Taking issue with the description of the presence of generalized effects as "weak stimulus control", they instead discuss a quantal interpretation of stimulus control (e.g., Bickel & Etzel, 1985). In essence, this interpretation suggests that the relation between the controlling stimulus and a response does not occur in a one-to-one relationship (i.e., for each stimulus, there is a subsequent response). Instead it is an averaging of multiple controlling relations among stimuli and responses. Therefore, when observing generalized responding, it is important to acknowledge that only a few stimuli are controlled within our investigations, and there are many more stimuli in the nonexperimental, "natural" environment in which the generalized responding occurs. These "uncontrolled variables" have their own conditioning histories with various, unknown stimuli. When they contact the newly-trained behavior, a relationship between the unplanned-for variables and the trained behavior results. When explicit efforts have been made in the experimental setting to establish stimulus control to a specific stimulus, it may fail in the nonexperimental environment because of the presence of a variety of stimuli that were not present in the training setting. Thus, "generalization may be less than that desired because the subject's responding has come under the control of some limited aspect of the experimenter-defined stimulus" (Kirby & Bickel, 1985, p 117). It is this establishment of inappropriate stimulus control that results in the absence of desired generalization of effects, not "weak" stimulus control.

The discussion of Kirby and Bickel (1985) proceeds to describe three major variables used to establish stimulus control: the reinforcer, the extraneous stimuli, and reinforcement schedules. The manipulation of the reinforcer is a description of direct-acting contingencies – present stimulus, provide reinforcement, and do this sufficient number of times to establish the controlling relation. Manipulation of extraneous stimuli means stimuli extraneous to the experimental setting – stimuli present in the nonexperimental (generalization) setting. In other words, bring those stimuli into the training setting and provide reinforcement (establish a direct-acting contingency). They then propose that the extraneous stimuli should be varied, and should be constant in both settings. Manipulation of reinforcement schedules involves the use of intermittent schedules following the initial continuous reinforcement used to develop the relation between the stimulus and the response, and also to ensure the presence of probe (generalization) trials in the training setting to systematically develop a relationship between the stimulus and stimuli present in the nonexperimental setting. By developing a training history of using direct-acting contingencies in the experimental setting, the occurrence of "accidental" stimulus-response relationships in the nonexperimental setting is diminished.

Stokes and Baer (1977) proposed nine principles of generalization programming: train and hope; sequential modification; introduce to natural maintaining contingencies; train sufficient exemplars; train loosely; use indiscriminable contingencies; program common stimuli; mediate generalization; and train "to generalize". It is these nine principles to which Kirby and Bickel (1985) responded with their discussion of stimulus control mechanisms that are responsible for generalized responding. Stokes and Osnes (1989) undertook a refinement of the original nine categories put forth by Stokes and Baer in an attempt to reduce overlap among them. Their refinement consisted of three categories of generalization promotion: exploit current functional contingencies, train diversely, and incorporate functional mediators. The third category "addresses the relationship between salient conditions of learning and the stimulus control exerted over behavior by environments related to original learning" (Stokes, 1995, p. 429).

Interestingly, the stimulus control discussion of generalized effects by Kirby and Bickel (1985) is virtually a mirror of the three general categories discussed by Stokes and Osnes (1989). Exploiting current functional contingencies (Stokes & Osnes) involves providing reinforcement when the trained response occurs in a nontraining setting (Kirby & Bickel); training diversely (Stokes & Osnes) involves variation of the stimuli present in the training setting (Kirby & Bickel); and incorporating functional mediators (Stokes & Osnes) involves the incorporation of stimuli in the training setting that tend to be present in natural settings to increase the likelihood that the stimuli will contact reinforcement outside the experimental setting (Kirby & Bickel). The third stimulus control tactic discussed by Kirby and Bickel, reinforcement schedules, is subsumed in the Stokes and Osnes framework within "training diversely". Undoubtedly, they would include the incorporation of functional mediators within their category of "treatment of the extraneous stimuli" as a maximization of common stimuli. It appears that both discussions reflect stimulus control functions, with the exception that the generalization-promoting categories of Stokes and Osnes focus on applied research and settings whereas the stimulus control tactics of Kirby and Bickel focus on basic experimental research. In concluding their discussion, Kirby and Bickel purport that their stimulus control interpretation identifies features that are absent in the Stokes and Baer analysis of generalization programming. Although they appeared to be implicit in Stokes and Baer, they were explicit in Stokes and Osnes.

Let us now return to the premise of the discussion of Kirby and Bickel (1988, p 116) that "the apparent spread of effect [generalized responding] is a function of discrete and incompletely understood stimulus control relations". This is not inconsistent with the conceptualizations offered by both Stokes and Baer (1977) and Stokes and Osnes (1989). Both introduce their generalization-promoting categories in reference to stimulus control. Quoting Skinner (1953, p 132): "Generalization is not an activity of the organism; it is simply a term which describes the fact that the control acquired by a stimulus is shared by other stimuli with common properties." Skinner also described response generalization, transfer, or response induction by noting that when one operant is reinforced, there is an increase in the frequency of other behaviors without their being directly reinforced.

What might be questioned in the discussion of Kirby and Bickel (1988) is their premise that "incompletely understood stimulus control relations" are partly responsible for generalized responding. It is not the premise itself that is troublesome; it is the assumption that it might be possible to completely understand stimulus control relations to the extent that a failsafe set of procedures resulting in generalized responding can be developed for applied settings that are replete with multiple variables, each with its own controlling function. As Stokes and Osnes (1989) pointed out, "traditional experimental psychology has documented such [response generalization] effects with measurement precision, demonstrating the functional variables controlling the generalization. For example, this is noted in a stimulus generalization gradient that specifies the dimension of stimulus control. The technical precision and contingency control allowed in applied behavior analysis and therapy is not as well developed, but the pursuit of generalization outcomes and the analysis of functional variables is nonetheless important" (p 338). So while applauding the efforts made in the experimental research to understand stimulus control and generalization-promoting variables, the quibble is with the less-developed understanding of the variables responsible for generalized responding in applied settings.

Beyond what has already been proposed, it is unclear what additional contribution the experimental research can make to understanding the complex area of generalization promotion with humans in real world settings. Shahan and Chase (2002) discuss stimulus control in regards to novelty. Describing discrimination as the basic unit of stimulus control, they continue to describe it as the driving force resulting in novel responding that occurs under the conditions of stimulus generalization. In order to better understand generalization of behavior change then, perhaps it is necessary to better understand discrimination functions. Their discussion of the relationship between stimulus generalization and responses that occur in the presence of novel stimuli provides support for the tactics of generalization-promotion proposed by Kirby and Bickel, Stokes and Baer, and Stokes and Osnes. Shahan and Chase discuss variation in consequences (the parallel of both "training diversely" and "incorporating functional mediators" in Stokes and Osnes) as a promising method to increase novel behavior, but report that this has received little attention in basic research. They refer to the discussion of Stokes and Baer (1977) regarding the contribution of variation of consequences of behavior as a promising method to facilitate generalized responding. Because investigations of this type are scarce in basic research, it may not be possible or recommended to rely heavily on the experimental research to discover causes for the production of novel behavior (generality of behavior change) in humans.

Returning to the questions posed earlier about the relationship between generalization and stimulus control, it appears that there is a very clear relationship that has been acknowledged since Skinner first discussed it in *Science and Human Behavior.* It also appears that a good understanding and appreciation of the experimental research in both areas still leaves gaps in the ability to understand the complexities of the multiple stimuli that are present in the natural environments of humans. In other words, what has been learned from the experimental research regarding generalization and stimulus control is insufficient to answer the puzzling questions about the process by which generalization can be facilitated in the applied arena. There remains a dire need for applied researchers to investigate the tactics developed by Stokes and Osnes who incorporated the tactics of Stokes and Baer into their framework for conceptualizing generalization-promotion.

Stokes and Baer (2003) suggest that a history of receiving differential consequences for behaviors within a person's repertoire results in the development of both discrimination and generalization. When a student hears the question "What are you going to do in class today?" for the second time (after the exposure to the consequences for having answered it the first time), she knows that the answer "I'm going to do a lot of work" and subsequently doing the work will result in access to the Happy Sack. She also knows that answering the question "I'm going to do a lot of work" and then not exhibiting the appropriate response of doing the work will result in no access to the Happy Sack. She has learned to discriminate the consequences for differentially responding after answering the question. Also she has learned that "doing a lot of work" means that she must do all types of work presented (stimulus generalization). Classifying the student's behavior according to the typology of Stokes and Osnes (1989), the student's answer to the question functioned as a mediator to generalize responding across multiple types of work tasks.

According to Schlinger (1993), the teacher's question also served as a function altering stimulus (FAS). After hearing the question, the student "knew" that if she did the work after telling the teacher that she would, she would receive reinforcement. Therefore, the question had acquired the function of a rule ("I have to do my work to get the Happy Sack"). Having acquired this function is an important property of the question, because the rule has the potential to evoke generalized responding. Hence, using Schlinger's conceptualization, mediators of generalization contain function-altering properties. Stokes and Baer (2003) suggest that the student produced the mediator (the statement) because the "stimulus control conditions in the generalization context occasion performance, evoking a repertoire of relevant function for the person" (p. 134). The mediating stimulus has developed its function as an SD because of a history of operant conditioning – following an antecedent stimulus, the performance of a behavior receives a reinforcer or punisher.

Conclusion

To return to the original question from which this paper's discussion emanated, "Are the areas of correspondence training, rule governance, generalization, and stimulus control connected or disconnected?" A subsequent question might be "To what extent is their connection or disconnection functionally relevant to issues of application?" To answer the first question is possible, maybe. There appear to be clear relationships between correspondence training procedures and generalization (e.g., Baer, Osnes, & Stokes, 1983; Baer, Williams, Osnes, & Stokes, 1985; Osnes, Guevremont, & Stokes, 1987; Guevremont, Osnes, & Stokes, 1988). There are hypothesized relationships between stimulus control and the promotion of generalization (Kirby & Bickel, 1988; Stokes & Baer, 2003). Rule governance is a theoretical area (Skinner, 1969; Malott et al., 2000) that lacks a discrete empirical base, but in theory, it appears that the stimuli present in correspondence training may be functionally related to rule governance.

In response to the second question, as always the data must lead the way. Despite a lack of definitive understanding regarding the functional properties that are responsible for their effectiveness, correspondence training procedures now have been investigated for two decades. In this period, they have delivered a solid database that demonstrates their utility in addressing areas of social importance for children and families. The durability of researchers' interests in the area signifies that it is an encouraging area for further research and application. Although an understanding of the properties and causal variables that are responsible for their effectiveness should be the ultimate goal in order to advance the science of human behavior, the effectiveness of correspondence training procedures and their contribution to generalization of behavior change substantiates their importance in the field of applied behavior analysis.

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Types of Relationships between Events: Their Implication in the Stimulus-Response Relationship

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"Every action of the individual is unique, as well as every event in physics and chemistry."
(Skinner, 1953/65, Science and human behavior, p.19)

The stimulus, like the response, is an event. Therefore, their relationship can be studied as a relationship between events. This paper describes and analyzes various types of relationships between events and discusses the appropriateness or inappropriateness of each type of relationship as an adjustable or illustrative model of the stimulus-response relationship. The "totally modifying, unidirectional and continuous reciprocal relationship" is proposed as the model which better represents the relationship between stimulus and response. The stimulus-response relationship is inadequately represented by both the interbehaviorist diagram (Behavioral Segment) and by the radical behaviorist diagram (Three Term Contingency). Here, we propose some modifications to both diagrams so they show more precisely what interbehaviorists and radical behaviorists want to show with their diagrams. Finally, the unified behaviorist diagram proposed by Los Horcones is presented.

Introduction

It is said that the stimulus is related to the response and that the response is related to the stimulus. In order to describe this relationship, terms such as "interrelation", "interaction", "interdependency", "interconnection", "mutual effect", "reciprocal influence", are used. But which is the precise meaning of these terms and what types of relationships do they involve?

What is a relationship?

What is a relationship? When is it said that two or more events are related?
We say that two or more events are related when in one way or another, one has an effect on the other or they affect each other.

Types of relationships between two events

There are different criteria we can use to classify the relationships between two events:
1) According to how they relate.
2) According to the direction in which they relate.
3) According to the events that are modified by the relationship.
4) According to the duration of the relationship.

Let us see each of them.

1. According to how events relate, the relationship can be:
a) Reciprocal
b) Non-reciprocal

a) A reciprocal relationship is a type of relationship between events in which all events relate to each other. For example event X and event Y; where event X relates to event Y and event Y relates to event X.
b) A non-reciprocal relationship is a type of relationship between events in which not all events relate to each other. For example between event X and event Y; where event X relates to event Y but event Y does not relate to event X; or where event Y relates to event X but event X does not relate to event Y.

The reciprocal relationship between two events is possible only if the events are not modified when relating. Thus, there is a reciprocal relationship between X and Y, only if they remain unmodified. However, we could speak of a reciprocal relationship between X and Y if we refer to them as event class. For example: X is reciprocally related to Y in the following case:

$$X{-}{-}{-}{-}{>}Y{-}{-}{-}{-}{>}X^1{-}{-}{-}{-}{>}Y^1{-}{-}{-}{-}{>}X^2{-}{-}{-}{-}Y^2$$

The event class X is reciprocally related to the event class Y because the event class X and Y remain unmodified as a result of the relationship, although modified as members of a class. This distinction between reciprocal relationships and between particular events and class events is very important when referring to the stimulus-response relationship, as we will see further ahead.
The second criterion to classify event relationships is the following:
2) According to the direction in which events relate:
a) unidirectional relationships
- Forward unidirectional relationships
- Backward unidirectional relationships
b) Bi-directional relationships

a) Unidirectional Relationships
A forward unidirectional relationship is a type of relationship between event X and Y, when X happens before Y and where the relationship occurs only forward. X relates to Y without Y relating to X.

A backward unidirectional relationship is a type of relationship between event X and Y, when X happens before Y and where the relationship occurs only backwards. Y relates to X without X relating to Y.

b) A bi-directional relationship (forward and backward) is a type of relationship between X and Y, when X happens before Y, and where the relationship occurs forwards and backwards. X relates to Y and Y relates to X.

The third criterion for relationship classification is:

3) According to the events modified as a result of the relationship:

a) Modifying relationship

Totally

Partially

b) Non-modifying relationship

a) Modifying relationship. A totally modifying relationship is a type of relationship between events in which all the events involved in the relationship are modified as a result of the relationship. For example, in the relationship between X and Y, both are modified.

A partially modifying relation is a type of relationship between events in which not all the events involved in the relationship are modified as a result of the relationship. For example, in the relationship between X and Y, only X or only Y are modified when relating, but not both of them.

b) Non-modifying relationship. It is a type of relationship between events in which none of the events involved in the relationship are modified as a result of the relationship. For example, in the relationship between X with Y, neither X nor Y are modified by relating to one another.

4) According to the duration of the relationship

a) Continuous

b) Discontinuous

a) A continuous relation is a type of relationship in which the events are always relating.

b) A discontinuous relation is a type of relationship in which the events are not always relating.

