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Dual Inheritance Theory

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Synonyms

Gene-culture coevolution; Culture-gene coevolution; Natural selection; History of natural selection

Definition

Dual Inheritance Theory is a theoretical framework positing that human biology and behavior are influenced by two lines of inherited information: a genetic line, which all species inherit from their biological parents, and a cultural line, unique to our species, which we inherit from other members of our society.

Introduction

Dual Inheritance Theory was first developed by two population geneticists (Cavalli-Sforza and Feldman 1981) and an anthropologist and an ecologist (Boyd and Richerson 1985) as a set of formal mathematical models to describe the transmission and evolution of culture – beliefs, values, behaviors, technology, and other socially transmitted knowledge possessed by societies around the world. Both pairs of scholars drew on the rich toolkit of evolutionary biology that had so nicely described the rest of the natural world, extending it to explain humans as a new kind of animal. The theory identified the conditions that lead any species to rely on social learning (learning from conspecifics) over individual or asocial learning (figuring things out by oneself); the ways in which social learning could transmit cultural information, copying biological parents (vertical transmission), peers (horizontal transmission), or other members of the parents' generation (oblique transmission); and the biases on what to learn and who to learn from – including payoff biases (e.g., copying successful individuals) and frequency biases (e.g., copying the majority). These models described how culture met the criteria for an independent adaptive evolutionary system: variation, transmission, and selection. Humans, they argued, have two lines of inheritance: (1) a genetic line, which all species inherit from their genetic parents, and (2) a cultural line, unique to humans, which we inherit

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from our societies. The secret to human success is cumulative cultural evolution – a package of knowledge, know-how, technology, beliefs, and behaviors, adapting and accumulating generation by generation, often outside conscious awareness, and beyond what even the brightest individual could create alone in a single lifetime.

In developing this framework, Cavalli-Sforza and Feldman and Boyd and Richerson expanded evolutionary biology to include the human animal and its social world; offered a formal mathematical toolkit that allowed scientists to develop theories about human behavior, psychology, and society in a manner consistent with the other natural sciences; and laid the foundations for a formal and general "Theory of Human Behavior." In the following decades, the next generation of researchers expanded the set of models and compiled and created anthropological, archeological, economic, and experimental psychological evidence testing the various formal predictions (Chudek et al. 2015; Henrich 2016; Laland et al. 2010; Mesoudi et al. 2006; Muthukrishna and Henrich 2016).

Theories falling under the Dual Inheritance Theory framework have offered explanations for a wide range of phenomena, from infant cognition, norm psychology, and in-group ethnic biases at an individual level to the source of cross-cultural differences, relationship between sociality and cultural complexity, and transitions between stable equilibria at a societal level. In an act of self-reflection, recent theories have also tackled the problem of innovation, offering an explanation as to why at least two groups of independent researchers developed Dual Inheritance Theory (Muthukrishna and Henrich 2016). Before discussing these processes, it would help to have some perspective on the history of evolutionary biology and psychology.

History

In 1859, Charles Darwin published *On the Origin of Species* laying out the theory and evidence for evolution by natural selection. The theory was far from universally accepted, and Darwin faced a great deal of hostility, not only from the religious but also from members of the scientific community. In 1864, physicist Lord Kelvin used the rate of cooling to calculate the age of the Earth as no more than 400 million years, an estimate which left insufficient time for evolution by natural selection. Given such opposition, evolution by natural selection did not become a dominant paradigm for some time, particularly in the psychological and behavioral sciences. Wilhelm Wundt, the father of experimental psychology, rejected the evolutionary approach altogether. However, evolution's impact was visible in some schools of early psychology. For example, the relationship of humans to other animals was assumed in George Romanes' work on comparative psychology and William James' search for human instincts.

