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INFORMATION SYSTEMS THEORIZING BASED ON EVOLUTIONARY PSYCHOLOGY: AN INTERDISCIPLINARY REVIEW AND THEORY INTEGRATION FRAMEWORK[1]

By: **Ned Kock**
Division of International Business and Technology Studies
Texas A&M International University
5201 University Boulevard
Laredo, TX 78041
U.S.A.
nedkock@tamiu.edu

Abstract

Evolutionary psychology holds great promise as one of the possible pillars on which information systems theorizing can take place. Arguably, evolutionary psychology can provide the key to many counterintuitive predictions of behavior toward technology, because many of the evolved instincts that influence our behavior are below our level of conscious awareness; often those instincts lead to behavioral responses that are not self-evident. This paper provides a discussion of information systems theorizing based on evolutionary psychology, centered on key human evolution and evolutionary genetics concepts and notions. It is argued here that there is often a need to integrate evolutionary and non-evolutionary theories, and four important preconditions for the successful integration of evolutionary and non-evolutionary theories are discussed. An example of integration of evolutionary and non-evolutionary theories is provided. The example focuses on one evolutionary information systems theory—media naturalness theory—previously developed as an alternative to media richness theory, and one non-evolutionary information systems theory, channel expansion theory.

Keywords: Information systems, evolutionary psychology, theory development, media richness theory, media naturalness theory, channel expansion theory

Introduction

While information systems as a distinct area of research has the potential to be a reference for other disciplines, it is reasonable to argue that information systems theorizing can benefit from fresh new insights from other fields of inquiry, which may in turn enhance even more the reference potential of information systems (Baskerville and Myers 2002). After all, to be influential in other disciplines, information systems research should address problems that are perceived as relevant by scholars in those disciplines and in ways that are consistent with the research traditions of those scholars.

The likelihood of obtaining fresh new insights is especially high in connection with fields that bring in notions yet unexplored in information systems theorizing. A field of inquiry that appears to hold much promise in this respect is evolutionary psychology (Barkow et al. 1992; Buss 1999). This field of inquiry builds on concepts and ideas related to human evolution—primarily human evolution during the period that goes from the emergence of the first hominids, the *Australopithecines* (Boaz and Almquist 2001), up to the present day. Evolutionary psychologists generally believe that many of our

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Note: The appendices for this paper are located at http://www.misq.org/archivist/appendices/KockAppendices.pdf.

modern brain functions evolved during the period that goes from the emergence of the first hominids around 3.5 million years ago until the emergence of modern humans about 100 thousand years ago (Buss 1999; Cartwright 2000).

Evolutionary psychology has the potential to become one of the pillars on which information systems theorizing can take place. The explanatory power of evolutionary psychology comes from the fact that its underlying ideas relate to the basic design of our brain, and thus can form the basis on which fundamental explanations of behavior can be developed (Barkow et al. 1992; Cosmides et al. 2003; Kock 2004; Tooby and Cosmides 1990). Evolutionary psychology also arguably holds the key to many counterintuitive predictions of behavior toward technology, because many of the evolved instincts that influence our behavior are below the level of conscious awareness (Barkow et al. 1992; Buss 1999; Cartwright 2000). Often those instincts lead to behavioral responses that are not self-evident to the individuals involved. One example of this is the recent evolutionary psychology-inspired study by Kock et al. (2008), which shows that including a Web page showing a large picture of a snake in attack position in between Web pages with text-based knowledge content leads to a significant improvement (of as much as 38 percent) in the absorption of the content on the Web pages adjacent to the snake page.

Past research has rarely employed evolutionary psychological explanations and predictions regarding human behavior for the understanding of information systems phenomena. There have been few studies building on human evolution ideas, and to some extent on evolutionary psychological ideas, in the areas of mobile technology use (Junglas et al. 2009) electronic consumer behavior (Hantula et al. 2008; Rajala and Hantula 2000; Smith and Hantula 2003), computer-mediated communication (Kock 2004, 2005; Kock et al. 2008), virtual team leadership (DeRosa et al. 2004), electronic user interface design (Hubona and Shirah 2006), online mate selection (Saad 2008), and information search and use behavior (Spink and Cole 2006). These few studies reflect the potential of evolutionary psychology to explain behavior toward technology. Nevertheless, with even fewer exceptions (Hantula et al. 2008; Hubona and Shirah 2006; Junglas et al. 2009; Kock 2004, 2005), these studies have been published in outlets or addressed topics that are generally considered outside the field of information systems.