Mixed Relationships

More than one type of relationship can exist between two events. We will present four possibilities, which we consider useful for analyzing the stimulus-response relationship

1) Reciprocal, unidirectional relationship (forward or backward)

2) Reciprocal, bi-directional relationship

3) Reciprocal, totally modifying, bi-directional relationship

4) Reciprocal, totally modifying, unidirectional relationship (forward or backward)

Now let us define each of them.

1) Reciprocal unidirectional relationship

It is a type of relationship between X and Y, where X relates to Y in one direction and Y relates to X in the same direction.

This type of relationship can be: a) forward, or b) backward.

a) Forward: is a type of relationship between X and Y, where X relates to Y forward, and Y relates to X in the same direction.

X----->Y------>X

(X is related forward to Y, and Y is related forward to X).

Note. Unidirectional forward reciprocal relationships are possible only between events that are not modified as a result of their relationship. X remains being X after Y occurs.

b) Backward: is a type of relationship between X and Y where Y relates to X backwards and X relates to Y backwards.

X<-------Y<--------X

(X relates to Y and Y to X, backwards).

Note. Unidirectional backward reciprocal relationships are not possible between events which happen in a temporal dimension.

2) Reciprocal bi-directional relationship.

It is a type of relationship where X relates to Y and Y to X in both directions.

X<----------->Y

(X relates to Y forward, and Y relates to X backwards).

Note. The bi-directional reciprocal relationship is possible only between events that are not modified as a result of the relationship. A bi-directional reciprocal relationship is not possible between events, which occur in time.

3) Reciprocal totally modifying bi-directional relationship

It is a type of reciprocal relationship between X and Y in which both are modified as a result of the relationship and the modifying effect operates forwards and backwards

X^1/X<------------->Y/Y^1.

(X relates forward to Y and modifies it into Y^1. Y^1 relates backwards to X and modifies it into X^1)

Note. This type of relationship is not possible between events that occur in time. The event (Y^1), which occurs in t^2, cannot affect a new event (X), which occurred in t^1.

4) Reciprocal totally modifying unidirectional relationship

This type of relationship can be: a) forward, or b) backward

a) Forward reciprocal totally modifying unidirectional relationship. It is a type of relationship between X and Y in which both are modified as a result of their relationship but the modifying effect only operates forward.

X----->Y/Y^1------>X/X^1.

(X relates to Y and modifies it to Y^1. Y^1 relates to X and modifies it to X^1. The modifying effect only operates forward).

Note. This type of modifying reciprocal relationship is not possible between events that happen in a temporal dimension time. X occurs in t^1 and in t^2. Further ahead we will see a diagram form of this type of relation, which eliminates this disadvantage.

b) Backward reciprocal totally modifying unidirectional relationship. It is a type of relationship between X and Y in which both are modified as a result of the relationship but the modifying effect only operates backwards.

X^1/X<---------Y^1/Y<---------X.

(X relates to Y and modifies it to Y^1. Y^1 relates to X and modifies it to X^1. Modification occurs backwards).

Note. A modifying reciprocal relationship is not possible in events that happen in temporal dimension. Event X occurred in t^3 affects the event that occurred in t^2, and the event Y^1 that occurred in t^2 affects the event X that occurred in t^1.

Characteristics of the events involved in a relationship

The events that relate can be:
a) Dependent
b) Interdependent
c) Independent
d) Repeatable
e) Non-repeatable
f) Modifiable
g) Unmodifiable

Let us see each of them:
a) Dependent: Events X and Y are dependent if the occurrence of event X depends on the occurrence of event Y but the occurrence of event Y does not depend on the occurrence of event X; or if the occurrence of event Y depends on the occurrence of event X, but the occurrence of event X does not depend on the occurrence of event Y.
b) Interdependent: Events X and Y are interdependent if the occurrence of event X depends on the occurrence of event Y; and the occurrence of event Y depends on the occurrence of event X. Event X and event Y cannot occur without each other.
c) Independent: Events X and Y are independent if the occurrence of event X does not depend on the occurrence of event Y and the occurrence of event Y does not depend on event X.
d) Repeatable: An event that occurs more than once in time. Event X occurs in t^1 and in t^2. (X is the same event).
e) Non-repeatable: An event that occurs only once in time.
f) Modifiable: An event that can change in some aspect.
g) Unmodifiable: An event that cannot change in any aspect.
The behavior and the environment are interdependent, non-repeatable (unique) as a particular instance of behavior or environment, and repeatable as a behavior or environment classes; and modifiable.

Interbehaviorist Diagram and Radical Behaviorist Diagram

Based on the relationships between events mentioned earlier, let us analyze the diagrams proposed by interbehaviorism and radical behaviorism.

Interbehaviorist Diagram

For interbehaviorism, the stimulus-response relationship is a bi-directional reciprocal relationship. The diagram it proposes is:
S<---------->R
(the stimulus relates to the response and the response relates to the stimulus. The relationship between them is reciprocal).

Advantages of the diagram:
a) Shows a reciprocal relationship between stimulus and response.

Note. A reciprocal relationship between particular events that change as a result of the relationship, such as the relationship that occurs with the stimulus and response, is not possible. If letter S refers to the stimuli and R to the responses, then a reciprocal relationship is possible between them. (The terms "stimuli" and "responses" refer to event classes).

b) Shows a continuous relationship between stimulus and response.

Disadvantages of the diagram:
a) It does not show a modifying relationship between the stimulus and the response (the diagram does not show that the stimulus as well as the response are modified as a result of the relationship).
b) It shows a reciprocal relationship between the stimulus and the response in a backward direction. The R which occurs in t^2 affects the S which occurred in t^1. (S<----------R)

Note. The backwards reciprocal relationship between stimulus and response is not possible since a stimulus, which already occurred, cannot be affected by the response which occurs. R occurs in t^2 so cannot affect S which occurred in t^1.

It is clear that we can speak of unidirectional modifying reciprocal relationships (but not about bi-directional modifying reciprocal relationships) between stimulus and response since both modify each other when relating but they do it only in a forward direction.

We could reduce the disadvantages of not pointing out the modifying reciprocal relationship between stimulus and response of the interbehaviorist diagram using the following:
S^1---------->R^1
S^2<----------R^2
(Stimulus 1 modifies Response 1 and turns it into Response 2. Response 2 modifies Stimulus 1 and turns it into Stimulus 2).

Advantages of this diagram:
a) It shows a reciprocal relationship between the stimulus and the response.
b) It shows a continuous relationship between the stimulus and the response.
c) It shows a modifying relationship between the stimulus and the response. (The stimulus as well as the response changes when relating).

Disadvantages of the diagram:
a) It shows which of the responses affects the stimulus in a backwards direction. R^2, which occurs in T^2, affects S^2, which occurs in t^1.
b) It does not clearly show how R^2 modifies S^1 to turn it into S^2 as a result of the relation.

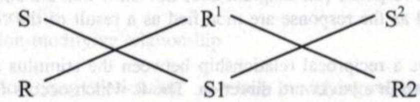
We could eliminate these disadvantages with the following diagram:
-------S^1---------->R^1-->R^2---------->S^1-->S^2-------
(S^1 affects R^1 modifying it to R^2; R^2 affects S^1 modifying it into S^2).

But a disadvantage remains: S^1 occurs both before R^1 and after R^2. This is not possible in events that happen in a temporal dimension.

We could eliminate this disadvantage with the following diagram:
-----S^1---------->R^1-->R^2---------->S^2--->S^3------
(S^1 affects R^1 modifying it to R^2; R^2 affects S^2 modifying it to S^3).

But a disadvantage remains: Although it shows that S^1 modifies R^1 into R^2, it does not show how R^2 modifies S^1 into S^2.

We could eliminate this disadvantage with the following diagram which is proposed by unified behaviorism:



This diagram shows how S and R are modified into S^1 and R^1 when relating and when S^1 and R^1 relate are modified into S^2 and R^2. This is the diagram proposed by the unified behaviorism.

Advantages of this diagram:
a) It shows a reciprocal relationship between stimulus and response.
b) It shows that the reciprocal relationship is modifying.
c) It shows that the reciprocal relationship between stimulus and response is totally modifying, which means that both change as a result of the relationship. Therefore, neither the same stimulus nor the same response is ever repeated.
d) It shows that the totally modifying reciprocal relationship is unidirectional —forward. The stimulus and the response are modified forward.
e) It shows a continuous and unidirectional totally modifying reciprocal relationship between the stimulus and the response.

There exists another way of modifying the scheme of the stimulus-response relationship proposed by interbehaviorism:
From the original diagram S<------------>R (Reciprocal relationship between the stimulus and the response) to the diagram

SE----------->RC------->SC

(Reciprocal relationship between a class of stimuli and a class of responses)

Note. From the diagram S<-------->R we do not continue to the diagram SC<--------->RC but rather to SC------->RC------->SC. The reason is that diagram SC<-------->RC shows a bi-directional reciprocal relationship between stimulus classes and response classes but bi-directional ability is not possible between events which happen in time.

Radical Behaviorist Diagram

Now let us analyze the stimulus-response relationship diagram proposed by radical behaviorism.
The diagram is:

S---------->R-------->S

(The stimulus that occurs before the response relates to it, and the response relates to the stimulus that follows it).

But what behaviorists really read in this diagram is: "the antecedent stimulus affects the response and the response is affected by the consequent stimulus".
Advantages of the diagram:
a) It shows a reciprocal relationship between stimulus-response (although the relation is only forward).
b) It shows unidirectionality (although the form in which behaviorists reads it "the antecedent stimulus affects the response and the response is affected by the consequent stimulus" it shows bidirectionality).
c) It shows that the stimulus and the response occur in a temporal order (as it is indicated in the diagram, not as it is read).
Disadvantages of the diagram:
a) It does not show a modifying reciprocal relationship between the stimulus and the response.
b) According to the way behaviorists read it, it shows that the response affects the stimulus backwards. R, which occurs in t^2 and is affected by S, which occurs in t^1.
c) It does not show continuity.

If the diagram reads: "the stimulus affects the response which produces a stimulus (consequence) which affects the response." Therefore we should use the following:

S------->R< ------->S

(The stimulus relates to the response. The response relates to the stimulus that follows it and this stimulus relates to the response).

Advantages of the diagram:
a) It shows a reciprocal relationship between the stimulus and the response.
Disadvantages of the diagram:
a) It does not show a modifying relationship between the stimulus and the response.
b) It shows that the stimulus affects the response backwards
c) It does not show continuity.

We could eliminate the disadvantages of this diagram with the following:

------S^1---------->R^1---------->S^2------------>R^2-----

(Stimulus 1 relates to response 1. Response 1 relates to stimulus 2. Stimulus 2 relates to response 2).

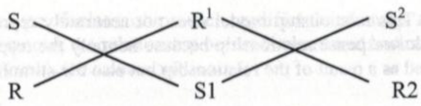
Advantages of the diagram:
a) It shows a relationship between behavior and environment.
b) It shows that the stimulus and the behavior relate forward (unidirectional).
c) It shows continuity.
Disadvantages of the diagram.
a) It does not show a modifying relationship between the stimulus and the response.

We could eliminate this disadvantage with the following diagram:

S^1----->R^1-->R^2------>S^2--->S^3---------

(S^1 affects R^1 modifying it to R^2, R^2 affects S^2 modifying it to S^3).

Disadvantage of the diagram:
a) Although it shows that S^1 changes R^1 to R^2, it does not show how R^2 changes S^1 to S^2.
We could eliminate this disadvantage with the following diagram:



This diagram shows how S and R are modified into S^1 and R^1 when relating and when they relate are modified into S^2 and R^2.

This is the diagram proposed by unified behaviorism.

Advantages of the diagram:
a) It shows a reciprocal relationship between the stimulus and the response.
b) It shows that the reciprocal relationship is modifying.
c) It shows that the reciprocal relationship between the stimulus and the response is totally modifying, with the stimulus as well as the response change as a result of the relationship. Therefore the same stimulus and the same response never repeat.
d) It shows that the totally modifying reciprocal relationship is unidirectional —forward. The stimulus and the response are modified forward.
e) It shows that the totally modifying forward unidirectional reciprocal relationship is continuous. The stimulus and the response are always relating.
This type of diagram shows more clearly the type of relationship proposed by radical behaviorism where the contingency scheme shows the three terms as immutable.

There is another form of modifying the stimulus-response relationship proposed by radical behaviorism:
From the original diagram:
S------------>R--------->S
to the diagram:
SC----------->RC-------->SC
(Reciprocal relationship between a stimulus class and a response class) is developed. But the relationship is between event classes and not between a stimulus and response.

Possible types of relationships between stimulus and response

We will analyze the types of relationships between the stimulus and the response progressing from the most simple to the most complex.

1. S------->R (The stimulus relates to the response).
Type of relationship:
Non-reciprocal (The stimulus relates to the response but the response does not relate to the stimulus).
Unmodifying (The relationship between stimulus and response does not modify the stimulus, nor the response).
Unidirectional (The relationship between the stimulus and the response only occurs in one direction:)
Discontinuous (No continuity is shown in the relationship).

2. R-------->S (The response relates to the stimulus)
Type of relationship:
Non-reciprocal
Unmodifying
Unidirectional
Discontinuous

3. S <---------> R (The stimulus relates to the response and the response to the stimulus)
Type of relationship:
Reciprocal
Non-modifying
Bidirectional
Continuous

Note. This is the inter-behaviorist diagram. It is appropriate in the sense that it shows a reciprocal relationship between the stimulus and the response but it is inappropriate in the sense that it does not show that they are both modified as a result of relating.

4. S------>R----->S ------->R----->S (The stimulus relates to the response, and the response to the stimulus).
Type of relationship:
Reciprocal
Non-modifying
Unidirectional
Continuous

5. S-------->R^1/R^2 (The stimulus relates to the response and modifies it from R^1 to R^2).
Type of relationship:
Non-reciprocal
Partially modifying
Unidirectional
Discontinuous

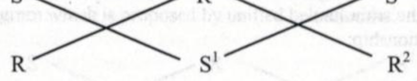
6. R--------->S^1/S^2 (The response relates to the stimulus and modifies it from S^1 to S^2).
Type of relationship:
Non-reciprocal
Partially modifying
Unidirectional
Discontinuous

7. ----S-------->R^1/R^2------------>S/S^1---- (The stimulus relates to the response and modifies it from R^1 to R^2. The response (R^2) relates to the stimulus and modifies it to S^1).
Type of relationship:
Reciprocal.
Totally modifying
Bidirectional (Although it seems unidirectional it is not because the relationship R2 to S1 is backwards.
Continuous

8. -----S-------->R/R^1------------>S^1/S^2--------->R^3/R^4----- (The stimulus relates to the response and modifies it from R to R^1. The response modifies (R^1) and relates to the stimulus (S^1) and modifies it to S^2. The stimulus S^2 relates to the response (R^3) and modifies it to R^4.
Type of relationship:
Reciprocal
Totally modifying
Unidirectional.

Continuous

Note. It does not show how S is modified to S^1.

9. 

S relates to R and as a result S is modified to S^1 and R to R^1. S^1 relates to R^1 and as a result S^1 is modified to S^3 and R^1 to R^3.

Type of relationship:
Reciprocal
Totally modifying
Unidirectional
Continuous

Note. This is the diagram proposed by unified behaviorism.

