

INFORMATION SYSTEMS THEORIZING BASED ON EVOLUTIONARY PSYCHOLOGY: AN INTERDISCIPLINARY REVIEW AND THEORY INTEGRATION FRAMEWORK¹

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Appendix A

Terms and Definitions

Ancient development environment (D_A). This term refers to the environment surrounding our hominid ancestors in their formative years, that is, while they developed from fertilized egg to reproductively mature individuals. The term *environment* is used here broadly; generally meaning all factors that were not genetic in nature, such as social, nutritional, climatic, and other related factors. Like the ancient task environment, this development environment refers to the evolutionary period that led to the emergence of *Homo sapiens*. Before birth, the ancient development environment was the mother's womb. After birth, and from a physical surroundings perspective, the ancient development environment is believed to have been fairly similar to the modern African savannas.

Ancient task environment (E_A). This term refers to the environment surrounding our hominid ancestors as they performed a task, during the evolutionary period that led to the emergence of *Homo sapiens*. Evolutionary psychologists generally consider the most relevant evolutionary period to range from approximately 3.5 million years ago, when the *Australopithecines* emerged, to about 100,000 years ago, when *Homo sapiens* emerged. This comprises most of what is known as the Pleistocene, which started about 1.8 million years ago, and is when the various species in the genus *Homo* evolved. The term *environment* is used here broadly; generally meaning all factors that were not genetic in nature, such as social, nutritional, climatic, and other related factors. As far as physical surroundings were concerned, the ancient task environment is believed to have been fairly similar to the modern African savannas.

Ancient task performance (T_A). This term refers to the performance of an individual in an ancient task such as hunting or foraging. It can be measured based on task attributes, such as amount of meat obtained through hunting per week. The term *task* is used here broadly; generally meaning action with a goal, and referring to tasks at various levels such as communicating knowledge (high level) and communicating knowledge about foraging for a specific type of food (low level). Examples of ancient tasks are communicating knowledge, foraging for fruits, killing prey, and socializing.

Fitness (*W*). In population genetics, the term fitness generally refers to the success with which an individual's genes are passed on to successive generations. It is usually measured based on the number of surviving offspring or grand-offspring of an individual. These measures are appropriate for theorizing efforts following the approach outlined in this paper. More elaborate theorizing efforts may need to revisit the appropriateness of these measures, due to the concept of inclusive fitness proposed by William D. Hamilton. According to inclusive fitness, an individual's genes may code for psychological mechanisms that maximize the reproductive success of closely related individuals (e.g., brothers and sisters), at the expense of the individual's own fitness. This will occur as long as the gene-replication benefits of helping close kin outweigh the gene-duplication costs for the individual.

Genotype (*G*). For the purposes of this paper, this term refers to a set of interrelated genes that influences the formation of a psychological trait. In population genetics, a genotype is often said to comprise a specific combination of alleles, which are variations of genes, coding for a particular trait. For example, let us assume that the allele combinations *AA* and *Aa* cause the manifestation of a psychological trait, whereas the combination *aa* does not. In this example, *A* and *a* are alleles, or variations of the same gene inherited from each parent, where *A* is said to be the dominant and *a* the recessive allele. This example is hypothetical and purposely simplified to convey a conceptual point; most psychological traits are in fact the result of the combined effects of many genes.

Modern development environment (*D_M*). This term refers to the environment surrounding modern humans in their formative years, as they develop from fertilized eggs to reproductively mature individuals. Before birth, the modern development environment is similar to the ancient development environment—the mother's womb—but differences may exist due to, for instance, the mother's consumption of modern chemical compounds and nutrients. After birth, more differences may exist. Differences between modern and ancient development environments may lead to differences in the way a particular genotype influences the formation of a psychological trait.

Modern task environment (*E_M*). This term refers to the environment surrounding modern humans as they perform a modern task. Often modern task environments differ significantly from ancient task environments, and many of those differences are caused by technologies invented and used by modern humans. Moreover, modern task environments generally present a higher degree of variability than ancient task environments.

Modern task performance (*T_M*). This term refers to the performance of an individual in a modern task such as searching for information using the Web or developing a new car design. It can be measured based on task attributes, such as the amount of time required to successfully search for a piece of information using the Web. The term *task* is used here broadly; generally meaning action with a goal. This term refers to tasks at various levels such as communicating knowledge (high level) and communicating knowledge about a specific production process (low level). Examples of modern tasks are communicating knowledge, preparing a contract, developing a new product, and socializing.

Psychological trait (*P*). In the discussion presented here, this term refers to a mental trait that has a genetic basis, and that is associated with a particular genotype. Mental traits can vary widely in terms of complexity and relationship with other traits. For example, the trait "attention to colors" is arguably a lot simpler, and likely dependent on fewer genes, than the trait "face-to-face communication mental modules". While the former refers to an instinct that makes humans pay particular attention to objects with colors other than black and white; the latter refers to a complex set of mental modules designed for face-to-face communication, which is associated with many interrelated instincts.

Survival success (*S*). Survival success refers to the success of an individual in keeping alive in the presence of adverse environmental factors such as pathogens and predators. It is usually measured through the age of an individual at the time of death. Survival success always influences fitness in a positive way, being positively correlated with it, because an individual must be alive to procreate and care for offspring.

Appendix B

Evolution Theory and Evolutionary Psychology

Evolutionary psychology builds on the modern synthesis (Mayr and Provine 1998) of Charles Darwin's (1859, 1871) theory of evolution of species by selection; which comprises evolution by natural (or environmental) selection in general (Darwin 1859), as well as in response to the more specific evolutionary force of sexual selection (Darwin 1871). Evolutionary psychology applies notions from the modern synthesis to the understanding of the evolution of the human brain and the complex set of brain modules that regulate human behavior.