An attempt is made here to break new epistemological ground (Audi 2003) through the proposal, not of a new epistemology, but of a theory development and integration framework for information systems theorizing based on evolutionary psychology that can be used within the scope of most epistemological traditions used in the field of information systems (Klein and Myers 1999; Orlikowski and Baroudi 1991). The theory development and integration framework builds on an extensive interdisciplinary review. The core components of this review are included in the main body of the paper. Other important ancillary components are organized by topic in various appendices.

The framework is illustrated based on an analysis of the development of a new evolutionary theory, namely media naturalness theory (Kock 2004, 2005). This new theory was developed to fill a theoretical gap in connection with a non-evolutionary theory known as media richness theory (Daft and Lengel 1986; Daft et al. 1987). While evolutionary theories can bridge gaps left by non-evolutionary theories, it is also argued here that evolutionary theories of information systems generally need to be integrated with other non-evolutionary theories in order to provide a more precise and testable picture of the information systems phenomena that they try to explain. This has not been fully accomplished by media naturalness theory, and is presented as leading to some limitations in explanatory and predictive power. A proposal is advanced on how media naturalness theory can be integrated with one non-evolutionary theory that seems to be a good complement to it, namely *channel expansion theory* (Carlson 1995; Carlson and Zmud 1999).

Notwithstanding the focus on communication media studies adopted in the illustrative examples provided, it is argued here that the framework can be used in a wide variety of theory development efforts in the field of information systems—and not only in communication media research. Traditional and emerging information systems topics that could also benefit from evolutionary psychological theorizing include (but are not limited to) information systems development (e.g., visual programming and other cognitively natural approaches), technology-mediated learning (e.g., technology-mediated storytelling and other natural cognitive aids), human–computer interface design (e.g., chunking approaches to address cognitive limitations that have an evolutionary basis), and use of virtual worlds to simulate and predict large-scale group behavior in catastrophic situations (where evolved flight-or-fight instincts are likely to strongly influence behavioral responses).

This paper is organized as follows. It starts with a discussion of information systems theorizing based on evolutionary psychology; this discussion is centered on a few key evolutionary concepts such as genotype, psychological trait, ancient and modern task performance, survival success, and fitness (Cartwright 2000; Hartl and Clark 2007; Mayr and Provine 1998; Zimmer 2001). For convenience, an easily accessible list of terms and definitions is provided in Appendix A. The paper then proceeds with a discussion of the need to integrate evolutionary and non-evolutionary information systems theories, followed by four important preconditions for the successful integration of evolutionary and non-evolutionary theories. Next an example of integration of evolutionary and non-evolutionary theories is discussed, focusing on the media naturalness (Kock 2004, 2005) and channel expansion (Carlson 1995; Carlson and Zmud 1999) theories. The paper concludes by building a conceptual link between this example and the earlier discussion on information systems theorizing based on evolutionary psychology.

Information Systems Theorizing Based on Evolutionary Psychology

The field of evolutionary psychology is concerned with evolved psychological traits (Barkow et al. 1992; Buss 1999; Cartwright 2000). These are mental traits that are hypothesized to have a genetic basis, and that are assumed to have evolved among our ancestors because they enhanced those ancestors' reproductive success. Evolutionary psychology acquired a unique identity in the 1980s and 1990s (Barkow et al. 1992; Buss 1995, 1999; Cosmides and Tooby 1981; Cosmides et al. 2003; Daly and Wilson 1999; Dunbar 1993, 1998; Tooby and Cosmides 1990; Trivers 2002; Wilson et al. 2002). Appendix B outlines how evolutionary psychology has emerged as a unique field of inquiry.

Evolutionary psychology builds on evolution theory (Darwin 1859, 1871; Mayr and Provine 1998; Zimmer 2001), to which many fundamental contributions have been made in the period going from 1910 to 1980 (Boaz and Almquist 2001; Fox and Wolf 2006; Hartl and Clark 2007; Kutschera 2003; Quammen 2006). Appendix C provides a list of key contributors to the expansion and refinement of the theory of evolution during this period, along with a summary of the key theoretical contributions made by each of these scholars.

The contributions made in the period going from 1910 to 1980 by evolutionary theorists provided the basis for the understanding of evolutionary patterns in behavior. Many of those contributions involved mathematical formalizations of the evolution of behavioral patterns (Maynard Smith 1998; McElreath and Boyd 2007; Rice 2004); patterns that in humans are associated with evolved psychological traits (Barkow et al. 1992; Wilson 2000).

Many evolved psychological traits are present in modern humans, and likely influence our behavior toward modern technologies (Barkow et al. 1992; Bickerton 1990; Buss 1995, 1999; Calvin and Bickerton 2000; Dunbar 1993, 1998; Pinker 1994, 2002, 2003). Theorizing about these traits and their influence on our behavior toward modern technologies is the essence of what is called here *information systems theorizing based on evolutionary psychology*.