Modifying relationships between the stimulus and the behavior

There are three types of modifying relationships between the stimulus and the response:
a) Forward unidirectional totally modifying
b) Forward unidirectional partial modifying
c) Backward unidirectional totally modifying
d) Backward unidirectional partial modifying
e) Bidirectional totally modifying

a) Forward unidirectional totally modifying
It is a type of relationship in which the stimulus as well as the response are modified; the relationship occurs forwards.
S---->R-->R^1-------->S->S^1
This relationship is totally modifying because the stimulus-response relationship modifies both. This relationship is unidirectional because the stimulus-response relationship only occurs forwards.

Note. This type of relationship does not accurately represents the stimulus-response relationship because R^1 which occurs in t^2 affects S which occurs in t^2 (although the diagram shows that events occur in time).

b) Forward unidirectional partially modifying
A type of relationship which modifies either the stimulus or the response and the relationship occurs forwards. There are two kinds of forward unidirectional partially modifying relationships: partial modification of response, and partial modification of stimulus.

Partial modification of the response:
S---------> R--> R^1
(S relates to R and modifies it to R^1).

This relationship is partially modifying because the stimulus-response relationship modifies the response.
This relationship is unidirectional because the stimulus-response relationship occurs only forwards.

Note: This relationship model does not accurately represent the stimulus-response relationship because not only the response is modified as a result of the relationship but also the stimulus.

Partial modification of the stimulus:
R---------->S--> S^1.
(R relates to S and modifies it to S^1).

This relationship is partially modifying because the stimulus-response relationship modifies the stimulus.
This relationship is unidirectional because the stimulus-response relationship occurs forwards.

Note: This model of relationship does not accurately represent the stimulus-response relationship because not only is the stimulus modified, but also the response.

c) Backward unidirectional totally modifying
It is a type of relationship which modifies the stimulus as well as the response; the relationship occurs backwards.
S1<---S<-------R^2<---R^1<---------S
(S relates to R^1 and modifies it into R^2. R^2 relates to S and modifies it to S^1).

d) Backward unidirectional partial modifying.
It is a type of relationship which modifies either the stimulus or the behavior; the relationship occurs backwards. There are two kinds of backward unidirectional partial modifying: partial modification of the response, and partial modification of the stimulus.

Partial modification of the response:
R^2<--R^1 <--------S
(S relates to R^1 and modifies it to R^2).

This relationship is modifying because the stimulus-response relationship modifies the response.
This relationship is unidirectional because the relationship only occurs in one direction: backwards.

Note. This model of relationship does not accurately represent the stimulus-response relationship for two reasons: a) not only the response is modified as a result of the relationship but the stimulus is also modified.

b) the S which occurs in t^2 can not affect R^1 which occurs in t^2

Partial modification of the stimulus:
S^1<---S^1 <--------R
(R relates to S^1 and modifies it to S^2).

This is a modifying relationship because the stimulus-response relationship modifies the stimulus.

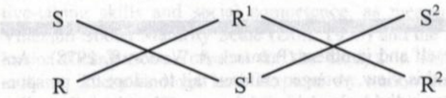
Note. This model of relationship does not accurately represent the stimulus-response relationship because of two reasons: a) both the stimulus and the response are modified as a result of the relationship. b) the R which occurs in t^2 can not affect S^1 which occurs in t^1.
c) Bidirectional totally modifying.

It is a type of relationship which modifies the stimulus as well as the response; the relationship occurs forward and backwards.

S^1<----S<---------->R----->R^1

Unified Behaviorist Model

Unified behaviorism describes the stimulus-response relationship as a totally modifying, unidirectional and continuous reciprocal relationship.



S relates to R and as a result S is modified to S^1 and R to R^1. S^1 relates to R^1 and as a result S^1 is modified to S^3 and R^1 to R^3.

We will define each of the terms used to classify the relationship.

- Reciprocal

The stimulus response relationship is reciprocal, when referring to the stimulus and response as event classes and not as particular events. Any stimulus-response relationship changes both therefore there is not reciprocity.

- Totally modifying

The stimulus-response relationship is totally modifying because the stimulus as well as the response change when relating.

Both the interbehaviorist and the radical behaviorist diagrams do not explicitly show the modifications of the stimulus and the response. Inter-behaviorism states that there is a reciprocal relationship between the stimulus and the response, but it does not make explicit the fact that the relationship modifies the stimulus as well as the response, making impossible any interaction between them. Therefore, it is not accurate to say that stimulus-response relationships as particular events are reciprocal because neither the stimulus nor the response remain unmodifiable.

Note. After relating, the stimulus and the response are never the same. They do not exist as immutable elements in a relationship. Thus, each instance of relating between a stimulus and a response is unique, although it occurs within a continuum of stimulus-response relationships (stimulus event classes and response event classes).

- Unidirectional

The stimulus-response relationship is always unidirectional. The stimulus and response only relate forwards. The reciprocal relationship between stimulus and response is not bi-directional because the stimulus occurring before a response cannot be directly affected by the response; nor can the response which occurs before a stimulus be affected by the stimulus which follows it. We cannot speak accurately of bidirectionality between events which occur in time.

The interbehaviorist diagram points out the bi-directional relationship between stimulus and response by showing between them an arrow in two directions. The radical behaviorist diagram implies bidirectionality when stated that a stimulus which follows the response, affects it, when states that the consequence affects the response which already occurred. The fact that the stimulus-response relationship is unidirectional does not mean that the stimulus and the response do not affect each other mutually (that there is not a modifying reciprocal relationship between them) but just that this reciprocity happens in the direction in which the events occur in time.

Relationship between the stimulus and the response as event classes

We could speak of a reciprocal stimulus-response relationship when we refer to stimulus classes and response classes. For example: S reciprocally relates with R in the following case.

S^1--------->R^1--------->S^2-------->R^2-------->S^3--------->R^3.

The event class "S" is reciprocally related to event class "R".

- Continuous

The stimulus-response relationship is continuous. However it is opportune to clarify that the relationship is continuous only between the stimulus and response as event classes: this is to say, between the environment and behavior event. The relationship is not continuous between a particular environmental instance (stimulus) and a particular behavioral instance (response). Continuity in the same stimulus-response relationship is not possible because both response and stimulus change when relating.

Reciprocal relationship between particular events and event classes.

The stimulus and response events pertain to the environment class and to the behavior class. At a molar level, when referring, to behavior and environment (stimuli and responses) it is appropriate to speak about a reciprocal relationship between them; but a molecular level – when referring to a stimulus and a response, is not appropriate to speak of a reciprocal relationship. A reciprocal relationship is not possible between a specific environmental event (stimulus) and a particular behavior event (response) since both continuously change as a result of the relationship.

Neither the interbehaviorist nor the radical behaviorist models make explicit the following fact: the stimulus and the response are continuously modified as a result of their interaction.

Assessing Relational Learning Deficits in Perspective-Taking In Children with High-Functioning Autism

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Southern Illinois University

Perspective-taking is a skill that requires a child to demonstrate awareness of informational states in himself or herself and in others. The ability to change perspective may result in successful interpersonal relationships, as perspective-taking facilitates comprehension of another person's position. Research has shown that children with autism spectrum disorders often perform poorly on perspective-taking tasks, putting such children at a disadvantage in social situations. Behavioral psychologists have recently suggested that perspective-taking emerges as generalized operant behavior following a reinforced history of relational responding. A procedure for evaluating perspective-taking skills from this perspective, known as the Barnes-Holmes protocol, was implemented with typically-developing children and adults; it was found that errors decreased as a function of age (McHugh, Barnes-Holmes, & Barnes-Holmes, 2004). The purpose of this pilot study was to extend the findings of McHugh et al. (2004) by using a computerized version of the Barnes-Holmes protocol to evaluate relational learning deficits in perspective-taking in four children with high-functioning autism. Results showed that most participants performed worse on the easier perspective-taking tasks, and performed with higher accuracy on the more difficult tasks. In fact, some participants scored with substantially higher accuracy than would be expected for their age group. The implications of the conceptualization of perspective-taking as generalized operant behavior are discussed.

Assessing Relational Learning Deficits in Perspective-Taking in Children with High-Functioning Autism

Perspective-taking, or the ability to observe a situation from the viewpoint of another individual, has been deemed an important skill because of its relationship to social functioning (Dixon & Moore, 1990). The individual who is capable of changing perspective may achieve greater success in interpersonal relationships, due to his or her ability to more fully comprehend the position of other individuals. Opportunities to utilize perspective-taking skills often present themselves during social interactions with others. For instance, it would be extremely difficult to formulate responses to questions such as "what would you do if you were me," "what will you do once you are there?" and "what did you do then?" (Barnes-Holmes, Hayes & Dymond, 2001) without a sufficient perspective-taking repertoire. Deficits in perspective-taking may contribute to impairments in interpersonal relationships and the ability to show empathy.

Traditional psychological approaches to the study of perspective-taking have focused on what has been called the "Theory of Mind," or the awareness of the informational states existing in oneself and in others (Premack & Woodruff, 1978). According to this view, younger children fail to adopt the perspective of other individuals and instead assume that the information they possess about events is the same as that held by others. In order to test this theory, Dixon and Moore (1990) investigated two types of perspective-taking skills in preschool children (whose mean age was 5 years, 1 month), second graders (whose mean age was 7 years, 11 months) and fifth graders (whose mean age was 10 years, 4 months). Participants were read a series of short stories about a child emptying his toy box, the content of which varied in terms of the boy's intentions for emptying the box, the consequences that followed, and the amount of information possessed by his mother. The first perspective-taking skill was assessed by presenting all of the relevant information to participants and then presenting a question which required them to take the perspective of the child's mother, who had incomplete information. Disregarding information not given to the mother was taken to be a demonstration of perspective-taking. The second perspective-taking skill was assessed by requiring participants to judge events from their own perspective and that of the boy's mother, when she possessed the same amount of information as the participants. Differences in the judgments made from the two perspectives were inferred as examples of perspective-taking. Second and fifth graders passed the perspective-taking tasks, but preschoolers failed to demonstrate either skill. Likewise, Taylor, Cartwright and Bowden (1991) asked participants a series of questions regarding the knowledge possessed by a six month-old baby, a four year-old girl, and a 36-year old woman (i.e., would the baby, the girl, or the woman be able to identify the contents of a picture). Responding to the questions correctly required that the participants change perspective. Children of four years of age were shown to be deficient in perspective-taking, while children of six years of age performed better than the younger children, but not as well as adult participants. These results lend support to the notion that perspective-taking skills emerge over the course of child development.

Autism spectrum disorder is characterized by deficits in the ability to form reciprocal social relationships with others (Klin, Volkmar & Sparrow, 1992). In light of the apparent relationship between perspective-taking and social skills, some researchers have suggested that perspective-taking deficits may be closely related to the social challenges experienced by individuals with autism (e.g., Klin et al., 1992). Baron-Cohen, Leslie and Frith (1985) administered a task known as the "Sally Anne task" (Wimmer & Perner, 1983) to children with autism, Down syndrome, and typically-developing children. The task involves two dolls (Sally and Anne) constructing a scene involving different perspectives of an object's location. For example, the scene begins with Sally placing a marble in a basket and then leaving, at which time Anne enters the scene, removes the marble from the basket, and places it in a box. Sally then re-enters the scene, and participants are asked where Sally would look for the marble. Typically-developing participants and participants with Down syndrome excelled on the task, but participants with autism were deficient in responding from the perspective of Sally (see also Baron-Cohen, 1989). Similarly, Dawson and Fernald (1987) reported a positive correlation between perspective-taking skills and social competence, as measured by the Vineland Social Maturity Scale (Doll, 1953) and the Social Behavior Rating Scale (created for the study), in children with autism. These findings have inspired the notion that children with autism lack a Theory of Mind, thus explaining the shallow affect and difficulties conveying empathy common in persons with autism.

An alternative behavioral interpretation of perspective-taking was recently proposed (Barnes-Holmes et al., 2001; McHugh, Barnes-Holmes & Barnes-Holmes, 2004). These theorists suggested that perspective-taking is generalized operant behavior, emerging following a reinforced history of relational responding. Specifically, children are directly reinforced for responding correctly to questions involving I –You, Here-There, and Now-Then relations, such as "What are you doing now?", "What did I do then?" and "What are you doing here?" (Barnes-Holmes et al., 2001). Once a history of reinforcement has established correct responding to such questions, perspective-taking may generalize to other questions. Thus, rather than focusing on perspective-taking as a developmental skill, behavioral psychologists have proposed to instead view the ability as a form of derived relational responding, where children derive accurate I-You, Here-There and Now-Then relations based on a reinforced history of responding to similar questions. Although the physical environment changes with each different question posed, the I-You, Here-There, and Now-Then relations will always be present in some form (Barnes-Holmes et al., 2001). This theoretical orientation suggests that deficits in perspective-taking may be due to a child's limited experiences deriving relations between I-You, Here-There, and Now-Then. Moreover, deficiencies in perspective-taking may be ameliorated via the establishment of a reinforced history of relational responding.

A promising approach to the study of relational learning deficits in perspective-taking was recently reported by McHugh et al. (2004). These authors administered a comprehensive protocol for evaluating relational learning deficits in perspective-taking to a large number of typically developing participants, ranging in age from early childhood to adulthood. Coined the Barnes-Holmes protocol, this assessment evaluates a child's ability to show a number of simple and complex I-You, Here-There, and I-You/Here-There relations. The protocol was originally administered in conversation format between the experimenter and participant, in which the experimenter presented a series of problems (i.e., "I have a green brick and you have a red brick. If I was you and you were me, which brick would you have? Which brick would I have?") and the participant was to answer both questions without receiving any feedback. The authors found that errors decreased as a function of increases in participants' ages, lending support to both the developmental and behavioral approaches to perspective-taking. Older participants had presumably experienced a longer history of reinforced relational responding (McHugh et al., 2004).

The findings reported by McHugh et al. (2004) pave the way for further research and application on the role of relational learning in perspective-taking. The purpose of the present pilot project was to extend the findings of McHugh et al. (2004) by using a modified, computerized version of the Barnes-Holmes protocol to evaluate the relational responding deficits involved in perspective-taking in four children with high-functioning autism. We compared their scores to the mean age equivalent scores reported by McHugh et al. (2004).

Method

Participants

Four children who attended the SIUC Center for Autism Spectrum Disorders served as participants. All participants had been recently diagnosed with mild or high-functioning autism. All were verbally fluent and attended regular educational classes. They included CP (age 7), EB (age 8), RW (age 9), and WP (age 10). CP had been scored at the 80th percentile in overall adaptive behavior on the Vineland Adaptive Behavior Scales, which had been administered 15 months prior to her participation in the study. She was scored below the 10th percentile on the Test of Pragmatic Skills – Revised, which was administered nearly four years prior to her participation in the study. EB was scored with an age equivalence of six years, eleven months on the Language Processing Test – Revised, which was administered two years prior to her participation in the study. RW was scored with an age equivalence of seven years, two months in reading comprehension on the Peabody Individual Achievement Test, which was administered two years prior to his participation in the study. The only assessment information available on WP was a recent diagnostic assessment, which confirmed that he experienced high-functioning autism. The diagnostic assessment also identified WP's advanced language skills and restricted display of reciprocal conversation.

