

The Bigger Picture: Development, Genes, Evolution, and Behavior Analysis

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Abstract

Behavior principles interact with the other principles that apply to the many elements of living systems--all of which develop and change over time. As scientific knowledge of these interactions grows, behavior analysts are more able to contribute to and learn from interdisciplinary work in the life and behavioral sciences. This article provides examples from a sampling of these varied fields.

Keywords

Developmental systems theory, nature-nurture, operant learning, genetics, epigenetics, evolution, imprinting, evo-devo

This article briefly discusses behavior analysis and some of its interdisciplinary nature-nurture cousins: genetics, epigenetics, evolution, and neuroscience, for example. As in nature-nurture relations themselves, exciting interactions are the rule--and behavior analysts have as much to gain as they have to contribute.

The developmental principles studied and applied by members of this SIG are a common theme in these areas. Indeed, "developmental systems theory" is the formal name for an inclusive scientific approach to nature-nurture (see Schneider, 2007), and it's been discussed previously in this journal (e.g., Meinhold, 1999).

■ WORKING TOGETHER

When it comes to nature-nurture relations, a basic principle is profound but simple: Every aspect of every living thing stems from 100% genes *and* 100% environment. That includes the behavior principles that are the focus of behavior analysis.

Simplistic genetic determinism is logically doomed by this genes-*and*-environment principle. The classic case of eye color provides a good illustration: With other factors held as equal as possible, for example, a single gene appears responsible for a *difference* in fruit fly eye color. BUT that gene can't be taken to code for eye color, which is the result of many genes and many environmental factors working together. Indeed, either genetic or environmental abnormalities (in combination with the standard building blocks) can result in heterochromia: two eyes of different colors. (The condition is rare but regular in humans, and relatively common in cats.)

For additional recommended readings in nature-nurture, please contact the author at sschneider@pacific.edu. This article is based on "Behavior Analysis and the Bigger Picture," invited discussant comments presented at the 2009 conference of the Association for Behavior Analysis: International. I thank Robert Lickliter and Bryan Midgley for looking over the manuscript.

The situation gets stranger: Even in "genetic" disorders, having the problematic allele (gene form) never guarantees that the disease will occur (e.g., Morange, 2001). Conversely, it is possible to get the disease even without the problematic allele. Multiple pathways to anywhere are the rule in a system that's turned out to be very complex indeed.

Further, as David Moore (2001) put it, "a critical recognition is the understanding that traits that seem impervious to experience are no more 'genetic' than are traits that seem 'open' to such influence" (p. 185). Species-typical behaviors like neonatal imprinting are a good example. In a masterful research line, Gilbert Gottlieb showed that "instinctive" imprinting depended on unhatched ducklings hearing their own or siblings' calls, and was readily malleable (see Schneider, 2003 for a summary). In quail neonates, my colleagues Harshaw, Tourgeman, and Lickliter (2008) were able to eliminate and even reverse the normal imprinting preference with just 5 min of a contingent imprinting call of a different species.

■ PRIMATES AND PARENTING

Closer to the human applications of interest to this SIG are Stephen Suomi's impressively interdisciplinary primate studies: behavioral, physiological, genetic, and longitudinal. With respect to neurotransmitter genetics, for example, rhesus monkeys raised by peers do especially poorly if they have the short form of the serotonin transporter gene (Suomi, 2004). (This sort of effect has also been suggested to exist in humans, but, according to Munafo, Durrant, Lewis, & Flint's 2009 meta-analysis, the evidence is merely suggestive at this point). In a cross-fostering study, other short-form and long-form monkeys were raised not by peers, but by mothers who weren't genetically related to the youngsters. Unexpectedly, the short-form youngsters proved to have some advantages over their long-form peers: for example, they consumed less alcohol (Suomi, 2003). Nonlinearities like this are part of the fascination of the nature-nurture picture.

Previously, Suomi had examined the role of parenting style in a different way. After selective breeding for “temperamental reactivity,” cross-fostered high-reactives exhibited problems when reared by control mothers, but reaped advantages when reared by high-nurturing mothers--and a high proportion of these individuals rose to the top of the dominance hierarchy despite having what had been considered a genetic disadvantage (Suomi, 1999; control youngsters were intermediate).