Evolution of Psychological Traits by Natural Selection

The diagram in Figure 1 depicts how a psychological trait P would have evolved in our evolutionary past by natural selection (Cartwright 2000; McElreath and Boyd 2007; Price 1970). The trait P was associated with a genotype G, which was a set of interrelated genes (Boaz and Almquist 2001; Hartl and Clark 2007; Maynard Smith 1998) that influenced the formation of P. An example of psychological trait P would be "attention to colors." Individuals possessing this trait would have an instinctive response to objects displaying colors other than black and white, paying more attention to them. Individuals not possessing this trait would pay no particular attention to those objects.

Like most gene–trait relationships, the relationship between G and P was moderated by the ancient development environment D_A. 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 (Boaz and Almquist 2001; McElreath and Boyd 2007; Pinker 2002; Wilson 2000). The environment D_A was the environment surrounding our hominid ancestors in their formative years, that is, while they developed from fertilized egg stage to reproductive maturity. For example, if a mother's milk was very low in certain nutrients, proper development of color vision could have been impaired. Even in the presence of the same genotype G, that impairment could make attention to colors impossible due to color blindness.

The psychological trait P influenced ancient task performance T_A, or the performance of an individual in an ancient task such as hunting or foraging (Boaz and Almquist 2001; Hubona and Shirah 2006). For example, let us assume that T_A was associated with the task of foraging for nutritious fruits. In this case, individuals who paid attention to colors would generally have higher T_A than individuals who did not, because colors are indicative of the presence of important nutrients in fruits (Boaz and Almquist 2001; Cartwright 2000). The relationship between P and T_A was moderated by the ancient task environment E_A.

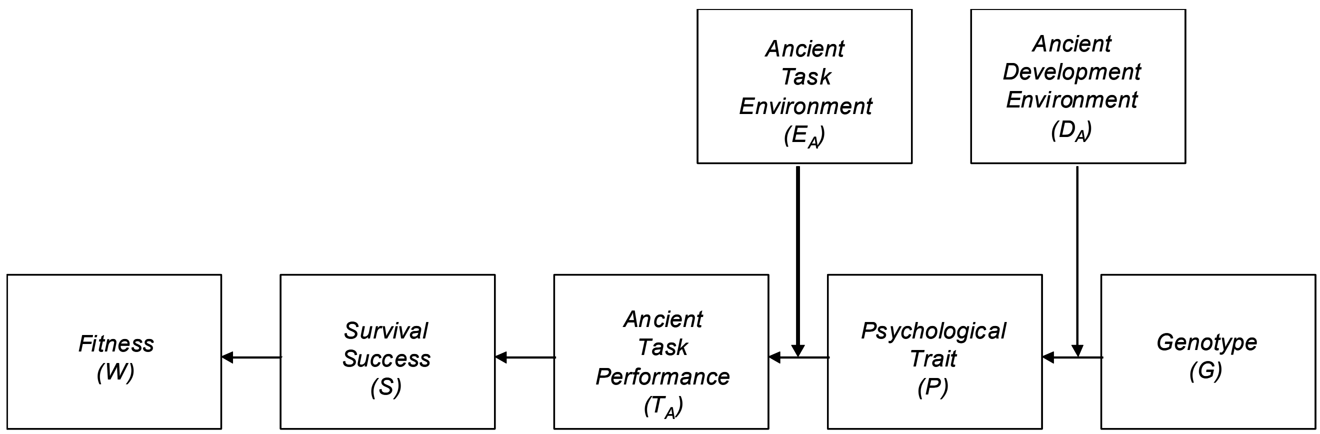

Figure 1. Evolution of Psychological Traits by Natural Selection

Individuals who were more successful at the task of foraging for nutritious fruits would also be more resistant to disease, and thus would survive in higher quantities (Gillespie 2004; Maynard Smith 1998). They would have a higher survival success (*S*). Since one must be alive to procreate and care for offspring, those individuals would also have higher fitness (*W*). In population genetics (Graur and Li 2000; Hartl and Clark 2007; Kimura 1994; Maynard Smith 1998; McElreath and Boyd 2007), the term *fitness* (usually indicated as *W*, as we do here) generally refers to the success with which an individual's genes are passed on to successive generations. It is usually measured through the number of surviving offspring or grand-offspring of an individual (Gillespie 2004; Maynard Smith 1998; McElreath and Boyd 2007; Rice 2004).

The process above, repeated generation after generation, would lead the genotype *G* and the related psychological trait *P* to spread from one single individual to the vast majority of our ancestors. This process is what is generally referred to as evolution by natural selection (Boaz and Almquist 2001; Maynard Smith 1998; Rice 2004). See Appendix D for a discussion of the difference between evolution and what is often referred to as *fixation*.