Renewed interest in evolutionary explanations of human behavior, particularly since the mid-1990s (Zimmer 2001), may suggest that Darwin's theory has been somehow rediscovered by modern researchers. This is incorrect. Researchers interested in evolutionary theories that can be used for information systems theorizing should be aware that there has been steady progress over the years in the expansion and refinement of the original theory of evolution. Much of that progress has been made by researchers who resorted to mathematical formalizations of evolutionary phenomena building on fundamentals of genetics (Hartl and Clark 2007), and who published their conclusions primarily in academic journals. By and large those conclusions have been hidden from the popular literature for many years, and have been partially disseminated through the efforts of bestselling authors such as Dawkins (1990), Miller (2000) and Pinker (2002).

Also interesting but less relevant for the discussion presented here is the fact that the main ideas of the theory of evolution were in fact published in 1858 as part of an essay by Alfred Russel Wallace, which prompted Darwin to rush his momentous book into publication in 1859; Darwin gave Wallace proper credit, and the theory is sometimes referred to as the Darwin-Wallace theory of evolution (Kutschera 2003). The theory of evolution was plagued by controversy up until the early 1900s (Fox and Wolf 2006; Quammen 2006). It was the rediscovery of Gregor Mendel's pioneering work on the fundamentals of genetics (of which Darwin and Wallace were unaware) by Hugo de Vries and others in the early 1900s that provided the impetus for a better understanding of how variation occurs in plant and animal traits (Mayr and Provine 1998; Quammen 2006). That variation is the main fuel used by natural selection to shape the wide variety of adaptive traits observed in organic life (Maynard Smith 1998; Rice 2004). Even though Hugo de Vries and other early geneticists were very critical of the theory of evolution, their rediscovery of and subsequent work on genetics eventually provided a solid basis on which the theory of evolution stood even more convincingly than when it was originally proposed (Boaz and Almquist 2001; Fox and Wolf 2006).

The progress in the expansion and refinement of the original theory of evolution continues up to this day, particularly due to new discoveries in various fields such as molecular genetics (Hartl and Clark 2007). The original formulation of the theory of evolution has been supported by a vast amount of empirical data, successfully withstanding the test of time (Mayr and Provine 1998; Zimmer 2001). Nevertheless many key theoretical contributions have been made over the years to explain evolutionary phenomena that were not fully addressed by Darwin, Wallace, or any of their contemporaries. A large proportion of these contributions have been made in the period going from 1910 to 1980, after which evolutionary theorizing has generally branched out into more specialized fields. One of these specialized fields is the field of evolutionary psychology (Barkow et al. 1992).

Among the key contributors to the expansion and refinement of the theory of evolution in the 1910–1980 period are the following scholars, listed in approximate chronological order of contribution: Ronald A. Fisher, John B. S. Haldane, Sewall G. Wright, Theodosius G. Dobzhansky, Ernst W. Mayr, William D. Hamilton, George C. Williams, Motoo Kimura, George R. Price, John Maynard Smith, Edward O. Wilson, Amotz Zahavi, and Robert L. Trivers. Information systems investigators interested in more detailed and technical discussions of the contributions made by these scholars can find them in the volume edited by Mayr and Provine (1998); in books by the scholars themselves (often out of print, but usually available from university libraries); and through searches based on those scholars' names in full text databases of scientific publications, of which ScienceDirect and JSTOR are particularly recommended.

Evolutionary psychology is a field of investigation that has acquired a unique identity in the 1980s and 1990s. It builds on the original theory of evolution by natural selection, as well as on the advancements made to it (many of which made by the above contributors), to explain and predict human behavior based on what are believed to be evolved brain mechanisms (Buss 1999; Cartwright 2000). Evolutionary psychology essentially assumes that the human brain is like a computer with a number of interacting programs, or mental modules, and that those modules have been developed over successive generations in response to evolutionary pressures (Barkow et al. 1992). Most of those mental modules are believed to have been developed to solve problems faced by our ancestors in the Stone Age. As pointed out by Buss (1999, p. 20), modern humans “carry around a stone-aged brain in a modern environment.”

Several researchers have made key contributions to the field of evolutionary psychology since the 1980s. Robert Trivers has not only made key contributions to evolution theory, but is also among the pioneers in the field of evolutionary psychology (for a collection of influential

papers, see Trivers 2002). Jerome Barkow, Leda Cosmides, and John Tooby are widely recognized for having taken the first steps in the path of establishing evolutionary psychology as a field of investigation with a clear identity (Barkow et al. 1992; Cosmides and Tooby 1981; Cosmides et al. 2003; Tooby and Cosmides 1990). Another pioneer of the field is psychologist David Buss (Buss 1995, 1999), who has conducted groundbreaking cross-cultural studies on the evolutionary psychological mechanisms underlying human sexuality, aggression, and mental disorders. Two other notable psychologists who pioneered the field are Martin Daly and Margo Wilson, having provided key evolutionary psychological explanations of violent and criminal behavior (Daly and Wilson 1999; Wilson et al. 2002). Among linguists and language development researchers who have contributed to the establishment of the field of evolutionary psychology are Jeffrey Laitman, Philip Lieberman, Derek Bickerton, William Calvin, and Steven Pinker. Notable anthropologists who also have greatly contributed to the establishment of the field are Napoleon Chagnon and Robin Dunbar.

Appendix C

Theorists and Contributions in the 1910–1980 Period

Ronald A. Fisher. English statistician who proposed key elements of a genetic theory of natural selection in the 1910s 1920s and 1930s. Fisher showed that the inheritance of discrete traits (e.g., flower color) described by Gregor Mendel has the same basis as the inheritance of continuous traits (e.g., human height) described by Francis Galton. He is credited, together with John B. S. Haldane and Sewall G. Wright, with setting the foundations for the development of the field of population genetics. In population genetics the concepts and principles of the theories of evolution (e.g., inheritance and natural selection of traits) and genetics (e.g., genes and alleles) have been integrated and mathematically formalized.