In 1903, the heat released by radioactive decay was discovered, setting the stage for a revision of Lord Kelvin's calculations by an order of magnitude, leaving enough time for Darwinian evolution. Evolution by natural selection gradually became the bedrock of the biological sciences. The early twentieth century saw the mathematical formalization of evolutionary theory, most notably spearheaded by Ronald A. Fisher, Sewall Wright, and J.B.S. Haldane. During the 1930s, apparent inconsistencies between macroevolution and microevolution, between the rediscovered discrete Mendelian genetics and both continuous population distributions (e.g., height) and gradual changes, were reconciled, creating a theoretical synthesis across a wide range of subfields of biology: *The Modern Synthesis*.

The Modern Synthesis was a milestone in the biological sciences, but the human and social sciences – including economics, anthropology, and psychology – were missing from this synthesis. As psychology transitioned through the behaviorist and then cognitive revolutions, the biological sciences, with evolution at its core, were largely ignored (with ethology as a notable exception). The psychological sciences had yet to fully incorporate the logic of evolution, biological approaches, and the formal mathematical toolkit.

Evolutionary approaches began to reenter psychology during the 1970s and 1980s. John

Bowlby, as part of his work on attachment theory, coined the term *environment of evolutionary adaptedness* (EEA). The EEA referred to the environment to which organisms had adapted. Evolutionary psychologists have since explored in great detail the mismatch between the modern world and the human ancestral environment in Africa (human EEA). Evolutionary approaches also reentered psychology in testing the predictions of evolutionary logic that applied broadly to animals, including humans. For example, the implications of Robert Trivers' *Parental Investment Theory* (1972) was tested by several researchers including Martin Daly and Margo Wilson (Cinderella Effect) and David Buss (sex differences in jealousy). This early work relied on testing predictions from evolutionary biology generated using its standard toolkit. In 1992, anthropologists Jerome Barkow and John Tooby and psychologist Leda Cosmides edited *The Adapted Mind*, laying out additional research and new methodological approaches to identifying further human-specific adaptations to the human EEA.

Earlier attempts to directly expand the modern evolutionary synthesis to the social sciences more generally can be traced to biologist Edward O. Wilson's 1975 book *Sociobiology: The New Synthesis* that brought together a growing body of work to explain the evolutionary processes underlying social behaviors such as communication, dominance, and altruism. In 1981, Wilson, along with his then postdoc, Charles J. Lumsden, published *Genes, Mind, and Culture*, an attempt to formalize some of the ideas Wilson had laid out in sociobiology as a step toward unifying the biological and social sciences (In a twist of history, Boyd and Richerson applied to spend time in Wilson's lab at around the time Lumsden was a postdoc. Wilson responded that his lab was full and their efforts ended up being independent.). It was in the same year, 1981, that Cavalli-Sforza and Feldman published their classic. In their book, the core tenets of evolution such as mutation, selection, and drift, along with the process of transmission, were used to create formal mathematical models of cultural transmission similar to those used in population biology. These models examined the conditions and factors facilitating cultural transmission and demonstrated its possible forms – namely, vertical transmission from one generation to the next and horizontal transmission between conspecifics. Soon after, in 1985, Boyd and Richerson took a similar approach, once again noting the similarities and differences between cultural transmission and biological transmission. Their research laid out the conditions and implications of biased cultural transmission – the role that learning biases have in the transmission of culture. Perhaps due to the independent disciplines in which they originated, throughout the 1990s, the traditions laid out by Boyd and Richerson and Cavalli-Sforza and Feldman proceeded largely independently from that laid out by Barkow, Tooby, Cosmides, and other evolutionary psychologists.

Dual Inheritance Theory and cultural evolution began to influence psychology through comparative and developmental work from figures such as Andrew Whiten and Michael Tomasello and their collaborators, as well as through the theoretical and experimental work of figures such as Joseph Henrich and Kevin Laland and their collaborators. The key aspects of Dual Inheritance Theory are an evolved psychology that undergirds our capacity for culture, the dynamics of cultural evolution, the selective pressure culture has exerted on our genes (culture-gene coevolution), and cultural-group selection.