As a result, *G* and *P* would be widely observed in modern humans, leading to the emergence of what is often referred to as a human universal (Brown 1991). The term *human universal* does not refer to a trait that is present in every single living individual, but to a trait that is widespread among humans regardless of cultural differences (see Appendix E for a more detailed discussion).

In summary, the evolution of any psychological trait *P* through natural selection is the direct result of the emergence, usually by chance, of a genotype *G*, which in turn positively affects fitness *W* through a chain of effects (Maynard Smith 1998; McElreath and Boyd 2007). The chain of effects is: genotype *G* influences psychological trait *P*, psychological trait *P* influences ancient task performance T_A, ancient task performance T_A influences survival success *S*, and survival success *S* influences fitness *W*. It can be shown that the product of the correlations between each of these pairs of constructs must be greater than zero for this evolution to take place (see Appendix F).

Evolved Psychological Traits in Modern Humans

The same genotype (*G*) and related psychological trait (*P*) that evolved in our evolutionary past can have an impact in the context of modern behavior toward technology, often affecting modern task performance in tasks where technology is used. However, that would not normally be related to the survival success or fitness of modern humans, because modern humans are no longer subject to the same selection pressures that our ancestors faced in our evolutionary past (Boaz and Almquist 2001; Buss 1999; McElreath and Boyd 2007).

For example, the psychological trait "attention to colors" could affect the performance of individuals in information search tasks using computer interfaces that employ various

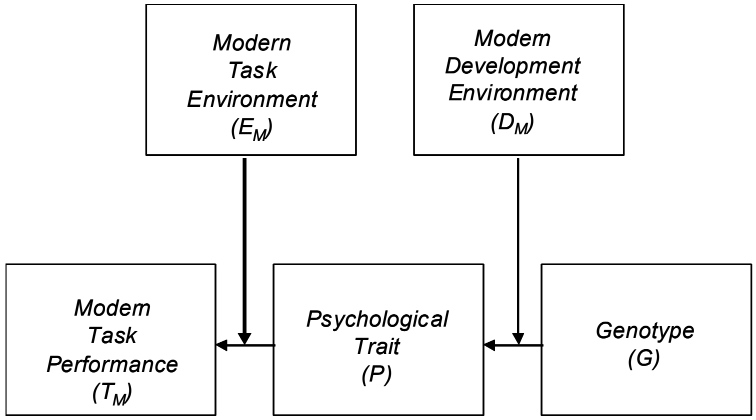

Figure 2. Evolved Psychological Traits in Modern Humans

colors, compared with interfaces that used no colors other than black and white. Yet, this psychological trait would have no impact on the survival success or fitness of modern humans.

Figure 2 depicts the process above. The genotype G influences the development of a psychological trait P, which in our example is attention to colors. This relationship is moderated by the modern development environment D_M, which is the environment surrounding modern humans in their formative years, as they develop from fertilized eggs to reproductively mature individuals.

The psychological trait P influences modern task performance T_M, which refers to the performance of an individual in a modern task such as searching for information using a computer interface. Individuals who possess the evolved psychological trait P (attention to colors), would have better T_M with a color-enabled computer interface than with a computer interface that displays only black and white objects.

Similarly to E_A's moderating effect on the relationship between P and T_A, the relationship between P and T_M is also moderated by a construct, namely the modern task environment E_M. This is the environment surrounding modern humans as they perform modern tasks. For example, a task environment E_M with poor lighting could negatively influence the relationship between P and T_M when compared with a well-lit environment, where P is attention to colors and T_M is the performance on a computer-based information searching task.

Building Evolutionary Information Systems Theories

What characterizes information systems theorizing based on evolutionary psychology is the search for an evolved psychological trait P, whose development is influenced by a genotype G, and for a technology-related impact on the performance of a modern task T_M. In these scenarios, the technology usually adds elements that help shape a modern task environment E_M in which the task is accomplished.

The main focus of evolutionary psychology theorizing is the relationship between genotype G and evolved psychological trait P (Barkow et al. 1992; Buss 1999), as indicated in Figure 3. On the other hand, the main focus of information systems theorizing based on evolutionary psychology is the relationship between an evolved psychological trait P and the performance of a modern task T_M, in a modern environment E_M. The modern environment E_M is shaped by technology created by modern humans, as well as by associated social structures aimed at technology appropriation (Bélanger and Watson-Manheim 2006; DeSanctis and Poole 1994).

If there is no evolved psychological trait P involved in the theorizing effort, and thus no assumption about the existence of a related genotype G, then the effort cannot be characterized as information systems theorizing based on evolutionary psychology. Two examples that illustrate this approach to theorizing are the development of media naturalness theory (Kock 2004, 2005), and the use by Hantula et al. (2008) of ancestral foraging theory to predict the behavior of online buyers.