John B. S. Haldane. English geneticist who, together with Ronald A. Fisher and Sewall G. Wright, is credited with setting the foundations for the development of the field of population genetics. Much of his research was conducted in the 1920s and 1930s. Particularly noteworthy is the work by Haldane through which he mathematically modeled and explained the interactions between natural selection, mutation, and migration. He is also known for what is often referred to as Haldane's principle, which explains the direction of the evolution of many species' traits based on the body size of the organisms of the species. Haldane's mathematical formulations also explained the rapid spread of traits observed in some actual populations of organisms, such as the increase in frequency of dark-colored moths from 2 percent to 95 percent in a little less than 50 years as a response to the spread of industrial soot in England in the late 1800s.

Sewall G. Wright. American geneticist and statistician who, together with Ronald A. Fisher and John B. S. Haldane, is credited with setting the foundations for the development of the field of population genetics. As with Fisher and Haldane, much of his original and most influential research was conducted in the 1920s and 1930s. He is believed to have discovered the inbreeding coefficient, related to the occurrence of identical genes in different individuals, and to have pioneered methods for the calculation of gene frequencies among populations of organisms. The development of the notion of genetic drift, where some of a population's traits result from random genetic changes instead of selection, is often associated with him. Wright is also considered to be one of pioneers of the development of the statistical method known as path analysis.

Theodosius G. Dobzhansky. Ukrainian-American geneticist and evolutionary biologist who migrated to the United States in the late 1920s, and is believed to have been one of the main architects of the modern evolutionary synthesis. Much of his original research was conducted in the 1930s and 1940s. In the 1930s he published one of the pillars of the modern synthesis, a book titled *Genetics and the Origin of Species*. The modern evolutionary synthesis is closely linked with the emergence of the field of population genetics, and is associated with the integration of various ideas and predictions from the fields of evolution and genetics. In spite of Dobzhansky's devotion to religious principles, he strongly defended Darwinian evolution against modern creationism. The title of a famous essay written by him is often cited in modern debates between evolutionists and creationists regarding the teaching of evolution in high schools: *Nothing in Biology Makes Sense Except in the Light of Evolution*.

Ernst W. Mayr. German taxonomist and ornithologist who spent most of his life in the United States, and is believed, like Theodosius G. Dobzhansky, to have been one of the main architects of the modern evolutionary synthesis. Mayr is credited with the development in the 1940s of the most widely accepted definition of species today, that of a group of organisms that are capable of interbreeding and producing fertile offspring. At that time organisms that looked alike were generally categorized as being part of the same species. Mayr served as a faculty member at Harvard University for many years, where he also served as the director of the Museum of Comparative Zoology. He lived to the age of 100 years, and was one of the most prolific scholars ever in the field of evolutionary biology. Unlike many evolution theorists, he was very critical of the use of mathematical approaches to the understanding of evolutionary phenomena.

William D. Hamilton. English evolutionary biologist (born in Egypt) widely considered one of the greatest evolution theorists of the 20th Century. Hamilton conducted pioneering research based on the gene-centric view of evolution, also known as the “selfish gene” perspective, which is based on the notion that the unit of natural selection is the gene and not the organism that carries the gene. His research conducted in the 1960s set the foundations for using this notion to understand social behavior among animals. The notion that the unit of natural selection is the gene forms the basis of the theory of kin selection, which explains why organisms often will instinctively behave in ways that will maximize the reproductive success of relatives, sometimes to the detriment of their own reproductive success (e.g., worker ants in an ant colony).

George C. Williams. American evolutionary biologist believed to have been a codeveloper in the 1960s, together with William D. Hamilton, of the gene-centric view of evolution. This view is based on the notion that the unit of natural selection is the gene, and not the organism that carries the gene or a group of organisms that happens to share the gene. Williams is also known for his pioneering work on the evolution of sex as a driver of genetic variation, without which a species would adapt more slowly in response to environmental pressures, in many cases becoming extinct. He is also known for suggesting possible uses of human evolution knowledge in the field of medicine.

Motoo Kimura. Japanese evolutionary biologist known for proposing the neutral theory of molecular evolution in the 1960s. In this theory Kimura argued that one of the main forces in evolution is genetic drift, a stochastic process that alters the frequency of genotypes in a population in a nondeterministic way. Kimura is widely known for his innovative use of a class of partial differential equations, namely diffusion equations, to calculate the effect of natural selection and genetic drift on the fixation of genotypes. He has developed widely used equations to calculate the probability of fixation of genotypes that code for certain phenotypic traits due to genetic drift and natural selection.

George R. Price. American geneticist known for refining in the 1970s the mathematical formalizations developed by Ronald A. Fisher and William D. Hamilton, and thus making significant contributions to the development of the field of population genetics. He developed the famous Price Equation, which has found widespread use in evolutionary theorizing. Price is also known for introducing, together with John Maynard Smith, the concept of evolutionary stable strategy (ESS). The ESS notion itself builds on the Nash Equilibrium, named after its developer John Forbes Nash (portrayed in the popular Hollywood film *A Beautiful Mind*). The concept of ESS explains why certain evolved traits spread and become fixed in a population.

John Maynard Smith. English evolutionary biologist and geneticist credited with several innovative applications of game theory (which is not actually a theory, but an applied branch of mathematics) in the 1970s to the understanding of biological evolution. Maynard Smith is also known for introducing, together with George R. Price, the concept of evolutionary stable strategy (ESS). As noted above, the ESS notion builds on the Nash Equilibrium, and explains why certain evolved traits spread and become fixed in a population. The pioneering work by John Maynard Smith has led to the emergence of a new field of research within evolutionary biology known as evolutionary game theory.