Apparatus and Setting

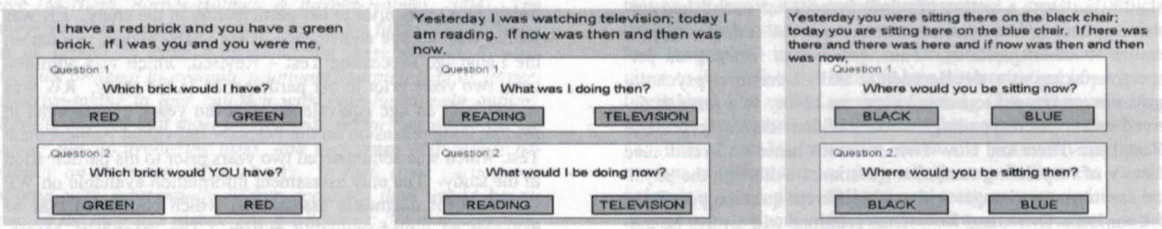
All sessions were conducted in a quiet, secluded classroom at the SIUC Center for Autism Spectrum Disorders. Trial presentation and data collection were computer-controlled. The experiment was programmed in Microsoft® PowerPoint® and Microsoft® Visual Basic® by the second author, and was conducted using a lap-top computer.

Procedure

The experiment consisted of 53 trials adopted from the Barnes-Holmes protocol (see McHugh et al., 2004), with each trial consisting of two questions. Both questions had to be answered correctly in order for the trial to be scored as correct. Participants were required to click the mouse upon one of two command boxes presented for each question. There were no consequences for correct or incorrect responses. Three types of relational tasks were presented, including I-you, Here-There, and Now-Then trials. The three tasks were presented at three varying levels of complexity involving either single, reversed, or double reversed relations. A simple relation was one in which a correct response was identical to the arrangements specified in the problem (McHugh et al., 2004). An example of a simple relational I-You trial was, "I have a red brick and you have a green brick. Which brick do I have? Which brick do you have?" An example of a simple relational Here-There trial was, "I am sitting here on the black chair and you are sitting there on the blue chair. Where are you sitting? Where am I sitting?" An example of a simple relational Now-Then trial was, "Yesterday I was reading. Today I am watching television. What was I doing then? What am I doing now?"

Reversed relations involved explicitly reversing the relations presented by the experimenter (McHugh et al., 2004). An example of a reversed relational I-You trial was, "I have a red brick and you have a green brick. If I were you and you were me, which brick would you have? Which brick would I have?" An example of a reversed relational Here-There trial was, "I am sitting here on the blue chair and you are sitting there on the black chair. If here was there and there was here, where would you be sitting? Where would I be sitting?" An example of a reversed Now-Then trial was, "Yesterday I was watching television; today I am reading. If now was then and then was now, what would I be doing now? What was I doing then?"

Figure 1. Examples of trials.



Simple I-You Relation ***Reversed Now-Then Relation*** ***Double Reversed Here-There/Now-Then***

Trial types for the double reversed relations presented two relations (either I-You and Here-There or Here-There and Now-Then) that were reversed simultaneously (McHugh et al., 2004). An example of a double reversed relational I-You/Here-There trial was, "I am sitting here on the blue chair and you are sitting there on the black chair. If I were you and you were me and if here was there and there was here, where would you be sitting? Where would I be sitting?" An example of a double reversed relational Here-There/Now-Then trial was, "Yesterday you were sitting there on the black chair; today you are sitting here on the blue chair. If here was there and there was here and if now was then and then was now, where would you be sitting now? Where would you be sitting then?"

A total of six simple relations (2 I-You, 2 Here-There, and 2 Now-Then), 34 reversed relations (8 I-You, 11 Here-There, and 15 Now-Then), and 13 double reversed relations (4 I-you/here-there, and 9 here-there/now-then) were presented. Trials were presented in this order. Examples are shown in Figure 1.

Prior to the experiment, participants were instructed to read each question aloud, and were oriented towards using the computer mouse to respond to each question. If participants asked the experimenter for help or commented on the difficulty of the task at any time during the experiment, they were simply reminded to do their best. Sessions lasted approximately one hour for each participant. Participants were allowed to take several brief breaks during the session, during which they engaged in a fun activity (i.e., jumping on a trampoline) with the experimenter. They were compensated with a $5 McDonald's gift certificate upon conclusion of the experiment.

Results

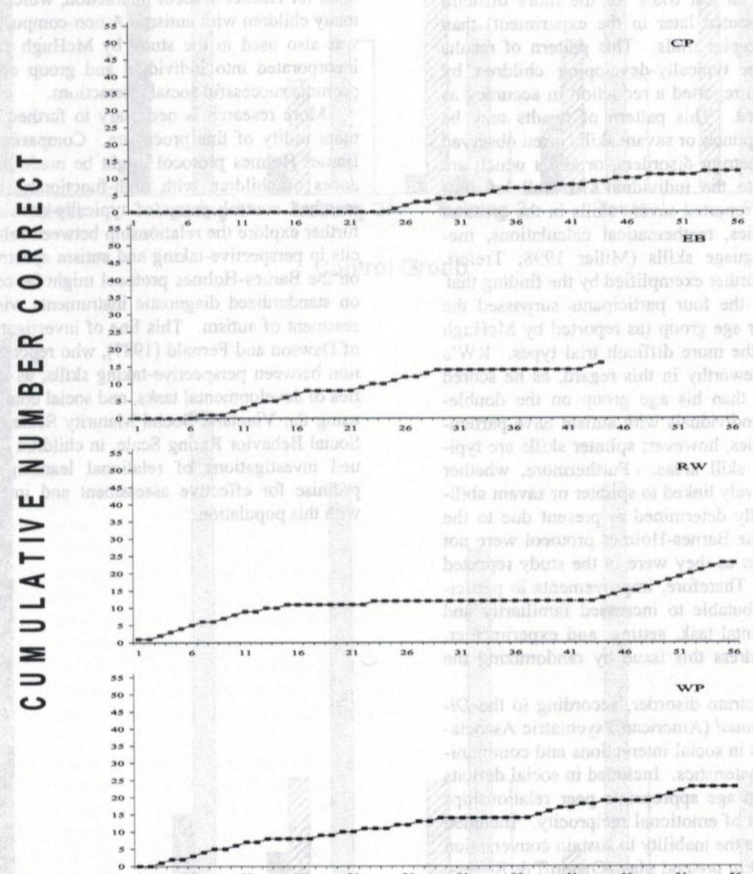
The dependent measure was the percentage of correct responses for each relational task (I-You, Here-There, Now-Then) at each level of complexity (simple, reversed, double reversed). Participants' scores were compared to the overall mean percentage of correct responses for their respective age group, as reported by McHugh et al. (2004). These data are shown in Table 1. Data are not presented for the double reversed relations for EB, as she withdrew from the experiment prior to completing these trials. The table shows that the four participants performed lower than their age group, as reported by McHugh et al. (2004), on several of the tasks: All of the participants performed with substantially lower accuracy than their age group on the simple I-You relations, the reversed Here-There relations, and the reversed Now-Then relations. At the same time, some participants performed with substantially higher accuracy than would be expected for their age group on several of the tasks: RW and WP performed with 100% accuracy on the simple Here-There relations; EB performed with 75% accuracy on the reversed I-You relations; CP and RW performed with 50% and 75% accuracy, respectively, on the reversed I-You/Here-There relations; and RW performed with 88% accuracy on the reversed Here-There/Now-Then reversed relations. Aside from their difficulty on the simple I-You relations, no particular pattern of weaknesses across relation type was observed across the four participants. WP performed with higher accuracy on nearly all of the relations tested than he did on the Simple I-You relations.

Figure 2 shows the cumulative number of trials correct for each participant. The figure shows accuracy improvement over the course of the experiment for all participants. RW's performance is most noteworthy, as his accuracy improved substantially on the later, more difficult trials.

Table 1. Percentage of correct responses for each relational task at each level of complexity for each participant, compared to the overall mean percentage of correct responses for each participant's age group, as reported by McHugh et al. (2004).

PARTICIPANT(S)	AGE	I-YOU SIMPLE	HERE-THERE SIMPLE	NOW-THEN SIMPLE	I-YOU RE-VERSED	HERE-THERE REVERSED	NOW-THEN RE-VERSED	I-YOU/ HERE-THERE REVERSED	HERE-THERE/ NOW-THEN RE-VERSED
McHugh et al. sample mean	7-8	≈87	≈81	≈78	≈60	≈57	≈46	≈30	≈38
CP	7	0	0	0	0	25	38	50	13
EB	8	0	0	25	75	50	19	-	-
McHugh et al. sample mean	9-11	≈81	≈81	≈81	≈55	≈40	≈44	≈50	≈50
RW	9	50	100	75	63	8	6	75	88
WP	10	0	100	75	38	42	38	0	38

Figure 2. Cumulative number of trials correct for each participant.



Discussion

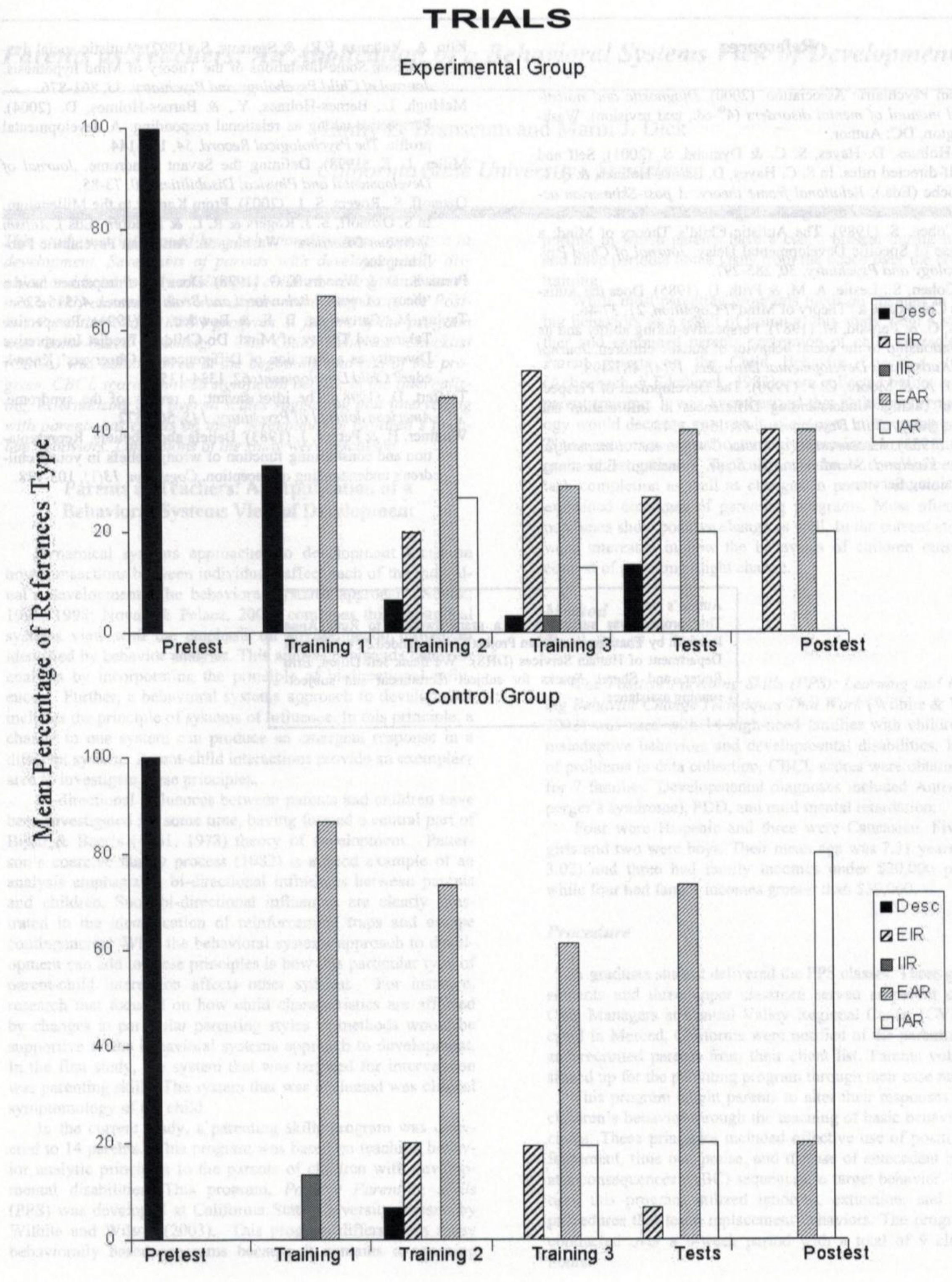
The results of this pilot project lend support to the notion that a history of deriving stimulus relations may provide the basis for perspective-taking skills, as perspective-taking was assessed in the context of simple, reversed and double reversed I-You, Here-There and Now-Then relations. These relations all exemplify the changes in perspective that must occur over the course of social interactions with others, if indeed those interactions are to be successful. Thus, perspective-taking may be a form of generalized operant behavior that emerges following a history of reinforcement for relating I-and-You, Here-and-There, and Now-and-Then. These results thus support the conceptualization established by Barnes-Holmes et al. (2001) and McHugh et al. (2004).

Comparisons were made between the results of our four participants and the overall mean scores for the participants' typically-developing peer age group, as reported by McHugh et al., (2004). Interestingly, accuracy improved over the course of repeated testing for all but one participant (WP); the other three participants scored higher on test trials for the more difficult relations (which were presented later in the experiment) than they did on the earlier, simpler trials. This pattern of results contrasts that reported for typically-developing children by McHugh et al. (2004), who reported a reduction in accuracy as problem difficulty increased. This pattern of results may be reflective of the notion of splinter or savant skills often observed in persons with autism spectrum disorders, or skills which are overly advanced relative to the individual's overall level of functioning. Studies have reported savant skills in the areas of artistic and musical abilities, mathematical calculations, mechanical abilities and language skills (Miller 1998; Trefert, 1998). This possibility is further exemplified by the finding that performances for three of the four participants surpassed the mean performance for their age group (as reported by McHugh et al., 2004), on some of the more difficult trial types. RW's performance was most noteworthy in this regard, as he scored over thirty percent higher than his age group on the double-reversed trial types. Few individuals with autism have particularly advanced social abilities, however; splinter skills are typically observed in solitary skill areas. Furthermore, whether these results can be definitively linked to splinter or savant abilities cannot be unequivocally determined at present due to the fact that the test trials of the Barnes-Holmes protocol were not presented in a random order as they were in the study reported by McHugh et al. (2004). Therefore, improvements in participants' scores may be attributable to increased familiarity and comfort with the experimental task, setting, and experimenter. Future research should address this issue by randomizing the presentation of trial-types.

Criteria for autism spectrum disorder, according to the *Diagnostic and Statistical Manual* (American Psychiatric Association, 2000), include deficits in social interactions and communication as two primary characteristics. Included in social deficits are the inability to develop age appropriate peer relationships and deficiencies in the area of emotional reciprocity. Included as communicative deficits is the inability to sustain conversation and the lack of engagement in pretend play (Ozonoff & Rogers, 2003). A relationship between a repertoire of deriving relations between I-and-You, Here-and-There, and Now-and-Then and deficits in these areas seems likely. Further research is necessary to further explore the relationship between the DSM-IV criteria for autism spectrum disorder and perspective-taking as relational responding.