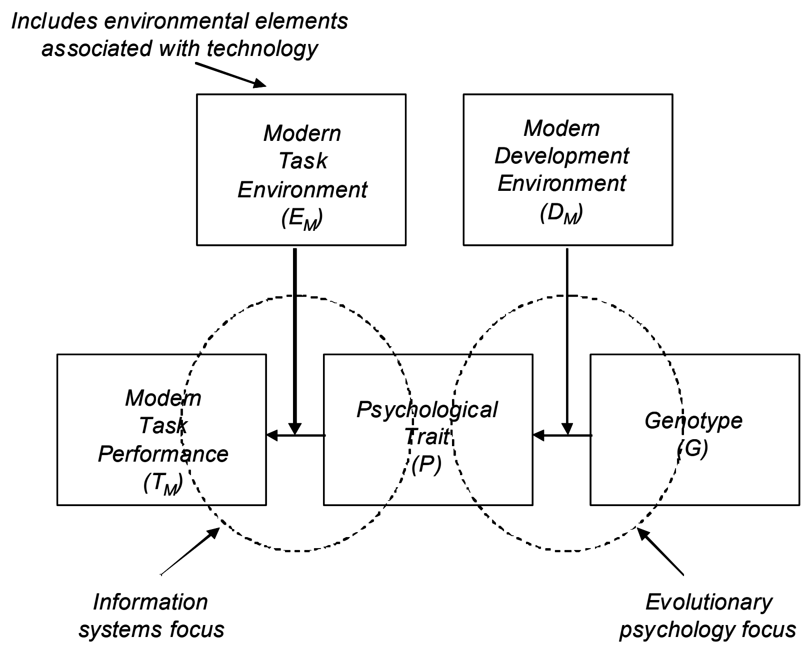

Figure 3. The Foci of Information Systems and Evolutionary Psychology Research

The development of media naturalness theory is an example of how evolutionary theorizing can be used to fill gaps left by a non-evolutionary theory. Media naturalness theory was developed to fill gaps arguably left by media richness theory (Daft and Lengel 1986; Daft et al. 1987). Those gaps were related to empirical findings suggesting the success of media richness theory in explaining users' perceptions about electronic communication media richness (Daft et al. 1987; Kock 2005), but not those users' actual choices of media (Markus 1994a) or task performance when using media of low richness (Kock et al. 2006).

The research conducted by Hantula et al. (2008) is an example of how evolutionary theorizing can be used to develop innovative and precise predictions of information systems phenomena. Hantula et al.'s research is based on ancestral foraging theory, and includes predictions about how modern humans make decisions in an online environment. Based on ancestral foraging theory, those researchers predicted that online buyers would react rather negatively to online in-stock verification delays. Their prediction was mathematically precise: the higher the delays, the lower would be the proportion of purchases and shopping times observed, following a hyperbolic decay function. Their empirical results provided strong support for their theoretical predictions, which are part of an evolving theoretical framework known as the behavioral ecology of consumption (Rajala and Hantula 2000; Smith and Hantula 2003).

Other Valid Forms of Evolutionary Theorizing Not Addressed Here

The discussion presented here does not cover all forms of information systems theorizing based on evolutionary psychology, or based on evolutionary thinking in general. Different evolutionary psychology outlets and institutions (see Appendix G) place emphasis on different forms of evolutionary theorizing. Attempting to cover all possible forms of information systems theorizing based on evolutionary psychology would increase the length of this paper beyond what would be acceptable. Particularly noteworthy are two valid forms of evolutionary theorizing that are not addressed here. The first is sexual selection theorizing, which builds on what is sometimes referred to as Darwin's (1871) *other* theory, or the theory of sexual selection (Miller 2000). The second is theorizing using evolution as a metaphor, which may be used to explain other types of evolution that are not biological but that appear to follow a process similar to that of biological evolution.

Theorizing based on sexual selection. Modern Darwinian evolutionary thinking builds on two main biological processes: natural selection (Darwin 1859), and sexual selection (Darwin 1871). In a nutshell, the first refers to evolution in connection with survival success, whereas the second refers to evolution in connection with mating success. In sexual selection, the selective pressures come not from the physical environment surrounding an individual, but from members of the opposite sex who find certain traits attractive. The classic example of sexual selection is that of the male peacock's train, which is actually a survival handicap (Petrie et al. 1991; Zahavi and Zahavi 1997).