Edward O. Wilson. American evolutionary biologist and naturalist who coined the term *sociobiology* in the 1970s to refer to the systematic study of the biological foundations of social behavior of animals, including humans. Wilson was one of the first evolutionary biologists to convincingly argue that human mental mechanisms are shaped as much by our genes as they are by the environment that surrounds us, setting the stage for the emergence of the field of evolutionary psychology. Many of Wilson’s theoretical contributions in the area of sociobiology are very general, and apply not only to humans but also to other species. Wilson has been acknowledged as one of the foremost experts in the study of ants’ and other insects’ social organizations. He is also known for his efforts to preserve earth’s environment.

Amotz Zahavi. Israeli evolutionary biologist best known for his widely cited handicap principle, proposed in the 1970s, which explains the evolution of fitness signaling traits that appear to be detrimental to the reproductive fitness of an organism. Zahavi argued that traits evolved to signal the fitness status of an organism must be costly in order to be reliable. An example is the large and brightly colored trains evolved by the males of the peacock species, which signal good health to the females of the species. The male peacock’s train makes it more vulnerable to predators, and as such is a costly indicator of survival success. Traits used for this type of signaling are often referred to as Zahavian traits.

Robert L. Trivers. American evolutionary biologist and anthropologist who proposed several influential theories in the 1970s, including the theories of reciprocal altruism, parental investment, and parent-offspring conflict. Trivers is considered to be one of the most influential living evolutionary theorists, and is a very active researcher and speaker. His most recent focus is on the study of body symmetry and its relationship with various traits that are hypothesized to have been evolved in our ancestral past. Trivers’s theories often explain phenomena that are observed in nature but are not easily understood based on traditional evolutionary thinking, and in some cases appear contradictory with that thinking. Reciprocal altruism, for example, is a phenomenon that is widely observed in nature and involves one organism benefitting another not genetically related organism, without any immediate gain to the organism (e.g., vampire bats regurgitating blood to feed non-kin).

Appendix D

The Difference Between Evolution and Fixation

To properly interpret empirical results from tests of models incorporating evolutionary predictions, it is important to understand the difference between evolution of phenotypic traits and fixation of genotypes (Gillespie 2004; Hartl and Clark 2007; Maynard Smith 1998). Phenotypic traits are traits possessed by, and often observable in, organisms that are subject to selective pressures. These include morphological, physiological and behavioral traits. Phenotypic traits are, in turn, coded by the organisms' genes. A particular genetic configuration that codes for one or more phenotypic traits is referred to as an organism's genotype in connection with that trait (Hartl and Clark 2007).

Genetic mutations occur at a relatively low and uniform rate in most species, often in the order of 1 per 100,000 new births in a population of individuals (Graur and Li 2000; Gillespie 2004). Few new genotypes produced by mutations lead to changes in phenotypic traits that impact an organism's reproductive success; that is, most mutations are neutral with respect to the environment in which they occur (Fox and Wolf 2006; Kimura 1971, 1994; King and Jukes 1969). New genotypes that do have an effect on reproductive success usually have a deleterious effect, decreasing the reproductive success of the individual in which they appear (Fox and Wolf 2006; Graur and Li 2000). These new genotypes will generally be eliminated from the population through selection because the individuals that possess them will produce fewer offspring, who will in turn possess the genotypes that impair their reproductive success and also produce fewer offspring, and so on, until all the individuals with that genotype disappear from the population.

Once in a while a mutation will lead to the appearance of a new genotype in a population, usually in one single individual, that will increase the reproductive success of the individual that possesses the genotype. The individual possessing the genotype will have more offspring than others; the offspring will also possess the genotype and will have more offspring, and so on (Gillespie 2004; Hartl and Clark 2007; Rice 2004). Since the genotype codes for a phenotypic trait (e.g., blood type, opposing thumbs, or aggressiveness) more and more individuals possessing the phenotypic trait will be present in the population. This increase in the frequency of a genotype and related phenotype in a population is generally referred to as evolution by natural selection (Price 1970; Rice 2004). The fixation of a genotype in a population is achieved when all the individuals in the population possess the genotype. As can be inferred from this line of reasoning, evolution is not the same as fixation. Evolution of a phenotypic trait (e.g., altruism toward relatives, color vision) may or may not lead to fixation of the genotype that is associated with the phenotypic trait in question (Graur and Li 2000; Kimura 1994).

The importance of differentiating evolution from fixation in the context of information systems theorizing based on evolutionary psychology comes from the fact that fixation is much less common than evolution. While a genotype may spread through evolution to a percentage of a population, it rarely spreads to all individuals in the population. Compounding that is the fact that most psychological traits that have a genetic basis are caused by many genes, which in turn interact with a complex environment to generate phenotypic traits. Therefore, most tests of models comprising evolutionary psychological predictions will not find complete uniformity with respect to a hypothesized mental trait. For example, some people will be better at using unnatural electronic communication media than others, even though it can be safely argued that the human brain is generally designed to excel in natural, or face-to-face-like, communication. Such higher ability to use unnatural electronic communication media presented by a group of individuals may be due to heritable factors that present a certain degree of variability.

Why do not all genotypes that increase reproductive success always proceed to fixation? There are many hypothesized reasons for this, some more technical and open to debate than others. One of the main reasons, also one of the least open to debate, is that the environment surrounding the population of individuals undergoing selection may change, sometimes unpredictably, while evolution is taking place. Since evolution with respect to a genotype is by definition a process that depends on selective pressures, it ceases when the selective pressures that favor a particular genotype cease to exist. Climatic changes and migration, for example, are types of events that may significantly change the selective pressures operating on a population of individuals. These types of events are believed to have occurred often in our evolutionary past, and their effects on genotypes are frequently subsumed under a general term, namely genetic drift (Gillespie 2004; Kimura 1994).