Cultural Evolution and the Capacity for Culture

Dual Inheritance Theory is an extension of evolutionary theory (rather than an analogy) into the realm of culture. An adaptive evolutionary system, be it genes or a computer scientist's genetic algorithm, requires three factors: variation, transmission, and selection (Or more generally, variance reduction, such as genetic or cultural drift. While this is still evolution, for evolution to be adaptive, the variance reduction needs to be in an adaptive direction.). Humans have evolved abilities and proclivities that give our cultural system these three properties. Variation is easy –

individuals do all kinds of things for all kinds of reasons: mistakes in copying, differential access to information and life experience, blind luck, and so on. The key lies in transmission and selection. The starting point is the tendency to rely on social learning.

In their 1985 classic, Boyd and Richerson laid out the environmental conditions that lead to any species relying on social learning. The answer lies in environmental variability. When the environment is highly stable, genes can adapt well. Consider the average amount of sunlight as a function of latitude. Although there is seasonal variability, as you move North the average amount of sunshine decreases. Rather than relying on culturally acquired information or individual learning, human skin color has genetically adapted to provide the appropriate amount of protection while also providing enough vitamin D through UV exposure. In the modern world of distant migrations, dark-skinned individuals in Northern latitudes generally require vitamin D supplementation, and lighter-skinned individuals in Southern latitudes generally require sunscreen. At the other extreme, when the environment is highly unstable, genes are unlikely to evolve at a rate fast enough to match the environmental change. In such unstable environments, genes for individual learning are favored, since the long-term past is not a good predictor of the future. Between these extremes is a Goldilocks zone where your parents and grandparents have knowledge worth paying attention to. As an example, consider a cyclical drought. You may never have experienced a drought, but your parents and grandparents remember the last time there was a drought and where the village found water and what else they did to survive. In this Goldilocks zone of intermediate environmental variability, social learning is favored. These predictions were formally modeled in 1985, but the data to test this theory didn't emerge till ice core data was made available in the next two decades. The data fit nicely – climate variability increased around 3 million years ago, just as the *Homo* genus emerged. Of course, this argument predicts widespread social learning (which is what we observe; Hoppitt and Laland 2013). Social learning alone is not sufficient.

One form of social learning is imitation: humans tend to copy with *high fidelity*, often with an absent or incomplete causal model. An experiment by Victoria Horner and Andrew Whiten (2005) nicely illustrates this proclivity. Chimpanzees and human children were presented with two versions of a puzzle box with a reward inside. The experimenter presented a series of causal and irrelevant actions to access the box. When the box was opaque such that both chimpanzees and children couldn't distinguish between the causal and irrelevant actions, both imitated all experimenter actions. But when the box was transparent and the irrelevant and causal actions were easily distinguishable, the chimpanzees only copied the causally relevant actions. The children, in contrast, continued to copy all actions. More recent evidence suggests that children can distinguish between instrumental behaviors where all that matters is the outcome and conventional behaviors that are either normative or where a causal model isn't apparent. However, life is mostly made up of a world too complex to fully understand, and understanding is often not required – from cooking by copying family recipes without the need to understand the underlying biochemistry to using a computer without the need to understand the computer science and physics which drive it. Research by Herrmann et al. (2007) further illustrates the abilities and proclivities that underlie the capacity for culture through cognitive tests with human children, chimpanzees, and orangutans. In the physical domain of space, quantiles, and causality, humans were no better than the other primates. But in the social domains of Theory of Mind, communication, and most clearly social learning, they thoroughly outcompeted their primate cousins.