Sexual selection has been used to explain the evolution of our appreciation of artistic expression, which in our evolutionary past would have little survival value (Miller 2000, 2001). This type of theorizing is fairly rare, and possibly nonexistent, in information systems. Sexual selection could be used to explain why the external design of computers is perceived by certain buyers as being fairly important, even though computers are primarily purchased for their functionality. Sexual selection is also associated with the emergence of sex differences, which have (the sex differences) often been the target of information systems theorizing, sometimes based on evolutionary arguments. For instance, Hubona and Shirah (2006) built on hunter–gatherer theory to argue that modern-day differences between men and women in spatial and cognitive abilities result from different roles played by our male and female hominid ancestors. They studied males and females performing visual spatial tasks using two- and three-dimensional virtual worlds, finding that females underperformed males in matching and positioning tasks, and outperformed males in resizing tasks. Analogous differences have been found in other studies (see, for example, Stenstrom et al. 2008). There are several difficulties associated with theorizing about sexual differences, which are discussed in Appendix H.

Theorizing based on evolution as a metaphor. Various transformative social processes involving individuals, groups, and organizations seem to progress in ways that are similar to the processes underlying biological evolution (McElreath and Boyd 2007; Price 1970; Wilson 2000). Examples are cultural or social evolution, individual learning, and organizational improvement. In cultural evolution, for example, units of cultural transmission, sometimes called memes, are hypothesized to be copied through imitation by individuals until they spread to a large number of individuals of a cultural group (Blackmore 1999, 2001; Dawkins 1990; Henrich 2004).

Information systems theorizing using evolution as a metaphor is fairly rare, and might have been nonexistent if it were not for the work of a few entrepreneurial scholars. Pioneering theoretical work in the field of information systems, using evolution as a metaphor, has been conducted by Porra (1999). That theoretical work shows fairly convincingly that the study of the evolution and organization of natural animal colonies can serve as a basis for the understanding of how information systems, organizations, and social institutions change. Following up on that work, Porra and Parks (2006) have proposed a broad model of sustainable virtual communities, largely based on the sustainability properties of natural animal colonies. Given the proliferation of virtual communities through new Internet-based social organizations, such as social networking sites and virtual worlds, this line of research seems to hold great promise as a basis for both practical applications and future theoretical work.

The Need to Integrate Evolutionary and Non-Evolutionary Theories

In many cases, evolutionary information systems theories will have to be integrated with non-evolutionary theories to fully explain certain information systems phenomena. There are four main reasons for this: (1) not all information systems phenomena have an evolutionary basis; (2) differences between ancient and modern tasks may prevent task-specific theorizing; (3) differences between ancient and modern task environments may prevent technology-specific theorizing; and (4) differences between ancient and modern development environments may prevent generation-specific theorizing.

Not all information systems phenomena have an evolutionary basis. While evolutionary psychology holds great promise as a basis for information systems theorizing, there are probably many facets of information systems phenomena that have no clear evolutionary basis. Evolutionary theorizing may lead to explanations and predictions of some facets of an information systems phenomenon, but not others, which calls for the integration of evolutionary information systems theories with non-evolutionary theories.

For example, one may be tempted to develop a fully evolutionary explanation of why flat keyboards are so widely used by individuals from different cultures. Yet, there has been no selective pressure in our evolutionary past in favor of flatness of typing surfaces. The task of typing is a very recent human invention, too recent to have shaped the morphology of our hands, or the design of our brain, in any significant way (Kock 2004). It would be possible to find a distant analogue of the task of typing in our evolutionary past, such as stone tool making (Boaz and Almquist 2001), but that would probably go only some way toward explaining the general flatness of modern typing surfaces. Moreover, past research suggested that the flat keyboard design is not the most optimal design from an ergonomics standpoint (Gilad and Harel 2000). The main conclusion one can reasonably reach based on that past research is that the flat design is quite widespread due to primarily being an efficient design from a manufacturing perspective.

Differences between ancient and modern tasks may prevent task-specific evolutionary theorizing. Building parallels between ancient task performance (T_A) and modern task performance (T_M) may be difficult due to differences in the tasks themselves. This makes it difficult to develop fully evolutionary theories to make predictions about some specific modern tasks. High level, or generic, tasks, such as the task of communicating knowledge, may be largely the same whether performed today or by our hominid ancestors (Miller 2000; Pinker 2003; Spink and Cole 2006; Wilson 2000). Low level, or more specific, tasks may be significantly different.

The task of communicating knowledge about foraging for a specific type of food was carried out in our evolutionary past (Boaz and Almquist 2001; Cartwright 2000) and is also carried out today in nonurban societies. On the other hand, the task of communicating knowledge about the design of a new car engine is carried out only by modern humans. Therefore, it is difficult to build a fully evolutionary theory of, say, electronic communication of knowledge about the design of new car engines. One could, however, build a fully evolutionary theory of electronic communication of knowledge (Kock 2004), and then integrate it with a non-evolutionary theory to explain various aspects of electronic communication of knowledge about the design of new car engines.