Appendix E

What Is a Universal Human Trait?

Evolutionary theorizing efforts in connection with human behavior will typically start with the identification of what is frequently referred to as a human universal (Brown 1991; Pinker 2002). Nevertheless, more often than not one will find a great deal of variation in phenotypic traits. Much variation will be found even in the genotypes that code for those traits; and even identical genotypes may lead to different phenotypes due to the interaction between genotypes and the environment, as individuals grow from conception to maturity.

So, what is a human universal? Generally speaking, it is a discrete trait that is found in all living human cultures, and for which there is no known exception (Brown 1991). To say that a discrete trait is present in a culture generally means that the discrete trait in question is found in most individuals of that culture, even if there are exceptions within that culture. Discrete traits can be measured through categorization based on presence or absence of the trait. This differentiates them from continuous traits, which are normally measured on a continuous scale (e.g., height, weight). Therefore, one can say that incest avoidance is a human universal by noting that it is present in all existing cultures. (Incest avoidance prevents inbreeding, which generally leads to a host of debilitating health conditions.) Continuous traits can also be categorized, leading to discrete trait measures. For example, tallness, if defined as adult height above 4 feet may be called a human universal, even though height varies greatly among individuals within and between cultures.

Thus information systems researchers interested in evolutionary theorizing should be mindful that, while there are several human universals that can be used as a departing point for their theorizing, quantitative variations in the traits will most likely show up in empirical tests of their evolutionary theories. Variation may also be found in qualitative empirical tests (Creswell 2002). It certainly will be found in almost all statistical tests, from simple correlation analysis to structural equation modeling (Chin 1998; Chin et al. 2003; Hair et al 1987; Kline 1998; Nevitt and Hancock 2001; Nunnally 1978; Nunnally and Bernstein 1994; Rencher 1998; Schumacker and Lomax 1996). Even in statistical tests that build on categorization and grouping of data into subsamples, such as analysis of variance and covariance (Hair et al. 1987; Rosenthal and Rosnow 1991), within-group variation of behavior that supposedly has a genetic basis should be expected.

It should be noted that, in the case of sex differences, evolutionary psychologists are generally interested in differences in behavior between males and females based on the assumption that behavior in each group (i.e., males and females) presents a high degree of similarity. Therefore, one can discuss human universals that are specific to men or women (Brown 1991), or that refer to how men and women behave toward one another (Buss 1995, 1999). The assumption is that there is a high degree of within-group similarity in groups of men and women, even though there may be a high degree of between-group dissimilarity. Information systems researchers looking for evolutionary explanations for those differences will usually depart from the same assumption.

Evolutionary psychological theories do not normally try to account for small genetic differences between individuals that may lead to corresponding differences in behavior. For example, the human eye is functionally the same for the vast majority of humans. Yet, each individual human being has specific eye characteristics that are unique to him or her; a finding that has inspired the use of retina patterns for individual identification purposes. Underlying those differences is the fact that, with the exception of identical twins, different human beings usually have slightly different genetic configurations. Evolutionary psychology generally places the study of those differences outside its scope of interests, which does not mean that those differences are irrelevant, but simply that they are studied in fields outside evolutionary psychology (e.g., clinical ophthalmology).

Appendix F

Selection and Correlation

Price (1970) showed that for any phenotypic trait to evolve through selection in any population of individuals, the trait must satisfy Equation (1). The left side of the equation contains a covariance term where: W is a measure of the fitness of an individual that possesses the trait (e.g., number of surviving offspring); and Z is a measure of the manifestation of the trait in the individual (e.g., $Z = 1$ if the trait is present, and $Z = 0$ if it is absent).

$$Cov(W, Z) > 0 \tag{1}$$

Since the genotype of an individual is also part of the individual’s phenotype (Rice 2004), Equation (1) can be rewritten as Equation (2), where G refers to the genotype (i.e., a set of genes) that is associated with a particular phenotypic trait.

$$Cov(W, G) > 0 \tag{2}$$

Equation (2) can be rewritten as Equation (3) in terms of the standardized measures of W and G , which are referred to as w and g . This allows for the use of the equation in the context of path analysis (Duncan 1966; Kenny 1979; Mueller 1996; Wright 1934, 1960).

$$Cov(w \cdot S_w + \bar{W}, g \cdot S_g + \bar{G}) = Cov(w \cdot S_w, g \cdot S_g) = S_w \cdot S_g \cdot Cov(w, g) > 0 \Rightarrow Cov(w, g) > 0 \tag{3}$$

The path model shown in Figure F1 depicts relationships among the following standardized measures: genotype (g), psychological trait (p), ancient task performance (t_A), survival success (s), and fitness (w). The path coefficients—i.e., $Path(w, s)$, $Path(s, t_A)$ etc.—are standardized partial regression coefficients. For simplicity, error terms are not shown.

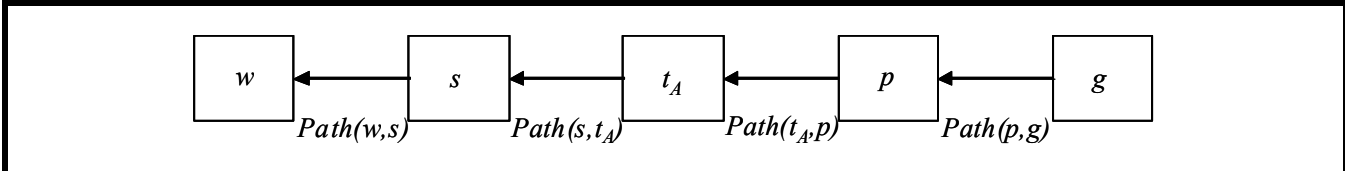


Figure F1. Path Model

The relationships depicted in the path model are hypothesized to have led to the evolution of the genotype (g) through selection. Standardized measures related to the ancient development (d_A) and task (e_A) environments are not shown in the path model because those environments are assumed to have been approximately constant during the evolution of the genotype.