An important implication of the conceptualization of perspective-taking as generalized operant behavior is the idea that deficits in perspective-taking may be ameliorated via the establishment of a history of reinforced relational responding. In other words, children who perform with difficulties on perspective-taking tasks may be exposed to instructional curricula which explicitly establish a certain subset of I-You, Here-There, and Now-Then relations. If such an intervention is effective, we would expect to see the child perform accurately on novel relations to which he or she has never been exposed. In other words, we would expect perspective-taking to emerge as a higher-order, overarching skill (see Barnes-Holmes et al., 2001). Moreover, a modified version of the Barnes-Holmes protocol might also serve an important function in screening and assessment for educational planning, as well as for intervention purposes. A computerized version of the protocol may reduce the need for teacher-student interaction, which is often difficult for many children with autism. A non-computerized version, which was also used in the study by McHugh et al. (2004), may be incorporated into individual and group educational lessons to promote successful social interactions.

More research is necessary to further investigate the treatment utility of this procedure. Comparisons of scores on the Barnes-Holmes protocol might be made between the performances of children with high-functioning autism and an age-matched control group of typically-developing children. To further explore the relationship between relational learning deficits in perspective-taking and autism spectrum disorders, scores on the Barnes-Holmes protocol might be correlated with scores on standardized diagnostic instruments widely used in the assessment of autism. This line of investigation is similar to that of Dawson and Fernald (1987), who reported a positive correlation between perspective-taking skills, as measured using a series of developmental tasks, and social competence, as measured using the Vineland Social Maturity Scale (Doll, 1953) and the Social Behavior Rating Scale, in children with autism. Continued investigations of relational learning deficits hold great promise for effective assessment and intervention procedures with this population.



TRIALS
Experimental Group
Mean Percentage of References Type
100
80
60
40
20
0
Pretest
Training 1
Training 2
Training 3
Tests
Postest
Desc
EIR
IIR
EAR
IAR
Control Group
100
80
60
40
20
0
Pretest
Training 1
Training 2
Training 3
Tests
Postest
Desc
EIR
IIR
EAR
IAR

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Parents as Teachers: An Application of a Behavioral Systems View of Development

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This study was influenced by a behavioral systems approach to development. Seven sets of parents with developmentally disabled and behaviorally challenged children were given 9 hours in 6 weekly classes of behavioral parent training using the Positive Parenting Skills (PPS) program. A feature of the program was home-based coaching. The Child Behavior Checklist (CBCL) was administered at the beginning and end of the program. CBCL scores showed significant decline in the internalizing, externalizing and overall scales suggesting that intervening with parents has effects on their perceptions of children's problem behaviors. Limitations of the study were discussed.

Parents as Teachers: An Application of a Behavioral Systems View of Development

Dynamical systems approaches to development focus on how transactions between individuals affect each of the individual's development. The behavioral systems approach (Novak; 1996, 1998; Novak & Pelaez, 2004) combines this dynamical systems view with the emphasis on environmental influences identified by behavior analysis. This approach expands behavior analysis by incorporating the principle of bi-directional influences. Further, a behavioral systems approach to development includes the principle of systems of influence. In this principle, a change in one system can produce an emergent response in a different system. Parent-child interactions provide an exemplary area to investigate these principles.

Bi-directional influences between parents and children have been investigated for some time, having formed a central part of Bijou & Baer's (1961, 1978) theory of development. Patterson's coercive family process (1982) is a good example of an analysis emphasizing bi-directional influences between parents and children. Such bi-directional influences are clearly illustrated in the identification of reinforcement traps and escape contingencies. What the behavioral systems approach to development can add to these principles is how this particular type of parent-child interaction affects other systems. For instance, research that focused on how child characteristics are affected by changes in particular parenting styles or methods would be supportive of the behavioral systems approach to development. In the first study, the system that was targeted for intervention was parenting skills. The system that was evaluated was clinical symptomology of the child.

In the current study, a parenting skills program was delivered to 14 parents. This program was based on teaching behavior analytic principles to the parents of children with developmental disabilities. This program, *Positive Parenting Skills* (PPS) was developed at California State University, Fresno by Wilhite and Wilson (2003). This program differs from many behaviorally based programs because it contains a coaching portion in which parents have a coach present during teaching and have periodic home visits from the coach over the course of training.

While most parenting programs focus on changes in parenting behaviors as a result of training, this study went a step further and examined parents perception of child characteristics. Parent reports on the Child Behavior Checklist, (CBCL) (Achenbach & Edelbrock, 1983) were collected before and after parent training. It was hypothesized that childhood symptomology would decrease as a result of changes in parenting practice. These outcomes are not commonly examined in parenting program investigations. Typically, children's compliance and/or task completion as well as changes in parent behavior are the examined outcomes of parenting programs. Most often, these outcomes show positive change as well. In the current study, we were interested in how the behaviors of children outside the context of parenting might change.

Method

Participants

The *Positive Parenting Skills (PPS): Learning and Practicing Behavior Change Techniques That Work* (Wilhite & Wilson, 2003) was used with 14 high-need families with children with maladaptive behaviors and developmental disabilities. Because of problems in data collection, CBCL scores were obtained only for 7 families. Developmental diagnoses included Autism (Asperger's syndrome), PDD, and mild mental retardation.

Four were Hispanic and three were Caucasian. Five were girls and two were boys. Their mean age was 7.31 years (SD = 3.02) and three had family incomes under $20,000 per year while four had family incomes greater than $30,000.

Procedure

A graduate student delivered the PPS classes. Three graduate students and three upper classmen served as parent coaches. Case Managers at Central Valley Regional Center (CVRC) located in Merced, California were notified of the parenting class and recruited parents from their client list. Parents voluntarily signed up for the parenting program through their case manager.

This program taught parents to alter their responses to their children's behavior through the teaching of basic behavior principles. These principles included effective use of positive reinforcement, time out, praise, and the use of antecedent behavior and consequences (ABC) sequences to target behavior. In addition, this program utilized ignoring, extinction, and shaping procedures that teach replacement behaviors. The program was conducted over a 6-week period with a total of 9 classroom hours.

The PPS supported parents' learning by incorporating three home visits across the program. Parents worked in collaboration with their coach and targeted a maladaptive behavior within their natural environment. During the home visit the coach and parent discussed questions regarding the course and reviewed any misunderstood or unclear material. In addition, the coach observed the parent-child interactions to reinforce changed behavior as well as to offer ways in which further change could be accomplished.

Measures

Child Behavior Checklist (CBCL)

The CBCL is a standardized measure used to assess children with behavioral and emotional problems (Achenbach. & Edelbrock, 1983). Parents or caregivers who interact with the children complete the assessment. This measure was written at a fifth grade level and comes in different languages.

The parent or caregiver completed the CBCL on the first and last class meetings. The CBCL was completed on average in 20 minutes. The parent answered questions based on their child's behavior within the last 6 months. There were 113 questions to fill out. Answers ranged from 0 = Not True (as far as you know), 1 = Somewhat or Sometimes True, or 2 = Very True or Often True.

The two summary scales of the internalizing and the externalizing behaviors were scored along with the overall score from the Total Problems scale. The internalizing scale is made up of symptoms of withdrawal, somatic complaints and anxiety or depression. The externalizing scale focuses on delinquent and aggressive behaviors.

The measure was scored by computer. Clinical significance for each of the behavior subscales and summary scales is based on T scores of 70 or higher, which represents approximately the 98th percentile. The lowest score attainable on a subscale is 50. If a child scores between 58 and 62 in the summary scales (Internalizing, Externalizing, and Total Problems), they are considered to be in the borderline clinical range; therefore the higher the score, the more problems within that area.

Results

A paired *t* test was utilized to compare the pre and post scores on the CBCL. A computer program was provided by the developer of the CBCL computed *T* scores. The *T* scores from the CBCL were derived for three areas: Total problems, Internalizing, and Externalizing Paired *t*-tests revealed significant decreases for the total problems scores, $t(6) = 1.94, p < .05$), the internalizing scores, $t(6) = 1.94, p < .05$), as well as the externalizing scores, $t(6) = 1.94, p < .05$). See Table 1 for means.

Discussion

These results support the hypotheses that childhood symptomology can be affected without direct intervention on the child, but by intervening in the family system through teaching and coaching parents in behavioral methods. Further, in addition to being statistically significant, the changes were clinically important as well. The total and externalizing scores dropped from being clinically significant in the pretest to borderline in the posttest. The internalizing score dropped from being of borderline clinical significance to the normal range.

The results show that applying a behavioral systems approach by focusing on parenting can provide useful information regarding child outcomes. It should be noted that these results are based on a small sample size.

A further caution to the current results is that only parent reports were obtained. Future studies should obtain scores from multiple sources. Most importantly, it would have increased the validity of the findings if we had been able to obtain self-reports from the children. Finally, these results should not be taken to provide causal information regarding how parenting influences childhood symptomology. It could be that true childhood symptomology did not change; however parental perception of symptomology was effected. Further research will be required before causation can be applied. However, these results should encourage researchers interested in pursuing systems level effects and non-linear growth.

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Table 1. Means and Standard Deviations for CBCL scores.

	M (SD)		*t*-value	df	Significance
	Pre	Post			
Total Problems	72.29	65.29	2.20	6	0.035*
Internalizing	63.71	54.43	2.09	6	0.040*
Externalizing	70.00	60.43	2.66	6	0.020*

Infant Responding Compared Under Conjugate- and Continuous-Reinforcement Schedules

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Florida International University

The performance of six human infants (aged 16 to 20 weeks) was compared under a conjugate- versus a continuous-reinforcement schedule. The contingent visual stimulus, a sequence of 5 colored lights, their intensity varying in proportion to response amplitude under the conjugate but not under the continuous schedule, was presented alone and together with a constant auditory contingent stimulus—chimes placed behind the lights—under both schedules. The target operant response—a foot press of a vertical panel—produced the lights with/without the tinkling chimes. A reversal design counterbalanced with alternating treatments was implemented for each half of the participants. Visual inspection of the graphed-operant frequencies for all six infants, and one-tail binomial tests, showed at $p < 0.008$ that: (a) the two contingent-stimulus complexes, visual alone and visual-plus auditory, functioned as reinforcers of leg thrusts under both reinforcement schedules; the visual-plus-auditory consequence was a more effective reinforcer for leg-thrust operants than was the visual consequence alone; and, (c) compared to the continuous CRF schedule, the conjugate-reinforcement schedule generated higher peak responding.

Infant Responding Compared Under Conjugate- and Continuous-Reinforcement Schedules

In operant learning, *reinforcement* is defined as the process in which a behavior unit can more likely recur as a result of the positive consequences it produces. Ferster and Skinner (1957) described four basic types of intermittent-reinforcement schedules: fixed ratio, variable ratio, fixed interval, and variable interval. Different patterns and rates of responses have resulted when behavior units/operant responses have been subjected to different reinforcement-contingency schedules. Almost all work on reinforcement to date has involved preparations in mammals using free-operant procedures in which operant classes are followed on some schedule by narrowly-defined classes of stimulus consequences (reinforcers), but with no other dependent relation between operant and consequence. Also, the features of the operant and the reinforcer class have remained constant in each research demonstration, features that ordinarily vary along diverse dimensions in life settings.

A *continuous*-reinforcement schedule (CRF) denotes a pattern according to which every narrowly-defined response instance is followed by a narrowly-defined consequence. A *conjugate*-reinforcement schedule departs from traditional reinforcement schedules with homogeneous consequences in that an attribute of its consequence (e.g., amount, size, consistency) is *proportional* to the rate, intensity, or duration of responding (Lindsley, 1957, 1963; Lipsitt, 1967).

In a schedule of reinforcement termed "synchronous," similar in effects to those associated with conjugate reinforcement, the onset and offset of each participant's response is in temporal synchrony with onset and offset of the reinforcer (Pelaez-Nogueras, Gewirtz, Field, Cigales, Malphurs, Clasky, & Sanchez, 1996; Pelaez-Nogueras, Field, Gewirtz, Cigales, Gonzales, Sanchez, & Clasky, 1997; Ramey, Hieger, & Klisz, 1972). The synchronized reinforcement operation used by Pelaez et al. (1996, 1997) is a contingency-based operant procedure that permitted comparison in the reinforcing effectiveness of types of adult stimulation (auditory, visual, tactile) in maintaining infant behavior. The procedure also allowed demonstration that caregiver touch can control infant eye contact, smiling, vocalization, and can establish the functional relation between reinforcing stimulation and diverse infant operants.

Continuous Reinforcement Research

There is a vast body of literature on operant learning in animals and humans, with most of the work having used a discrete delivery of reinforcers. Continuous reinforcement denotes a discrete delivery of a more or less constant reinforcing stimulus in that each response produces an instance of that reinforcer. Continuous reinforcement (CRF) is the most basic of schedules, leading to rapid increases in response rate (i.e., acquisition of the particular behavior unit).

It is well established in the operant-learning literature, primarily from animal experimentation, that CRF schedules generate the rapid acquisition of new behaviors, and numerous studies have demonstrated its effectiveness in behavioral acquisition with humans as well. Etzel and Gewirtz (1967) used a CRF schedule of reinforcement to reverse the problem-crying behavior of one-month infants . Similarly, Bloom (1974, 1975; Bloom & Esposito 1975), and Wahler (1967) demonstrated the efficacy of social reinforcers for the behavior of 3-month-old humans. Silverstein (1972) and Silverstein and Lipsitt (1974) used continuous reinforcement with 10-month-old humans in a spatial discrimination task to demonstrate the effect of secondary reinforcement and to produce a subsequent spatial preference on the part of the participants.

The continuous-reinforcement schedule has been extended to the investigation of learning and emotional responsivity of infants who were exposed to cocaine *in utero* (Alessandri, Sullivan, Imaizumi, & Lewis, 1993), to infants developing verbal behavior for several response classes over a one-year period (Wahler, 1969), and to the shaping of self-initiated toileting in infants (Smeets, Lancioni, Ball, & Oliva, 1985).

Conjugate Reinforcement Research

Among the first to use the free-operant model with humans, Lindsley (1957) coined the term "conjugate reinforcement" to label how a reinforcer attribute (rate, duration, or intensity) can become associated with some response attribute. Mira (1968) used the conjugate reinforcement paradigm to analyze patterns of looking and listening preferences among children, with the rate of responding on a hand switch controlling the intensity of a continuously available consequence. Mira (1970) later researched the rate at which hearing-impaired school-aged children responded to audio narrations and the varying ways in which they responded to the opportunity to listen. The use of conjugate reinforcement was extended to the investigation of verbal narrative preferences of children (Lovitt, 1967a; 1967b; 1968a). Similarly, Lovitt (1968b) researched the musical preferences of children. Participants were provided with a hand switch to select continuously the music of their choice by either pressing or not pressing the switch.

Lipsitt, Pederson, and DeLucia (1966) were among the first to use a conjugate schedule in the study of infant learning. Seated in front of a dark screen, 12-month-old infants could press with either one or both hands a panel to illuminate and view a stimulus on the screen. Reinforcement (the viewing in focus of a colorful image of a clown) was provided proportional to the infants' response rate.