Differences between ancient and modern task environments may prevent technology-specific evolutionary theorizing. Modern task environments (E_M) frequently differ, sometimes significantly, from ancient task environments (E_A), and those differences are often due to the use of technology. While this may not prevent evolutionary theorizing in connection with high level, or generic, technologies, it may make it difficult to conduct evolutionary theorizing in connection with low level, or specific, technologies. Evolutionary psychological theories rely on predictions associated with Stone Age problems, and with how those problems have led to the development of brain mechanisms to deal with them in order to maximize reproductive success (Barkow et al. 1992; Buss 1995). A look back at our evolutionary past leads to the conclusion that our brain is probably designed for face-to-face communication, the mode of communication used by our ancestors during over 99 percent of our evolutionary history, where learning was an integral part of hominid survival and mating strategies (Boaz and Almquist 2001; Lieberman 1998; Wilson 2000). As a corollary, one can also conclude that our brain is probably maladapted for the use of communication media that suppress too many of the elements found in face-to-face communication in learning tasks.

Yet, when we look at the virtual environments created by online learning technologies, it is undeniable that electronic media are widely used by modern humans for online learning in universities and other education institutions (Summers et al. 2005). This would not be the case if the vast majority of the students who have taken courses online had failed them due to their brain being designed for face-to-face communication. The widespread use of electronic media for online learning allows students who live in rural areas, and also those who are unable to attend classes due to working full time, to obtain the education that they need to improve their lives. The existence of factors such as living in rural areas and working full time, which strongly influence the use of electronic communication technologies for online learning, is probably not best explained by evolutionary forces, if it can be explained at all in that way. This illustrates the need to integrate evolutionary and non-evolutionary theories to explain phenomena associated with use of a specific type of technologies, namely the technologies that shape online learning environments.

Differences between ancient and modern development environments may prevent generation-specific evolutionary theorizing. Differences between modern (D_M) and ancient (D_A) development environments may lead to differences in the way a genotype *G* influences the formation of a psychological trait *P*. This is likely to be especially true with different generations of individuals (e.g., baby boomers, generation X, generation Y). In fact, each new generation of modern humans may develop psychological traits somewhat differently, even though those traits may be coded for by the same genotype *G*. As a result, it may be very difficult to explain generation-specific information systems phenomena entirely based on evolutionary theorizing.

Except for some rare traits, such as blood type, the vast majority of human traits are the result of a complex interplay between genotypes and developmental influences (Boaz and Almquist 2001; Wilson 2000). Often events experienced during the early developmental stages of one's life have a fairly strong effect on behavior later in life (Chagnon 1977; Dunbar 1998; Wilson 2000). In those cases, the effects of genetic influences can and should still be studied, as they may shed light on intriguing patterns of behavior, but researchers must be mindful that developmental influences can also have a strong effect on behavior. The study by Kock et al. (2008) of surprise-enhanced cognition can be used to illustrate this.

Kock et al. (2008) provided an evolutionary explanation for the phenomenon associated with unpleasant, unexpected events causing enhanced cognition within their temporal vicinity, namely a few minutes before and after they occur. This is a well-documented phenomenon, sometimes referred to as flashbulb memorization (Brown and Kulik 1977; Nairne et al. 2007; Schutzwohl and Reisenzein 1999). Kock et al. argued that the reason for such enhanced cognition is that it was adaptive in our evolutionary past, because unpleasant, unexpected events (e.g., a snake attack) were often associated with survival threats in our evolutionary past, and those threats often occurred within predictable contexts (e.g., a snake's habitat) with clear markers such as specific terrain and rock formations.

For example, most animals seem to live in well-defined habitats, which were likely invaded by our human ancestors, as they generally are today in nonurban societies, a few minutes before and after the attacks (Hung 2004; Manipady et al. 2006). Therefore, having vivid memories associating an animal attack with habitat markers would have helped an ancestor avoid future animal attacks after the first was experienced (this assumes that animal attacks were not always fatal). This surprise-enhanced cognition notion was used to explain an unusual experimental finding in Kock et al.'s study. The inclusion of a Web page showing a large picture of a snake in attack position, in between Web pages with text-based knowledge content, led to a significant improvement in test scores on the content of the Web pages adjacent to the snake page.

However, studies of responses to surprise events of a social nature suggest that we tend to be much more surprised by events that affect the social group to which we are taught to belong, as we grow up, than other groups; for example, news of an invasion of our native country, as opposed to a country about which we have never heard (Berntsen and Thomsen 2005). Analogously, for the effect observed in Kock et al.'s study, that effect might not have been the same for individuals who were used to handling snakes from an early age, as those individuals might have been desensitized to the use of that type of stimulus as a source of unpleasant surprise. This illustrates the need to integrate evolutionary theories with non-evolutionary theories that incorporate influences associated with modern developmental environments (D_M) that shaped psychological traits of certain individuals, especially during childhood.