The First Law of Path Analysis (Kenny 1979; Mueller 1996) states that the covariance between any two variables in a path model equals the sum of the products of all path coefficients in all paths that connect the two variables. Since there is only one path connecting w and g , this leads to Equation (4).

$$Cov(w, g) = Path(w, s) \cdot Path(s, t_A) \cdot Path(t_A, p) \cdot Path(p, g) \tag{4}$$

Combining equations (3) and (4) leads to Equation (5), which re-states Price’s (1970) fundamental covariance requirement for evolution through selection in terms of path coefficients.

$$Path(w, s) \cdot Path(s, t_A) \cdot Path(t_A, p) \cdot Path(p, g) > 0 \tag{5}$$

The path model does not contain competing paths; that is, it does not have any instance of multiple paths pointing to the same variable. Thus all of the path coefficients are reduced to the corresponding correlation coefficients. This leads to Equation (6).

$$\text{Corr}(w, s) \cdot \text{Corr}(s, t_A) \cdot \text{Corr}(t_A, p) \cdot \text{Corr}(p, g) > 0 \quad (6)$$

Correlations between standardized variables have the same values as the correlations between the corresponding non-standardized variables (Mueller 1996). Therefore Equation (6) can also be written in terms of measures of the corresponding non-standardized variables—indicated as W, S, T_A, P and G —as in Equation (7).

$$\text{Corr}(W, S) \cdot \text{Corr}(S, T_A) \cdot \text{Corr}(T_A, P) \cdot \text{Corr}(P, G) > 0 \quad (7)$$

The correlation between fitness (W) and survival success (S) is always positive, because an individual must be alive to procreate and pass on genes to the next generation. The correlation between psychological trait (P) and genotype (G) is also always positive, because by definition the genotype codes for the psychological trait.

Therefore, assuming a positive correlation between survival success (S) and ancient task performance (T_A), it can be concluded that the correlation between ancient task performance (T_A) and psychological trait (P) must have been positive for the genotype (G) to evolve through selection.

Appendix G

Evolutionary Psychology Outlets and Institutions

- **Main research association:** Human Behavior and Evolution Society (<http://www.hbes.com/>)
- **Main annual conference:** Annual meeting of the Human Behavior and Evolution Society (<http://www.hbes.com/>)
- **Specialized journals:**

Evolution and Human Behavior (<http://www.ehonline.org/>)

Evolutionary Psychology (<http://www.epjournal.net/>)

- **Research centers and institutions:**

Center for Adaptive Behavior and Cognition at the Max Planck Institute in Germany
<http://www.mpib-berlin.mpg.de/en/forschung/abc/>

Center for Evolutionary Psychology at the University of California at Santa Barbara
<http://www.psych.ucsb.edu/research/cep/>

Darwin College at Cambridge University, England
<http://www.dar.cam.ac.uk/>

Evolutionary Psychology Lab at the University of Texas at Austin
<http://homepage.psy.utexas.edu/homepage/Group/BussLAB/>

Laboratory for Experimental Evolutionary Psychology at the University of Pennsylvania
<http://www.psych.upenn.edu/PLEEP/>

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Appendix H

The Difficulties of Theorizing About Sex Differences

It is undeniable that human males and females differ in their genetic makeup. The genetic differences between men and women are very likely the largest within the human species. In humans genetic material is organized in 23 pairs of chromosomes. One of these pairs, often referred to as the sex chromosomes, differs in men and women. Men have what is often referred to as an *XY* pair, where the *X* chromosome is inherited from the mother and the *Y* from the father; women have an *XX* pair (Boaz and Almquist 2001; Hartl and Clark 2007).

Information systems researchers interested in evolutionary theorizing may be tempted to hypothesize sexual differences based on the known genetic differences between men and women. Those researchers are likely to encounter several difficulties. One of them is that many traits that have been evolved because of selective pressures on one sex are also present, at least to a certain extent, in the other sex. For example, men have nipples. This phenomenon is often referred to as gene correlation (Gillespie 2004; Maynard Smith 1998). It creates a particularly serious problem for information systems researchers trying to hypothesize sex differences in behavior toward technology based on assumptions about different selective pressures on men and women in our evolutionary past. Even when different selective pressures are clearly identified, it is often difficult to argue convincingly that evolved brain mechanisms associated with behavioral responses have been passed on only to men or women, and not both.

Another difficulty awaiting information systems researchers trying to explain sex differences based on evolutionary thinking is that sex differences are often associated with sexually selected traits. Many of these traits confer no survival advantage to the individuals that possess them; some actually handicap those individuals (Zahavi and Zahavi 1997). Sexually selected traits are generally used in mate choice, meaning that they evolved because they were considered attractive by members of the other sex. The classic example of sexually selected trait is the big and bright train of the male in the peacock species, which is actually a handicap from a survival perspective (Petrie et al. 1991; Zahavi and Zahavi 1997). Examples of traits in the human species that are hypothesized to be at least in part sexually selected are testosterone markers in men such as angular facial features, and fertility markers in women such as a .7 waist-to-hip ratio (Buss 1995, 1999; Miller 2000). Many other examples exist (see, particularly, Buss 1995) that can be used as a basis for the formulation of hypotheses on human behavior toward technology, and differences in that behavior displayed by men and women.