Suomi (2003) concluded that, although characteristics like impulsivity and aggression were highly heritable in his rhesus monkeys, “they are also subject to major modification by specific early experiences, particularly those involving early social attachment relationships” (p. 132). Heritability is a construct with many problems (e.g., Moore, 2001; Reese, in preparation).

■ NONGENETIC INHERITANCE

Suomi’s research has documented that rhesus daughters tend to adopt the parenting style of their mothers, with consequent effects on the behavior of the offspring--and that these parenting behaviors are learned (Suomi & Levine, 1998). Behavioral inheritance mechanisms (of which parenting is only one) are the most flexible of all, and the ones most familiar to behavior analysts. Both operant learning and classical conditioning are ubiquitous at this level.

More surprisingly, hormones are in on the action too. From a series of well-known studies with gerbils, female embryos that happened to be next to males in the womb received more testosterone exposure and more licking after birth as a result. These animals later showed more aggression than female-adjacent females. Because the male-adjacent females tended to bear more males than females, their daughters were similar to them and the effects were inherited nongenetically (e.g., Clark & Galef, 1998; Clark, Karpiuk, & Galef, 1993).

Even more of a foreign field to most behavior analysts are the cellular-level inheritance mechanisms classified as epigenetics. Epigenetic inheritance includes, for example, changes in the material that constitutes the chromosomes (i.e., “chromatin marking” mechanisms). It’s long been known in invertebrates: fruit flies and paramecia, for example. DNA methylation is an epigenetic inheritance mechanism known to occur in mammals. It’s affected by the environment during the lifetime of an individual, and it’s reversible. Epigenetic mechanisms can thus be much more flexible than the genetic mechanisms with which they work in tandem, but the extent of their influence is still being determined (see Schneider, 2007 for more examples).

■ INTERACTIONS EVERYWHERE

The spontaneously hypertensive “SHR” strain of rats was developed through selective breeding to provide a model for high blood pressure in humans. However, these animals don’t develop hypertension *unless* they’re raised by SHR mothers. Conversely, normal rats don’t become hypertensive when raised by SHR mothers (e.g., Cierpial & McCarty, 1987). The environmental mechanisms appear to include maternal behavior, because simple handling of SHR infants also alleviates the normal development of hypertension in this strain (Tang, Gandelman, & Falk, 1982; see Zicha & Kunes, 1999 for a review).

It’s long been known that environmental variables like radiation, mutagens, and reverse transcriptase can directly alter the genes. More commonly, gene activity and timing are modified by a host of variables, including many categorized as environmental/behavioral (see, e.g., Gottlieb, 1998). In humans, for example, stress reduces mRNA activity in the interleukin 2 receptors, adversely affecting immune system responses. Operant learning and classical conditioning can reduce or add to stress, of course.

Indeed, associative learning, the focus of behavior analysis, affects and is affected by all the nature-nurture levels (see Schneider 2003, 2007). Of particular importance to developmental behavior analysts are the processes that make and break reinforcers. Nizhnikov, Molina, Varlinskaya, and Spear (2006) found that prenatal exposure of rats to ethanol increases ethanol’s reinforcing value; the level of exposure is well below that which produces fetal alcohol syndrome. According to Spear and Molina (2001), the evidence suggests that these results have a corollary in humans. Cruz, Quadros, Planeta, and Miczek (2008) found that an apparently unrelated manipulation--early maternal separation and consequent stress--had similar effects in mice: The reinforcing value of alcohol increased.

Conversely, the beneficial effects of environmental and behavioral enrichment are now well recognized in both animals and humans, especially when they occur at an early age. Over its history, behavior analytic research has contributed strong support, culminating in Hart and Risley’s 1995 developmental behavior-analytic classic, *Meaningful Differences*.

■ DEVELOPMENTAL PLASTICITY

Both applied and basic researchers can contribute to the increasing influence of behavior analysis within the bigger nature-nurture picture. For example, the skill described as “joint attention” has become of increased interest to behavior analysts recently because of autism: As is the case for other social relations, those suffering from autism spectrum disorders often manifest deficits. Behavior analysts have developed ways to teach joint attention (e.g., Rocha, Schreibman, & Stahmer, 2007).