A direct outgrowth of Lindsley's work was Siqueland's and DeLucia's (1969) development of a high-amplitude sucking procedure. Infants' sucking response that exceeded a predetermined amplitude threshold was reinforced in intensity proportionally to the rate of responses. Other researchers of infant learning, memory, and perception have used a similar procedure (Lipsitt, 1966; Spence, 1996). Lindsley (1963) used a conjugate-reinforcement procedure with a five-month-old human to investigate the efficacy of social reinforcers produced by the increased rate of kicking to produce the reinforcing event (a silent movie of a smiling female). Rovee and Rovee (1969) used conjugate reinforcement produced by an overhead mobile connected without slack via ribbon to infants' left ankles. The rate and amplitude of infant leg-movement instances resulted in the mobile's figures swaying and colliding proportionately to the responses. Because of its simplicity and ease of implementation, the mobile's movements that provided conjugate reinforcement for the leg kick sparked a flurry of investigations of infant learning and memory. Thus was studied the effects of quantitative shifts in visual reinforcers on operant responses (Fagen & Rovee, 1976); the positive behavioral contrast in 3-month-olds (Rovee-Colier & Capatides, 1979); the efficacy of auditory and visual conjugate reinforcement in conditioning (Mc Kirdy & Rovee, 1978); the conditioning of long-term memory (Sullivan, Rovee-Collier & Tynes, 1979); the reactivation of memories in early infancy (Fagen, Yengo, Rovee-Collier & Enright, 1981, Hitchcock & Rovee-Collier, 1996; Rovee-Collier, Enright, Lucas, Fagen & Gekoski, 1981; Rovee-Collier & Hayne, 1987); learning and memory in pre-term infants (Gekoski, Fagen & Pearlman, 1984); the amount of training and retention by infants (Ohr, Fagen, Rovee-Collier, Hayne & Linde, 1989); long-term maintenance of infant memory (Rovee-Collier, Hartshorn & Manda, 1999); encoding and retrieval of infant memory (Hartshorn & Rovee-Collier, 2003); conditioning and long-term memory in three-month-olds with Down syndrome (Ohr & Fagen, 1991); and memory processing of a serial list by young infants (Gylya, Rovee-Collier, Gallucio & Wilk, 1986). In all of the aforementioned studies, the conjugate-reinforcement procedure was associated with maintaining high and steady response rates for lengthy time periods.

The notion that the infant is an incomplete organism who gradually performs higher levels of accomplishment defined in terms of adult behavior (White, 1959) no longer appears tenable. In contrast, Rovee-Collier and Gekoski (1979) proposed that the human infant is simply a different organism who occupies an ecological niche that departs from that of adults. Therefore it is possible that infants learn the contingencies of conjugate reinforcement more readily because the schedule is analogous to the situations controlling their development in their ecological niche. In the natural environment, for example, when an infant cries, the frequency and loudness of the cry may prompt the mother to approach more rapidly, or the amount of milk obtained by a sucking baby may be proportionate to the pressure and the frequency of each suck.

Lindsley developed the conjugate schedule to handle situations in which continuity is often interrupted and the reinforcing efficacy is compromised when the stimulus is turned off by discrete reinforcement schedules (variable interval, fixed interval, variable ratio, fixed ratio). Lindsley contended that this schedule is the most basic and fundamental, particularly for humans with incomplete or impaired cortical functioning (e.g., infants, individuals with presumed minimal brain damage, psychotics, and mental retardates). The schedule appears to have ecological significance because it closely resembles the way in which the aforementioned organisms learn what contingencies operate in the natural environment.

Synchronized Reinforcement Procedure

Similar to the conjugate reinforcement procedure is the synchronized reinforcement procedure developed by Pelaez-Nogueras et al. (1996). This is a contingency-based operant procedure that specifically allows the experimenter to compare the reinforcing efficacy of different types of adult stimulation in maintaining infant behavior. It permits a systematic comparison of the effects of different adult compound stimuli (e.g., auditory, visual, tactile) alternated during face-to-face interactions. The procedure allows the experimenter systematically to demonstrate that caregiver touch can regulate infant state (attention) as well as control infant positive affect (denoted by smiles and vocalizations). During extinction, in the absence of auditory stimuli and changes in maternal facial expression, the rate of infant response is expected to decrease, thus demonstrating a functional relation between the reinforcing tactile stimulation and the infant behavior.

Using this synchronized reinforcement procedure, Pelaez et al. (1996) compared the effect of an adult stimulus compound treatment that included touch with the effect of an adult stimulus compound treatment that did not include touch (only auditory and visual stimuli) on infant behavior during face-to-face interactions.

The results demonstrated that a social stimulus compound that included touching the infants functioned as a more effective reinforcer for infant eye-contact behavior than a stimulus compound that did not include touch.

While the traditional approaches have permitted researchers to investigate many phenomena with infants (e.g., habituation), these have had their limitations. Because infant attention span is fluctuating and short, experimental sessions with them are usually brief in order to reduce subject attrition (Hulsebus 1973). While brevity of experimental sessions insures that the infant is kept alert and interested, it may prevent experimenters from measuring fully the impact of the independent variable on dependent measures (Pomerleau & Malcuit, 1992). On the other hand, an operant task, such as the synchronized reinforcement procedure, appears to be more amenable in maintaining responding on the part of the participants being tested.

In summary, the study being reported had a dual objective. First, it would permit a direct comparison of two different reinforcement schedules, both on a one-to-one fixed ratio (FR1). Second, the study would enable the experimenter to compare various measures of responding (frequency, intensity, or duration) of the target behavior emitted under the continuous-reinforcement schedule with measures of responding emitted under the conjugate-reinforcement schedule, where the infant participant would have a greater degree of control of his or her own stimulation.

Research Hypotheses

The *first* hypothesis was that operant learning would occur: that the presentation of a contingent visual stimulus alone, followed by a contingent visual-plus-auditory stimulus complex, would *both* reinforce infant leg-thrust responses. Consequently, a pattern of zero-slope responding during *baseline* phases of positive-slope responding during reinforcement phases, and of negative-slope responding during reversal phases, was expected in the graphed-response pattern of each participant. This conditioning hypothesis was a corollary of the sequential contingencies functioning as positive reinforcers for the leg-thrust operant. The *second* hypothesis was that, compared to responding producing the visual-stimulus alone, responding producing the consequence of the visual-plus-auditory stimulus complex would result in a higher rate, particularly under the conjugate schedule. The *third* hypothesis was that the visual-plus-auditory stimulus complex, of greater reinforcer efficacy for leg-thrust operants with a higher response level under conjugate reinforcement, would provide clear evidence of a difference between the conjugate- and the continuous-reinforcement schedules. Because the auditory stimulus would be presented as a constant and in the same order to all participants, change in responding could be attributed largely, if not solely, to the visual stimulus. Thus, the third hypothesis was that the visual-plus-auditory stimulus complex, of greater reinforcer efficacy for leg-thrust operants with a higher response level under conjugate reinforcement, would provide clear evidence of a difference between the conjugate and the continuous reinforcement schedules. Responding during the presentation of visual-auditory stimuli would result in a higher rate than during the presentation of visual-stimulus consequences alone, particularly when participants' responding was reinforced under a conjugate schedule.

Method

Participants

Eleven human infants (4 boys, 7 girls) between the age of 16 and 20 weeks participated in this study. They were recruited by word of mouth, from nurseries, and from the Office of Vital Records in Miami-Dade County, independent of such demographic variables as ethnicity, "race," socioeconomic status, or gender. Parents were acquainted with the purpose of the study, and signed an informed consent form denoting their agreement to permit their infants' participation. The requirement for eligibility was that potential participants were full-term healthy infants with a normal birth and no medical or neurological problems.

The criteria to stop sampling during treatment phases were as follows: (1) the last 2 data points should not differ by more than 3 units, (2) the last 2 data points should be part of an ascending trend and (3) the rate of responding at the end of the treatment phases should be at least 3 times the average rate of responding of the last 3 data points of the baseline condition. As for the reversal conditions, the criteria to cease sampling were that data points should depict a descending trend, if possible, to the mean responding level in the baseline condition.

Not all data collected for the participants are reported: two infants participated only in the study's exploratory phase; two infants were disqualified because they exhibited an excessive fussiness (i.e., fussing/crying continuously) when placed under an experimental condition; and one did not perform to criterion on the operant task. The responding of the residual 6 infants, who were exposed to the entire experimental procedure, are graphically reported (see Fig. 1-6).

Apparatus and Stimuli

Participants were tested in their homes. Each infant was seated in an infant seat placed in an enclosure (46 cm wide, 81 cm long, and 20 cm high), with feet facing a vertical panel (41 cm wide, and 33 cm high) which was kept in place by a spring calibrated from 0 to 2,500 g. The visual consequence of the leg kick consisted of 5 colored 12-volt 5-watt lights serially connected. When following the visual, the auditory chimes consequence was produced by 5 metal pipes (15 cm long, 1 cm in diameter) that hung vertically by way of strings and a metal bar (9 cm in length, 0.50 cm in diameter) that hung horizontally via strings as well. Each press of the panel lit the series of five 5-watt lights (orange, yellow, green, blue, violet) that provided the putative visual reinforcer, or produced a tinkling metallic sound resulting from the chimes being struck by a wooden hammer protruding from the back of the vertical panel, in conjunction with lighting the series of colored lights.

Because of the necessity of comparability when presenting the visual stimulus to the participants under both schedules of reinforcement, the brightness of the light when presented discretely was powered by 6 rather than 12 volts (mid-illumination) and was kept constant regardless of the rate or intensity of responding. Under the conjugate-schedule presentation, however, the brightness of the lights was programmed to fluctuate linearly from the dimmest (1-g pressure) to the brightest illumination (2500-g pressure). A leg thrust that caused any displacement of the panel, and the onset of the contingent visual with/without auditory stimulus, scored a response.

Design

The experiment was conducted using a single-subject reversal design (A-B-A-C-A for 3 participants and A-C-A-B-A for 3 participants), with 2 alternating treatments across phases (Barlow & Hayes, 1979). The phases encompassed baseline or reversal conditions (A), continuous reinforcement (B), and conjugate reinforcement (C) were implemented in two orders, but (B) and (C) phases were counterbalanced between the two halves of the participants. The first phase (A) in the sequence denoted the *baseline* control condition. The subsequent (A) phases referred to non-reinforcement reversals and were implemented to minimize the possibility of finding a carryover effect. The (B) and (C) conditions were counterbalanced across participants to control for sequential confounding.

Procedure

Each session lasted from 12 to 20 min, and began with establishing that the infant was on schedule (i.e., fed, diapered, and not sick). If an infant cried for more than 5 sec on an occasion, a halt was enacted and the parent or present caretaker was directed to comfort the child. The experimental sessions were held in abeyance if the infants were not attending to the visual stimuli for more than 10 sec. If an infant cried continuously for more than 25 sec, in spite of a parent's effort to comfort him/her, the session was terminated for that day. Each infant was tested at the time of the day the caregiver indicated to be the infant's alert or play period.

Ideally, collecting the data across all conditions in one session would have better served the purpose of this investigation, but doing so would have required participants' cooperation for at least 50 consecutive min. During the exploratory phase of the study, two participants could not tolerate being in the experimental condition for an entire session of 50 min, and the intolerance became even more apparent when other participants were subsequently tested. Consequently, the data collection was divided into as many sessions as were required over several days until each participant served in all phases of the experiment.

Baseline. The caregiver seated the participant in the seat with side partitions in place so that the infant faced the vertical panel and the unlit colored lights. No consequences (visual or auditory) were presented to the participant when s/he pressed the panel. After establishing that a stable baseline was manifested (zero slope), the first treatment (continuous or conjugate reinforcement) was implemented.

Continuous reinforcement. Each time the infant foot pressed the panel, irrespective of response intensity, the colored lights turned on simultaneously for a duration of 100 ms. After at least 5 min of such visual presentations, the visual-auditory presentation was effected for a duration of at least 5 min. The presentation of the visual stimulus under either schedule always preceded that of both stimuli in combination (visual plus auditory).

Conjugate reinforcement. During the conjugate reinforcement schedule, each foot press of the panel produced the visual stimulus. The vigor with which participants pressed the panel was directly proportional to the brightness of the contingent colored lights produced. The engagement of the panel (i.e., the duration of a response) always resulted in the presentation of the visual consequence, and forward displacement of the panel resulted in the brightness of the colored lights. The visual-plus-auditory consequence series always followed that of the visual-consequence alone series, and data collection lasted at least 5 min in each phase.

Reversal. During the reversal phases, no consequence (visual or visual plus auditory) was presented. Participants remained seated in the enclosure with the side partitions in place, and could press the panel. Data were collected until participants' rate of responding had dropped to a level approaching that of the baseline condition.

Coding of Responses and Interobserver Agreement

Two individuals, who were instructed by the principal researcher on what constituted a response, independently coded the occurrence of responding in all phases for three participants chosen at random (50% of the data). The definition of a response was unequivocal: any forward displacement of the calibrated spring, even when the displacement did not originate from zero on the 0-2500 gram range, denoted a response. The interobserver reliability focused specifically on the frequency of occurrence of the target behavior (panel displacement resulting from leg thrust). Because the rate (frequency/time) of responding was easier to ascertain than any other behavioral dimension (i.e., amplitude or duration), the examiners were instructed simply to count the forward displacements of the calibrated spring from videotaped sessions with participants.

Interobserver reliability was calculated for each participant and for all phases by dividing the smaller frequency of occurrence reported, either by the principal investigator or the reviewers, by the larger frequency of occurrence reported for each phase and multiplying by 100. The percentage of agreement of all phases was aggregated and divided by the number of phases to arrive at the interobserver agreement. Thus, the interobserver agreement was 94% for one-half of the data.

Results

Data for the behavior pattern of infants who successfully completed every phase of the study were graphed. Figures 1 to 6 represent the participants' operant responding. Although videotaping the calibrated spring provided enough information for participants' responding to be measured in terms of many behavioral attributes (i.e., rate, response amplitude, response duration), the primary responding assessment was of participant response rate because that was the simplest of the response attributes for the independent reviewers to code. Each data point depicts responding in successive one-minute blocks for each participant.

In this frame, the data analysis consists of the visual inspection across all experimental phases to identify trends within and between subjects, and then to make the direct comparison among the various treatments (visual vs. visual-plus-auditory; conjugate vs. continuous reinforcement). That (B) or (C) condition occurred first or second was ignored. The hypotheses that were tested follow: (1) the visual and auditory stimuli would function as reinforcers, singly or combined; (2) the visual stimulus, because of its ease of manipulation, would evidence the dissimilarity between the two schedules of reinforcement, and (3) the pairing of visual and auditory modalities would differ, or possibly result in higher rates of responding than when the visual consequences were presented alone.

Fig. 1 Response frequency of infant participant #1 during four successive sessions.