Sexually selected traits used in mate choice pose another problem for information systems researchers because they often present a much greater level of variability than traits evolved in response to other environmental pressures. This higher variability of mate choice traits is a general phenomenon that extends well beyond the human species (Boaz and Almquist 2001; Miller 2000; Zahavi and Zahavi 1997). Therefore, hypothesized sex-linked instincts affecting behavioral toward technology may present a great deal of variation among any sample of individuals. A high level of variability leads to problems in empirical tests employing quantitative data collection and analysis techniques, and may lead to misleading conclusions even in qualitative studies. For example, it poses restrictions on the types of tests that can be employed, and requires quantitative tests with large statistical power. Moreover, since in most cultures attitudes toward men and women are different, and have a differential effect on how men and women behave, a great deal of variability in connection with a hypothesized effect may make it very difficult to isolate genetic from cultural influences.

Yet another difficulty may be faced by information systems researchers trying to explain sex differences based on evolved behavioral patterns. It comes from the fact that the variability of many traits differs in men and women (Buss 1995; Miller 2000), with variability often being higher in men than women. For example, general intelligence scores present a higher variation in men than in women, even though on average men and women score equally well in general intelligence tests (Deary et al. 2007). From a statistical standpoint, this is reflected in a flatter (i.e., higher variance) normal distribution of the trait for men than for women. This finding has led to what is sometimes referred as the “more idiots, more geniuses” effect; that is, there are more idiots and geniuses among men than among women (Deary et al. 2007; Miller 2000).

Differences in within-sex variability may create difficulties in empirical tests, and lead to misleading interpretations of differences in behavior toward technology. For example, a random sample of men and women may contain a higher percentage of men than women unable to effectively use a computer system with a very complex interface, and also a higher percentage of men than women showing extremely high proficiency at using the computer system; even though a comparison of mean proficiencies may suggest no significant differences between men and women.

The above discussion is not meant to imply that information systems researchers should avoid theorizing about sex differences in behavior toward technology based on evolved psychological traits. What should be clear is that such line of research will be generally more difficult to undertake than theorizing about human universals that apply to both sexes. Empirical tests of hypotheses related to sex differences will probably require large cross-cultural samples to be convincing. Moreover, the conclusions reached might be too counter-intuitive or go against established thinking, making publication and acceptance of grant proposals more difficult.

Appendix I

A Set of Four Steps to Guide Theorizing Efforts

Step 1: Identifying a theoretical gap. The first step refers to the identification of a theoretical gap in the field of information systems that can be filled with an evolutionary theory. One of the main foci of the field of information systems, although not the only one, are explanations and predictions of behavioral patterns toward various technologies, particularly information technologies, and the related outcomes of those behavioral patterns (Baskerville and Myers 2002; Galliers et al. 2006). In this case, the gap will usually take the form of a context-bound behavioral response to a type of technology that cannot be reasonably explained based on existing information systems theories.

Normally theoretical gaps will be identified based on mismatches between the results of empirical studies and the predictions of existing theories. A good example of empirical result that suggests species-wide similarities in behavior toward technology is the frequently replicated empirical finding that electronic media that suppress face-to-face interaction elements are perceived as posing communication obstacles to users performing complex collaborative tasks, when compared with the face-to-face medium (Graetz et al. 1998; Kahai and Cooper 2003; Simon 2006). This is a finding that has even been reported in the context of multi-country studies (Kock and DeLuca 2007; Tan et al. 1998; Wainfan and Davis 2004), and that has provided a key motivation for the development of media naturalness theory discussed earlier.

Step 2: Developing a new evolutionary theory. In most cases this step will likely involve several sub-steps, of which the most important are those related to the review of relevant human evolution and evolutionary psychological theories, and the review of empirical findings in connection with those theories. Good sources of articles that report on evolutionary psychological studies are the journals listed in Appendix G. Even though literature reviews regarding this step are likely to start with publications in the field of evolutionary psychology, they are likely to lead to reviews of research literatures in areas outside the purview of evolutionary psychology. Some of those areas may include language development, anthropology, ethology (i.e., the study of animal behavior), and cognitive neuroscience (i.e., the study of the neurological mechanisms underlying cognition).

For example, a researcher interested in evolutionary theorizing about behavior toward electronic communication technologies may have to review human evolution theories that explain the emergence of biological communication systems in general, including oral and symbolic language (Bickerton 1990; Pinker 1994). That may lead to a comparative review of evolutionary theories of language development and its heritability (Lieberman 1998; Pinker 2003). In order to fill the possible gaps identified in this comparative review, the researcher may have to review the anthropological literature related to the use of symbolic language by early civilizations (Dunbar et al. 1999; Gombrich 1995). A review of the related literature regarding the development of the human vocal apparatus and related brain mechanisms may also be needed to clarify certain issues (Laitman 1984; Laitman and Reidenberg 1997; Lieberman 2000).

Step 3: Integrating the new theory with other non-evolutionary theories. As discussed earlier, it is doubtful that evolutionary theories addressing information systems phenomena can fully explain those phenomena, at least at the outset of the development. As with the motivation for the development of an evolutionary theory, the search for a theory (or theories) that can supplement the evolutionary theory should be based on the explanatory and predictive gap left by the latter regarding specific information systems phenomena. Certain evolutionary predictions can be made regarding, for instance, problems associated with the use of electronic media in learning tasks. A study of our evolutionary past leads to the inevitable conclusion that our brain is designed for face-to-face communication, the mode of communication used by our hominid ancestors during over 99 percent of our evolutionary history, a period where learning was an integral part of hominid survival and mating strategies (Boaz and Almquist 2001; Lieberman 1998; Wilson 2000).

Based on the above, one can reasonably conclude that our brain is maladapted for the use of modern electronic communication media that suppress face-to-face communication elements, particularly in learning tasks. This is the essence of media naturalness theory (Kock 2004, 2005). Nevertheless, electronic media are widely used today for online learning in various education institutions (Summers et al. 2005). This calls for a theory that explains students not failing online courses en masse, and that is compatible with the notion that our brain is designed for face-to-face, as opposed to electronic, communication. Our previous discussion suggests that channel expansion theory (Carlson 1995; Carlson and Zmud 1999) is a good candidate. Four important preconditions for the integration of evolutionary and non-evolutionary theories are met by the media naturalness and channel expansion theories. Those preconditions are that (1) the theories should refer to the same general type of task; (2) the theories should refer to the same general type of technology; (3) the theories should comprise similar theoretical constructs; and (4) the theories should complement each other.