The fact that it’s also possible to do so in nonhumans is of special interest for nature-nurture relations. Initial studies in canids suggested that dogs might be “innately” capable of joint attention, but that wolves were incapable of learning it even after significant training effort. However, controlling for past confounds, Udell, Dorey, and Wynne (2008) showed that joint attention was indeed learned: Unsocialized dogs did not show it, but socialized pet wolves could and did. (Indeed, they tended to do better than the socialized dogs.)

Such results harken back to Gottlieb’s finding of unexpected environmentally-based malleability in duckling imprinting. Degrees of malleability vary, but it has been demonstrated under many unexpected circumstances. Although it contains only one chapter on associative learning, West-Eberhard’s 2003 compendium, *Developmental Plasticity and Evolution*, offers a valuable summary across a wide range of nature-nurture relations.

■ EVOLUTION AND NEUROSCIENCE

I conclude this brief survey with two areas integral to both nature-nurture and developmental behavior analysis. The role of environment and behavior in evolution was recognized long ago (e.g., the Baldwin effect of the turn of the 20th century, and, even earlier, back to Darwin and Lamarck). After all, phenotypes are the subject of natural selection, and environments do the selecting. Environments are inherited as well, *or else*: Imagine being born into a world without oxygen. “Evolutionarily stable strategies” rely on behavior; so do unstable ones, for that matter. And behavior change routinely leads evolutionary change, with niche construction being just one of many examples. When flamingo foraging style changed--and that’s an operant behavior--flamingo beaks followed (see Schneider, 2003 for additional examples). The behavior change came first.

It’s also worth noting that “evo-devo”--evolutionary developmental biology--has demonstrated that the regulation of gene products is what gets moved around and modified most often in evolution, not the genes themselves (e.g., Carroll, 2005). Because of the many interactions of behavior and environment with gene expression, and with physiology more generally, there’s growing recognition of the involvement of psychological principles.

Evolution is conservative, and many of the proteins that genes code for have multiple functions (*pleiotropy*). Similarly, most if not all neurotransmitters have multiple functions. What are the neurophysiological underpinnings of associative learning? Despite 21st century technology, there’s still a long way to go to find out. Scientists *have* established that neural plasticity is immense, and at last it’s known in some detail how behavior and environment change the brain. These results enhance movement toward a more complete understanding of associative learning for, as Skinner fully recognized (e.g., Morris, Lazo, & Smith, 2004), there is no “black box,” and knowing the physiological correlates of behavior principles can only be beneficial all around. Recent work with fMRI scans has confirmed earlier physiological research in showing that very different positive reinforcers appear to have similar effects. That goes for punishers too, and Eisenberger, Lieberman, and Williams (2003) found that an aversive as different as social exclusion causes the standard “pain regions” in the anterior cingulate cortex to light up. By supporting the common behavioral effects that behavior analysts have long researched, these results help integrate behavior analysis into the larger interdisciplinary realm.

The functional processes that behavior analysts study are an especially important element in any aspect of nature-nurture that involves behavior. General principles of associative learning are well-established, for example (see Schneider, 2003). But interactions are again the rule, and a better understanding of the neuroscience will help researchers delineate the different behavior categories. Many years ago, imprinting stimuli were shown to serve as reinforcers for a variety of behaviors (e.g., Bateson & Reese, 1968; Peterson, 1960). But relatively little is still known about how species-typical released behaviors and operant contingencies relate. Even operant-Pavlovian interactions require further study--and many of these questions are developmental in nature, interdisciplinary to the core. In this, as in so many

ways, the future for behavior analysis, development, and nature-and-nurture is bright.

■ CONCLUSION

Nature-nurture systems are large and complex beyond imagining, abounding with nonlinear interactions across analytic levels. Those interactions are necessarily developmental in nature, and “developmental systems theory” has been suggested as the new overarching context for the life sciences (see, e.g., Oyama, Griffiths, & Gray, 2003; Schneider, 2007). By any name, behavior analysis holds a position of critical importance in this grand scientific effort.

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