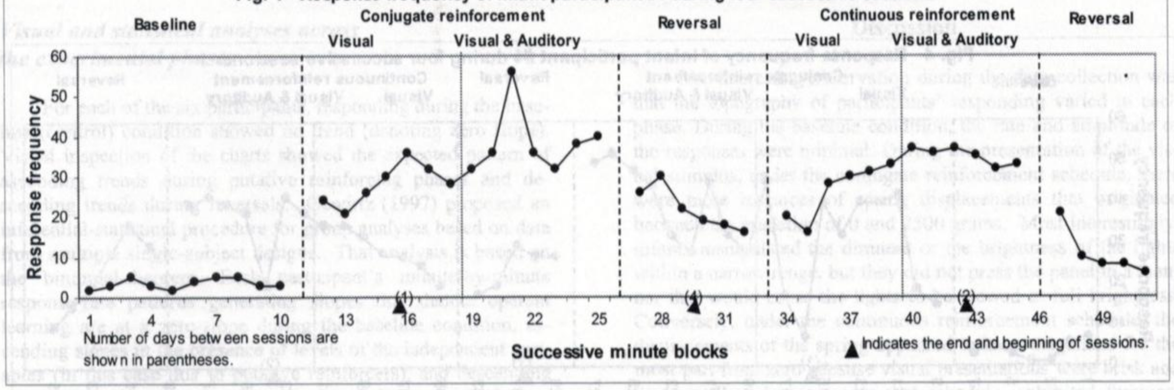


Fig. 2 Response frequency of participant #2 during four successive sessions.

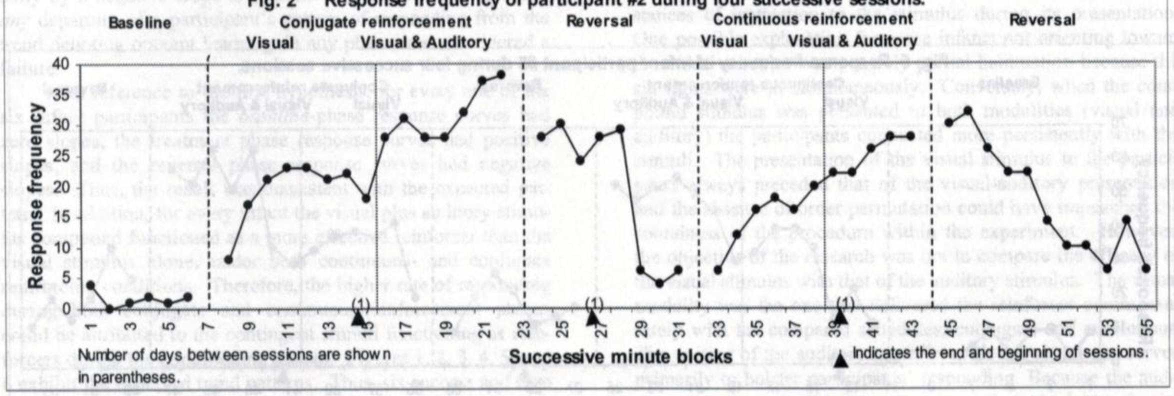
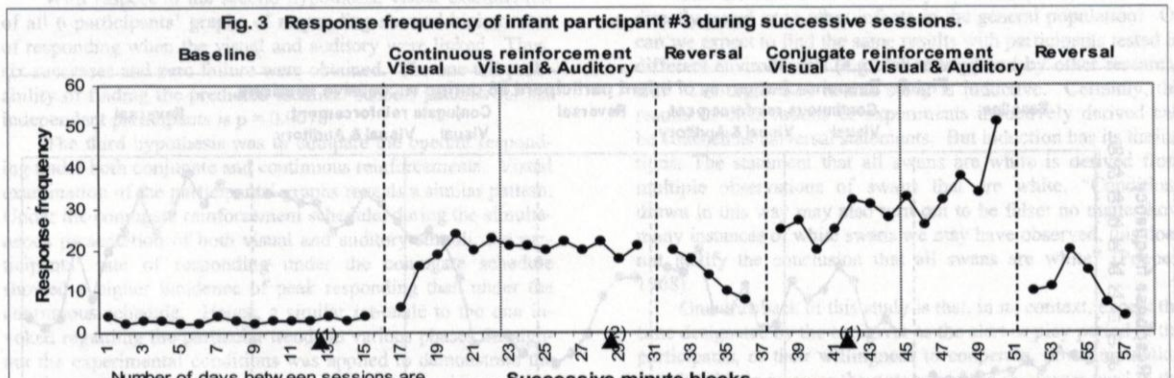


Fig. 3 Response frequency of infant participant #3 during successive sessions.



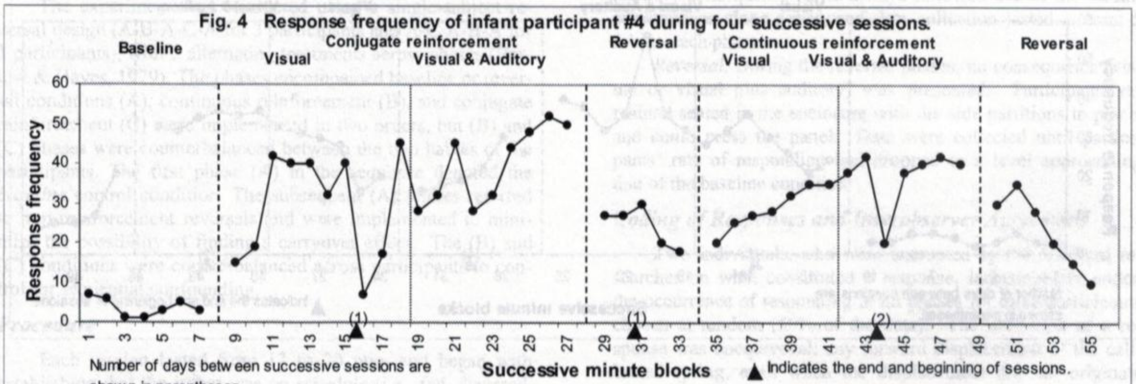


Fig. 4 Response frequency of infant participant #4 during four successive sessions.

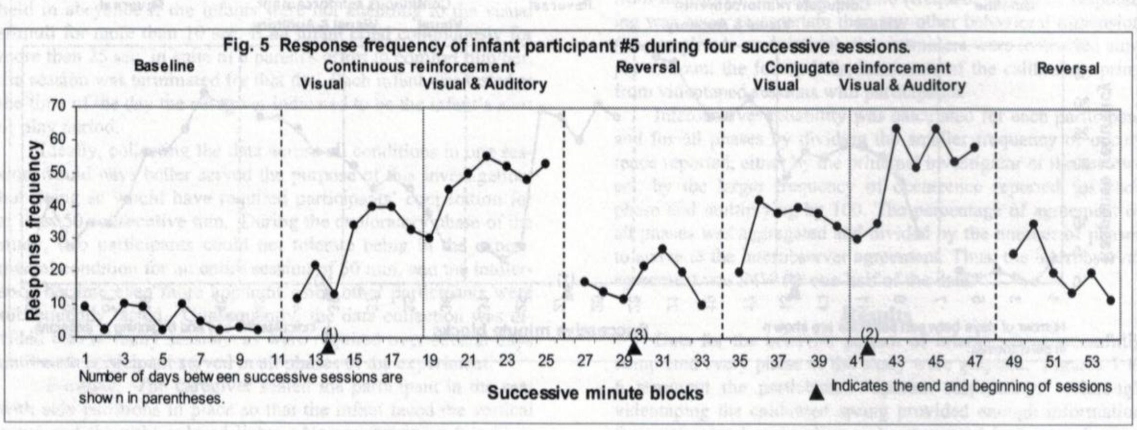


Fig. 5 Response frequency of infant participant #5 during four successive sessions.

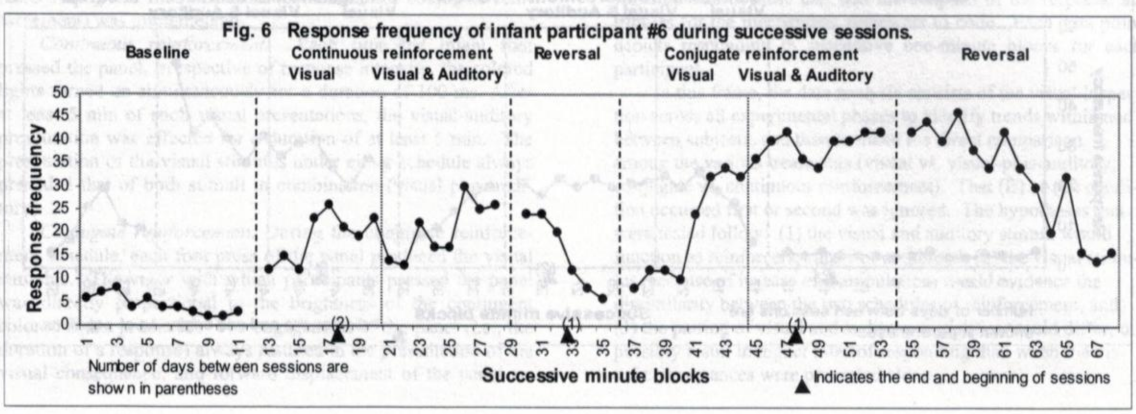


Fig. 6 Response frequency of infant participant #6 during successive sessions.

Visual and statistical analyses across the experimental phases

For each of the six participants, responding during the baseline (control) condition showed no trend (denoting zero slope). Visual inspection of the charts showed the expected pattern of ascending trends during putative reinforcing phases and descending trends during reversals. Gewirtz (1997) proposed an inferential-statistical procedure for group analyses based on data from multiple single-subject designs. That analysis is based on the binomial-theorem. Each participant's minute-by-minute response-rate patterns generating slopes that denote operant learning are at a zero-slope during the baseline condition, ascending slopes in the presence of levels of the independent variables (in this case due to putative reinforcers), and descending slopes when the reinforcers are eliminated during reversal treatments. Thus, for each participant a five-phase response pattern in which a zero slope is followed by a positive slope that, in turn, is followed by a negative slope, a positive slope, and finally by a negative slope is considered a success. Conversely, *any* departure of a participant's pattern of responding from the trend denoting operant learning, in any phase, was considered a failure.

With reference to the first hypothesis, for every one of the six infant participants the *baseline*-phase response curves had zero slopes, the treatment phase response curves had positive slopes, and the reversal phase response curves had negative slopes. Thus, the result was consistent with the expected pattern. In addition, for every infant the visual plus auditory stimulus compound functioned as a more effective reinforcer than the visual stimulus alone, under both continuous- and conjugate reinforcing conditions. Therefore, the higher rate of responding during both conjugate and continuous-reinforcement phases could be attributed to the contingent stimuli functioning as reinforcers during the conditioning phases. Figures 1, 2, 3, 4, 5, and 6 exhibit the expected trend patterns. Thus, six success and zero failure patterns were obtained. The one-tail probability of finding six success patterns for six independent participants is $p = 0.0078$.

With respect to the second hypothesis, visual examination of all 6 participants' graphs of responding showed higher rates of responding when the visual and auditory were linked. Thus, six successes and zero failure were obtained. The one-tail probability of finding the predicted identical success patterns for six independent participants is $p = 0.0078$.

The third hypothesis was to compare the operant responding under both conjugate and continuous reinforcements. Visual examination of the participants' graphs reveals a similar pattern. Under the conjugate reinforcement schedule, during the simultaneous presentation of both visual and auditory stimuli, the participants' rate of responding under the conjugate schedule showed a higher incidence of peak responding than under the continuous schedule. Hence, a similar rationale to the one invoked regarding the particular trends in various phases throughout the experimental conditions was applied to demonstrate the consistent trend in six independent cases. The one-tail probability of finding six (success) patterns of higher responding during conjugate than under continuous reinforcement in six participants is $p = 0.0078$ (one tail).

Discussion

One interesting observation during the data collection was that the topography of participants' responding varied in each phase. During the baseline condition, the rate and amplitude of the responses were minimal. During the presentation of the visual stimulus, under the conjugate reinforcement schedule, there were more instances of spring displacements that originated between the gradation of 0 and 2500 grams. Most interestingly, infants manipulated the dimness or the brightness of the lights within a narrow range, but they did not press the panel in a manner that would cause the lights to be viewed at full brightness. Conversely, under the continuous reinforcement schedule, the displacements of the spring appeared to have originated for the most part from zero because visual presentations were brisk and discrete. Participants, under that schedule, exhibited fussiness and displeasure.

Contrary to the expectation that participants in performing the operant task would sustain a prolonged interest in the presence of the visual stimulus, some infants exhibited many instances of inattention to the stimulus during its presentation. One possible explanation for some infants not orienting toward the visual stimulus was possibly partial habituation because the six lights were lit simultaneously. Conversely, when the compound stimulus was presented in both modalities (visual and auditory) the participants connected more persistently with the stimuli. The presentation of the visual stimulus to the participants always preceded that of the visual-auditory presentation and the absence of order permutation could have impeached the soundness of the procedure within the experiment. However, the objective of the research was not to compare the efficacy of the visual stimulus with that of the auditory stimulus. The visual modality was the one that delivered the reinforcer commensurately with the compared schedules: conjugate and continuous. The pairing of the auditory modality with the visual one served primarily to bolster participants' responding. Because the auditory consequences did not vary across the schedules of reinforcement, behavioral changes can be ascribed to the visual consequences.

Can the results of this study by extended to infants not directly tested or to other infants in the general population? Or can we expect to find the same results with participants tested in different environments (e.g., laboratory) and by other researchers? The logic used in this study is inductive. Certainly, the results of observations or experiments inductively derived can be couched as universal statements. But induction has its limitations. The statement that all swans are white is derived from multiple observations of swans that are white. "Conditions drawn in this way may also turn out to be false: no matter how many instances of white swans we may have observed, this does not justify the conclusion that all swans are white" (Popper, 1968).

One drawback of this study is that, in its context, except the time designated by the caregiver as the alert or play period of the participants, or their willingness to cooperate, no manipulation may be able to increase the potency of the reinforcer used in the study. There were some where participants, when placed in the experimental condition, did not respond as expected. The effectiveness of the reinforcers was, it seemed, at the mercy of the participants' vagary. In hindsight, it might have been better to use stimulus (e.g., a nursing bottle containing milk) the value of which could be rendered more effective during the period that precedes feeding time. Siqueland (1964) has reported the use of such reinforcing events under mild deprivation conditions where participants did not exhibit fussiness or any aversive behavior.

Rovee and Rovee (1969) have reported a behavioral stability on the part of participants under reinforcement that lasted entire sessions of 46 min. The fact that the participants were tested in a familiar environment—the crib—and positioned as they are usually in the natural environment, might have accounted for the high behavioral persistence they exhibited. The preparation used in this study has not permitted participants' responding in various phases to be recorded in one session. Data collection had to be broken into various sessions because many participants could not tolerate being in the experimental setting for more than 12 minutes. One possible explanation is that infants seldom find themselves in the natural environment seated in an enclosure and facing a series of colored lights. The artificiality of the setting might have contributed to the mild apprehension expressed by some of the participants when placed in the experimental situation. That said, it is problematic to refer to the acquisition rate of the target behavior when session truncation may have disrupted the continuity of responding. Participant 4, for example, exhibited an unexpected drop in responding 24 hours after the first session ended and the second one began.