Step 4: Testing the combined theoretical model. For an evolutionary theory of information systems phenomena to be integrated with any other theory it is necessary that the two theories make different yet complementary predictions. This also applies to the case in which more than one theory is used to complement the new evolutionary theory. That is, the theory or theories complementing the evolutionary theory must explain and predict phenomena that the latter does not, and in a way that is compatible with the evolutionary theory. The real test of whether the above condition is met is an empirical test of the combined theoretical model. Such a test must be built on hypotheses or research questions that separately address different aspects of the two or more complementary theories. The goal here should be to identify possible mismatches, or lack thereof, between each theory that make up the combined theoretical model and the empirical data.

The empirical test may be designed in ways that are compatible with any of the main epistemologies used in information systems research, and may rely on qualitative and/or quantitative data analyses (Audi 2003; Klein and Myers 1999; Orlikowski and Baroudi 1991). Once Step 4 is completed, and any of the theories in the combined model is not fully supported by the empirical test, the researcher should consider either removing the unsupported theory from the model or revising the theory. Removal of a theory from the model is advisable for the non-evolutionary theory or theories chosen to complement the evolutionary theory. With respect to the new evolutionary theory the natural following step would be one of these: (1) refutation and abandonment of the new theory, if it is clear that the theory's lack of compatibility with the findings of the empirical test is beyond doubt and that the tests are free from methodological problems; (2) replication of the study with small modifications, if methodological problems such as measurement errors are suspected; or (3) refinement of the new theory, if the theory seems to be largely correct but gaps are suggested by the empirical test.

The latter option, refinement of the new theory, should be based on theoretical gaps that the theory could not properly explain. Thus it could be seen as essentially entailing going back to Step 1 in the normative framework for information systems theorizing proposed here (see Figure I1). In this case, Step 2 in the new cycle could be seen as more of a refinement of the new evolutionary theory than a full theory development step.

As shown in Figure I1, steps 1 to 4 can be seen as forming a closed theory development and testing cycle. It should be noted that steps 1 to 4 do not necessarily have to be conducted by the same researcher or research team. For example, steps 1 and 2 may be conducted by one theoretical researcher, Step 3 by another theoretical researcher, and finally Step 4 by a research team with enough resources to conduct a full test of the combined theoretical model.

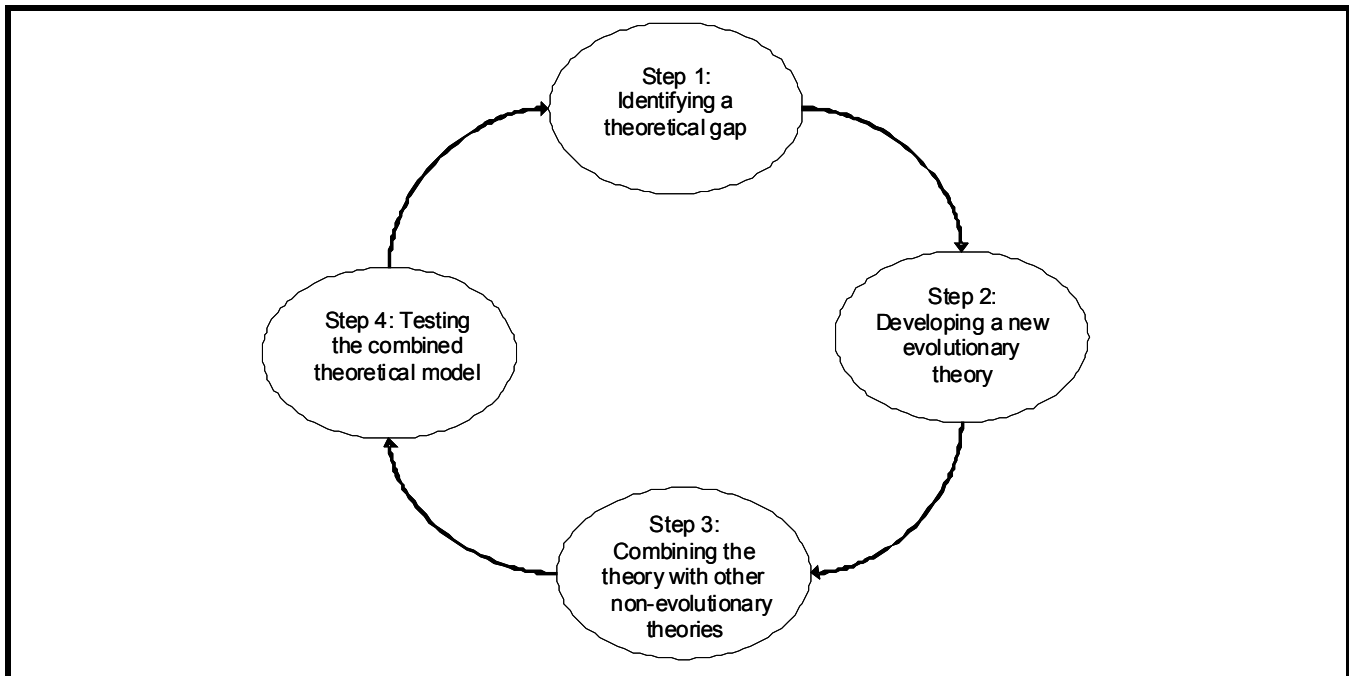


Figure I1. The Four Steps as Part of a Theory Development Cycle