Humans are highly reliant on high-fidelity social learning, but we don't copy arbitrarily; we learn selectively from successful, self-relevant and reliable sources of information. Much theoretical and experimental research in cultural evolution has identified a constellation of strategies and biases through which we acquire information. For example, we tend to copy experts with greater skill, those who are generally successful, and those who others are paying attention to (prestige). When these payoff biases exist, over time, the population acquires a package of the most adaptive beliefs and behaviors, so we also copy majorities and pay attention to changing frequencies (trends) in the population. Not all information is equally relevant; sometimes someone is a better model for you. We moderate these selective biases on self-similarity, such as sex and ethnicity. Children will often copy children only slightly older than themselves, since they provide behaviors more relevant to their personal ecology. Since not all sources of information are equally sincere, we also seek out costly and credibility-enhancing displays (CREDs) that increase our trust in the information. And because not all domains are equally important, we focus on certain content over others, such as dangers, mating-relevant information, reputational information and norms (Chudek et al. 2015).

The world in which we now find ourselves is more complex than any one of us can understand or recreate. Culture adapts to the local environment, including to aspects of the environment that are genetic. For example, our species gives birth to large-brained, helpless infants that require extra care. There are many cultural solutions to this core problem, from controlling female sexual access and forcing fathers to look after their children to the fatherless societies where brothers are expected to look after their sisters' children to societies with multiple fathers and corresponding partible paternity beliefs (Henrich 2016; Muthukrishna and Henrich 2016). Similarly, genes will adapt to features of the environment that are highly stable, sometimes over short periods. Many of these features to which genes adapt are part of the cultural environment, leading to culture-gene coevolution.

Culture-Gene Coevolution

The classic case of genes adapting to cultural practices is lactase persistence, the uniquely human ability to process lactose beyond infancy. Drinking milk in infancy is a typical mammalian trait, but the ability to process lactose in adulthood is a uniquely human ability but found in less than a third of humans. The domestication of animals, a cultural practice, provided the selection pressure for such variation – milk is a rich source of calories and nutrients, and the ability to process it is highly advantageous, offering an evolutionary advantage to members of a society who could process it beyond childhood. Lactase persistence nicely tracks the domestication and herding of livestock. In an exception that proves the rule, lower levels of lactase persistence are present in populations that turned milk into lower-lactose products, such as cheese and yogurt, using culturally evolved milk-processing technologies. Other examples of culture-gene coevolution include processing of alcohol and other food types, and immunity and pathogen defense. Other human features, including language and our social learning abilities and proclivities, may also have been products of culture-gene coevolution adapting to ever-increasing levels of information (Laland et al. 2010).

Cultural-Group Selection

Cultural-group selection is one of the most misunderstood aspects of Dual Inheritance Theory (Richerson et al. 2016). The main sources of misunderstanding are perhaps the problems associated with genetic-group selection, what people think is being selected, and conflation between equivalence of mathematical accounting systems and causal processes.

Genetic-group selection is the idea that natural selection might act at the level of the group as well as at the level of the individual. Group selection would allow for behaviors that were good for the group at the expense of the individual. While in theory group selection might be possible, one key problem is that genetic groups often struggle to maintain their genetic boundaries, such that in the long run, even small amounts of migration (from, e.g., individuals with genes that favor themselves over the group) will eventually make interacting groups genetically similar. Such migration destroys between group differences, and without sufficient variance between groups relative to the variance within groups, intergroup competition can't select between genetic groups.

Some researchers have proposed that cultural-group selection can overcome this problem. Cultural-group selection as a force can be considered a consequence of various aspects of our cultural psychology, most notably our ethnic and norm psychology. That is, our ability to identify the cultural groups to which we belong and to assimilate new members, and our capacity to represent norms and tendency punish violators. We know which groups we belong to and the norms associated with belonging to those groups. As long as migrants are assimilated into the group norms (e.g., immigrants following the laws of their new country or newcomers speaking the group language), group boundaries are maintained. Cultural groups with packages of norms that cause the groups to grow and outcompete neighboring groups can be favored by selection. Empirical research supports the idea that cultural groups can maintain their boundaries. For example, at a country level, cultural differences between neighboring countries far outweigh genetic differences. Similarly, at small-scale societal level, neighboring groups of hunter-gatherers have larger between-cultural-group variance relative to within-cultural-group variance. These group differences allow for selection between cultural groups. This leads to the second misunderstanding of what is under selection.