Pelaez et al. (1997) compared the effects of systematic stroking, tickling, and poking on infant attention and affective behavior, closely paralleling a juxtaposition of the schedules being compared in this study. Poking, tickling and systematic stroking, as a form of touching, were administered to infants and they responded preferentially to the types of touch they experienced (i.e., systematic stroking vs. tickling or poking). Poking and tickling, because of the break in the continuity associated with their delivery, resembled a discrete delivery of touch. In contrast, the uninterrupted movement of a stroke, because of the continuity of the massaging hand to the participants' skin resembled a conjugate delivery of touch. Quite expectedly, during the stroking regimen, infant participants exhibited more instances of positive affect than when they were subjected to treatments of tickling and poking.

The present study is inconclusive, yet can be the springboard that sparks research interest in the direct comparison of continuous and conjugate reinforcement. Future studies might use as potential reinforcers stimuli that can be manipulated (e.g., via mild deprivation) at the opportune time and in an experimental milieu that closely parallels that of the participants' natural environment.

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Learning is *The* Developmental Process and Behavior Analysis Has a Lot to Say About Complex Human Behavior:

A Review of Novak and Pelaez's (2004) Child and Adolescent Development: A Behavioral Systems Approach

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Behavior-analytic approaches to complex human behavior all too often receive minimal consideration in undergraduate psychology textbooks. Despite this, Skinner is one of the most frequently cited authors in introductory texts (Griggs & Proctor, 2002). While further analysis is needed to determine the content areas in which Skinner ad other authors are cited in undergraduate textbooks, it is perhaps uncontroversial to assume that behavior-analytic research on verbal behavior, self awareness, problem solving, creativity, rule-following, and moral behavior are usually absent from introductory chapters on these topics (see Hobbs, Cornwell, & Chiesa, 2000). Verbal behavior research, for instance, has often faired the worst of all with textbooks seemingly content to mention in passing that behavioural principles of generalization and imitation alone are insufficient to explain generative language performances. In this way, psychology students might be forgiven for thinking that behavior analysis has little to say about complex human behavior. What then can be done about this anomalous state of affairs?

One approach would be to continue to highlight the misrepresentation of the behavioural approach, but a better strategy would be to correct the stereotypical view and provide an alternative behavioural account of complex behavior in an accessible introductory textbook. Novak and Peláez (2004) have clearly adopted the latter strategy and in their book they provide a welcome and much-needed alternative to the mainstream misrepresentation of the behavioral approach by synthesizing key developmental concepts with contemporary research findings from behaviour analysis.

Until I had read this book, I had been struck by how little consideration has been given in developmental psychology textbooks to the position that learning is *the* critical developmental process occurring across the life span. Novak and Pelaez's approach, called a behavioral systems approach, "is a natural science approach to development that emphasizes constant, reciprocal interactions between behavior and environment" (p. 3) in which "neither nature nor nurture alone is responsible for development: both are" (p. 4). This "holistic perspective" (p. 4) is, they argue, unique and confers many advantages to a scientific study of development.

Child and adolescent development comprises fifteen chapters on the range of topics one would expect a developmental text to cover (e.g., genetics, cognitive development, personality and self, etc.). Each chapter has been written to be "systematic, not encyclopedic" (xxi) with an emphasis placed on covering a limited number of concepts in detail. The writing style is clear and engaging, many of the topics are very well described, and the behavioural interpretations are effectively conveyed with illustrative examples of infant and child behaviour. Pedagogic features of the text include highlight-boxes in every chapter and an end-of-book glossary of terms. Some of the chapters, however, would benefit from additional learning features such as review quizzes, multiple-choice questions, self-assessment exercises, and so on - something behavioural texts are particularly renowned for (e.g., Miltenberger, 2004).

What sets this text apart from other developmental texts is the incorporation of modern behavior-analytic research on derived stimulus relations, the self, perspective taking, and relational frame theory (RFT; Hayes, Barnes-Holmes, & Roche, 2001). In Chapter 7 on cognitive development, the authors confront the mistaken view that behavioral psychology has little to say about cognition: "Behavioral psychologists… are interested in cognitive behavior, its organization and the processes that maintain it, not in presumed underlying structures such as schemes. What develops is behavior, not hypothetical constructs. Cognitive behaviors may have structures, but these structures are the relationships between behaviors" (p. 228). The authors then cogently outline the phenomena of stimulus equivalence as a behavioral approach to understanding cognition. Recent research on the burgeoning topic of stimulus equivalence and other derived stimulus relations has provided a means of studying the emergence of novel, untrained cognitive behaviors that cannot readily be traced to a history of direct learning. It is in this way that the most common criticism of behavioral approaches to complex human behaviour - that it cannot explain the generative nature of language and cognition with recourse only to mechanisms of direct learning and imitation - is refuted (see Hayes et al., 2001).

The authors go on to define an equivalence class as "a group of stimuli that have the same function as discriminative stimuli" (p. 242). This definition is somewhat problematic because the novel outcomes on tests for equivalence and other derived relations are better described as "discriminative-like" since the stimuli do not have a history of differential reinforcement with regard to each other (a defining property of discriminative stimuli), and therefore neither stimulus should control selection of the other (Dymond, Barnes-Holmes, & Roche, 2003). Indeed, one of the reasons why the study of derived stimulus relations has generated such considerable research interest is precisely because traditional behavioral concepts of discrimination and generalization have been unable to explain the novel performances. Putting such minor quibbling aside, the discussion of equivalence classes in this chapter is educational, informative and illustrated with applied examples. A student who takes the time to read this material will come away with an excellent grasp of a vitally important research area.

In the same chapter, Novak and Pelaez describe the core principles of relational frame theory, which is a post-Skinnerian theory of human language and cognition (see Dymond et al., 2003; Hayes et al., 2001). The description of this complex theory is well written, cogent, and informative. It provides a clear overview of the key concepts of RFT and gives useful references for further reading. I know of no other undergraduate psychology textbook in which RFT is covered with such accuracy. Indeed, I can think of only a handful of textbooks in which stimulus equivalence is even mentioned, let alone is there space dedicated to discussing RFT (e.g., Carlson, Buskist, & Martin, 2000; Leslie, 2002; Malott & Trojan Suarez, 2004). Clearly, this is another advantage of the authors' behavioral systems approach in that they prove that modern behavioral research on language and cognition, and theoretical accounts of these phenomena, have much to contribute to our understanding of cognitive development.

Subsequent chapters on the development of communication (Chapter 8) and personality and self (Chapter 9) further support the utility of an approach to development that emphasizes the role played by learning processes throughout the life span. The next chapter on social and emotional development (Chapter 10) contains many illustrative data graphs. The stylistic format of many of these figures is not standardized, which makes interpretation difficult, and the contents of this chapter would benefit from a more detailed introduction to single-case designs than that provided in Chapter 2. The remaining chapters address antisocial behavior (Chapter 11), the family (Chapter 12), schools (Chapter 13), adolescence (Chapter 14), and childhood behaviour disorders (Chapter 15). Each is well written and informative.

In conclusion, Novak and Peláez are to be commended for their unique and contemporary approach to studying development. The strengths of this text, in particular the authors' incorporation of modern behavioural research on stimulus equivalence, relational frame theory, perspective-taking, and other topics, should help to ensure that it becomes essential reading for undergraduate developmental psychology courses.

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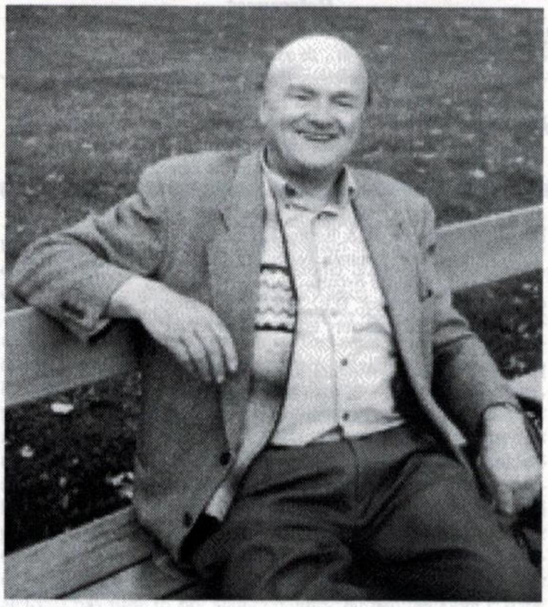
OBITUARY

In Memory of Ernst L. Moerk (1937 – 2004)



Ernst Moerk, Professor Emeritus of Psychology at California State University at Fresno, passed way on August 2, 2004 in Los Angeles after a courageous battle with brain cancer. Although not a behavior analyst by training, his unwavering pursuit of the truth and his search for environmental explanations in the language acquisition process led him increasingly to the behavioral community. He published in JEAB and AVB, and attended many behavioral conferences where he participated in several DEV SIG symposia.

Ernst Lorenz Moerk was born on March 10, 1937 in Gallbrunn, Austria. He began his collegiate career majoring in Chemistry, with minors in Physics and Mathematics at the University of Vienna. Later, he switched to psychology and obtained his Ph.D. in Psychology in 1964 from the University of Innsbruck. After some research and clinical experience in Europe, he traveled to the United States in 1966 to take a psychotherapeutic and psychodiagnostic position working with adults and children in an outpatient clinic on a post-doctoral fellowship in Los Angeles.

Upon taking the position in Los Angeles, he was unaware that the orientation of the staff was psychoanalytic, and chafing from these Freudian constraints, he soon applied for positions in academia. He had to choose between two very different institutions, the University of Minnesota, and Fresno State University. He suggested to me that he chose Fresno because he had given away all his winter clothing after moving to Los Angeles. Given his pragmatism, I assume this is at least partly accurate.

He took the post of Assistant Professor of Psychology at Fresno State in 1967 and remained there until his retirement in 2001. Although Fresno's mission is primarily undergraduate teaching, which he did well, mostly in developmental psychology, Ernst managed to develop a remarkable research career. Working without any Ph.D. students or major research support, Ernst was able to challenge the hegemony of psycholinguistic research emanating from Harvard and MIT.

Much of his career was marked by a heroic tilting at the ascendent nativist view of language acquisition that marked the last decades of the 20th century. Brought to the fore by Chomsky and later Pinker, Ernst counterattacked nativism with his environmental-empiricist view based upon a rigorous analysis of the data. In a characteristic style, Ernst turned the nativists own data against them. The clearest example was his use of Roger Brown's longitudinal transcripts of the early language interactions of three children (Adam, Eve, and Sarah) that had become the Holy Grail to nativists when they appeared in Brown's (1973) book: *A First Language*. Ernst was able to demonstrate that the children's mothers provided much more structured learning environments than Brown and his colleagues claimed. He rebutted the psycholinguists' innate LAD (Language Acquisition Device) with a paper that was wryly titled "The LAD was a lady and the tasks were ill-defined" (Moerk, 1989). Unable to rebut Moerk's analysis of his own data, Brown eventually refused to further share his transcripts with Ernst.

Moerk's painstaking analyses of early parent-child language interactions and the resulting detailing of the process by which parents serve as effective teachers using prompting, reinforcement, and corrections are detailed in scores of articles and presentations, and in four books. In recent years, Ernst moved closer and closer to behavior analysis, notably publishing a 3-term contingency analysis of parent-child interaction (Moerk, 1990) as well as other articles in behavioral journals. He was a frequent contributor to ABA and CalABA conferences and participated in many DEV SIG symposia to which he contributed a unique perspective and helped behavior analysts expand theirs. Recently he also developed a passionate interest in environmental-behavioral causes of war and peace.

Those of us who got to know Ernst over the years will not forget him. He was the consummate European scholar, rigorous in his scholarship, but personally charming, refreshingly polite, and very generous with his time and friendship. Ernst always wore a smile and had kind words to say. It seemed as if he was always looking for ways to help. After his retirement from Fresno State a few years ago, Ernst split his time between his ancestral home in Austria and his beloved home in Fresno, which was well-known in the neighborhood for its prodigious gardens, one of his favorite pastimes other than science. He continued to research, write, and lecture in the areas of language development and world peace.

Ernst is survived by his daughter, Kirsten, who received her Ph.D. in clinical psychology from SUNY, Stony Brook. The two had a very close relationship. They spoke often and Ernst was very proud of his daughter and her accomplishments. Those of us in the behavior analysis of development were very fortunate to have Ernst L. Moerk as a colleague and friend. The DEV SIG will be sponsoring a symposium to honor Ernst's work at the 2005 ABA conference.

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ANNOUNCEMENTS

Child and Adolescent Development
A Behavioral Systems Approach

Textbook authored by:
Gary Novak California State University, Stanislaus
Martha Pelaez Florida International University, Miami

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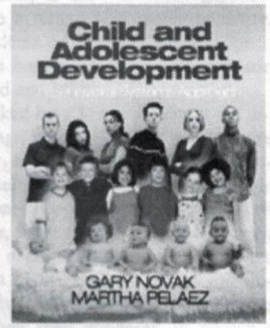

"The book very nicely incorporates behavior analysis and modern developmental theories. . . . Another nice feature is that it is not encyclopedic; it organizes the disparate developmental phenomena in terms of principles and mechanisms. . . . The writing style is easy to follow and suitable for college students. The scholarship and coverage are excellent."

—Jesus Rosales-Ruiz, *University of North Texas*

"The book is a very good read. It is also truly unique in the field of developmental psychology...a field in which far too little attention is typically paid to the obvious fact that children's development involves learning."

—Michael W. Vasey, *The Ohio State University*

"Presents behavioral principles in a systematic and fairly sophisticated manner (as contrasted with the simplistic treatment those principles often receive in textbooks of introductory or developmental psychology), while linking up with contemporary conceptions of dynamic systems. . .straightforward and clear, accessible to undergraduates without coming across as simplistic."

—Philip N. Hineline, *Temple University*

There are two fundamental questions in developmental psychology – what develops and how does it develop? The "what" is largely a question of developmental structure and describes development, while the "how" is primarily a question of function or process and explains development. Developmental psychology has become increasingly focused on the process aspect, but many texts do not provide readers with a clear perspective of how development actually occurs.

Child and Adolescent Development: A Behavioral Systems Approach integrates the views of dynamical systems concepts with a behavioral view of development. This combination of perspectives is unique and from it something new emerges – "a behavioral systems approach" to development. It is an approach that incorporates both personal and environmental influences and the constant reciprocal interactions between nature and nurture. The book emphasizes learning as the major process for change in development and the integration of environmental influences with genetic and historical factors. Authors Gary Novak and Martha Pelaez provide a coherent understanding of the learning process in childhood and adolescence and present successful interventions to minimize typical problematic behavior during this period.

Features of this text:

- *Unique. Connects development with learning concepts, a topic neglected in most developmental psychology books.*
- *Concise. Provides a coherent framework for exploring selected features of development in greater depth and detail rather than an encyclopedic volume of facts, figures, and theories. Accessible. Written in an engaging style that clearly conveys even sophisticated theoretical material and difficult, advanced topics.*
- *Pedagogical. Includes highlight boxes, chapter-opening outlines, chapter summaries, key words, and an end-of-book glossary that enhance student understanding.*

Child and Adolescent Development is an exceptional, process oriented textbook for advanced undergraduate and graduate students taking child development and developmental psychology courses in Psychology, Human Development & Family Studies, Education, and related fields.