Cultural-group selection refers to selection among cultural groups (rather than a cultural variety of standard "group selection") – that is, differences in traits between cultural groups may give one group, and the members therein, a selective advantage over a competing group. But what is a cultural group? In the anthropological literature, the cultural group is often defined as the ethnolinguistic group, individuals with a shared cultural history who speak the same language. While this is a strict cultural group, humans belong to multiple embedded and overlapping groups. We can talk about differences between East Asian and Western culture, but equally between Chinese and Japanese culture, or rural and urban regions within China and so on. Similarly, we can belong to overlapping groups such as Boston Catholics and Belfast Catholics. What is really being tracked in a mathematical model and what defines the group are a package of cultural traits – the norms, values, beliefs, and behaviors of the group. That is, cultural groups can be thought of as groups of cultural traits possessed by clusters of people; it's important to distinguish between the cultural traits and the population. Since cultural-group selection is often used to help explain the extraordinary levels of human altruism – groups made up of altruistic individuals would outcompete groups made up of selfish individuals – the cultural traits that often define the cultural group of interest are altruism norms and behavior. But depending on the question of interest, many cultural traits or packages of traits may constitute the cultural group. There are mechanisms and combinations of mechanisms for competition between groups of cultural traits, for example, direct competition, such as warfare between groups; demographic swamping, whereby one set of traits grows at the expense of another; migration, whereby individuals move between groups bringing with them traits that match the new group (assortative migration) or taking on the traits of their new group (assimilation); and prestige-biased cultural-group selection, whereby entire groups of people take on the attributes of a more prestigious group (such as the spread of democracy).

The final misunderstanding lies in the equivalence of the mathematical models of group selection compared to inclusive fitness or individual fitness. These approaches are simply different, but mathematically equivalent approaches to partitioning the variance when modeling the evolutionary process. Which accounting system makes the most sense (in terms of making it easy to model and understand the selection process) depends on the degree to which the differences between groups contribute to the evolutionary process. The mathematical equivalence does not mean that the causal processes are equivalent, but especially in modeling cultural-group selection, a group selection framework is often the most useful.

Conclusion

Dual Inheritance Theory is an extension of evolutionary biology into the human realm of culture and society. By making precise formal predictions about human physiology, anatomy, and psychology, it offers a potential "Theory of Human Behavior." And in using the toolkit of the biological sciences, it allows us to synthesize the psychological and social sciences with the biological sciences. It is no surprise then that the models of Dual Inheritance Theory, particularly those associated with social learning, have proven useful in biology and in understanding social learning in other animals. As a theoretical framework, it may do to the psychological and social sciences what the periodic table did to chemistry and what natural selection did to biology. Offer a lens through which thus far disparate empirical findings suddenly make sense.

Cross-References

- ▶ Cognitive Science
- ▶ Cooperation
- ▶ Joseph Henrich
- ▶ Michael Tomasello
- ▶ Cultural Transmission
- ▶ Social Learning
- ▶ Theory of Mind
- ▶ Altruism Norms
- ▶ Cultural Intelligence Hypothesis, The
- ▶ Robert Boyd
- ▶ Pete Richerson
- ▶ Cultural Evolution
- ▶ Social Darwinism
- ▶ Sociobiology
- ▶ Genetical Theory of Natural Selection, The
- ▶ Population Level Differences
- ▶ Natural Selection
- ▶ Mutation and Genetic Drift
- ▶ Multi-level Selection Theory
- ▶ Group Selection
- ▶ Examples of Group Selection
- ▶ History of Natural Selection
- ▶ Lactose intolerance

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