Integration of evolutionary and non-evolutionary theories may be only a first step in the development of progressively more comprehensive information systems theories. Once the integration of theories A (evolutionary) and B (non-evolutionary) is complete, it is possible that a new evolutionary theory C may be developed, where C encompasses A and B. However, there are a few good reasons to believe that evolutionary information systems theories will often have to be complemented by non-evolutionary theories. The continuously changing nature of information systems phenomena, often fueled by the development of ever new technologies, places constant pressure for the identification of theoretical frameworks to explain those new phenomena. New theories take time to develop, and existing non-evolutionary information systems theories far outnumber evolutionary ones, making the use of non-evolutionary theories almost inevitable in many theory-based information systems research investigations.

Integrating Evolutionary and Non-Evolutionary Theories: Four Important Preconditions

The discussion above provides arguments in favor of the integration of evolutionary and non-evolutionary theories of information systems phenomena. Fundamental epistemological contributions, such as those made by Popper (1992) and others (see, for example, Audi 2003; Stinchcombe 1968), suggest that for this integration to take place successfully some preconditions should be satisfied. It is argued here that there are four important preconditions: (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. For simplicity, the discussion presented here focuses on information systems theorizing that gravitates around the development of causal models (Bagozzi 1980; Davis 1985) depicting the relationships between independent, intervening, moderating, and dependent constructs (Kline 1998; Rosenthal and Rosnow 1991). Causal modeling can generally be used in information systems research employing various research approaches, data collection and analysis methods, and epistemologies (Davis 1985; Klein and Myers 1999; Orlikowski and Baroudi 1991).

The theories should refer to the same general type of task. Since the discussion is presented here in an information systems context, an object-oriented analogy (Chuang and Yadav 2000; Sircar et al. 2001) may help clarify this precondition for theoretical integration. This precondition is equivalent to saying that evolutionary and non-evolutionary theories should refer to the same task *class*, even though either theory may refer to a *subclass* of the task. Task performance attributes, such as task outcome quality and task performance efficiency, are frequently included in causal models as dependent constructs (Davis 1985; Rosenthal and Rosnow 1991). Therefore, without this precondition being satisfied, it could be difficult to identify task-related constructs that could serve as dependent constructs in a causal model depicting the complete theoretical framework including both evolutionary and non-evolutionary theories.

Our previous discussion provides a good example: one could build a fully evolutionary theory of electronic communication of knowledge (Kock 2004), and then integrate it with a non-evolutionary theory to explain various aspects of electronic communication of knowledge about the design of new car engines. In this example, both theories refer to the same task class, which could be seen as the task of electronic communication of knowledge. One of the theories refers to a subclass of this task, namely electronic communication of knowledge about the design of new car engines.

The theories should refer to the same general type of technology. Again using an object-oriented analogy, this precondition is equivalent to saying that evolutionary and non-evolutionary theories should refer to the same technology *class*, even though either theory may refer to a *subclass* of the technology. In information systems investigations, technology-related attributes such as the naturalness of an asynchronous electronic collaboration technology, are often included in causal models as independent constructs (DeLuca et al. 2006; Simon 2006). Therefore, without this precondition being satisfied, it could be difficult to identify technology-related constructs that could serve as independent constructs in a causal model depicting the complete theoretical framework.

Using the same example as above, a fully evolutionary theory of electronic communication of knowledge may be integrated with a non-evolutionary theory to explain various aspects of electronic communication of knowledge about the design of new car engines. Here both theories refer to the same technology class, namely the class of electronic communication technologies. While no technology subclasses are mentioned in this example, either theory might have referred to a subclass of electronic communication technologies, such as instant messaging technologies, which would not prevent theoretical integration.

The theories should comprise at least one similar theoretical construct. This precondition is closely related to the preconditions above. It is challenging to integrate two theories that refer to constructs that are very different, and a good indication of construct discrepancy is the inability to measure the constructs of the two theories in the same way or using the same instrument (Davis 1985; Popper 1992; Rosenthal and Rosnow 1991). This refers to constructs that are measured objectively (e.g., an individuals' age) or subjectively (e.g., perceived amount of knowledge communicated). The latter are usually referred to as latent constructs (Rencher 1998; Schumacker and Lomax 1996).

Let us refer again to the example of a fully evolutionary theory of electronic communication of knowledge being integrated with a non-evolutionary theory to explain various aspects of electronic communication of knowledge about the design of new car engines. In this example, one of the constructs that provide a bridge between the two theories is communication of knowledge, which could be measured in the same way for both theories through a latent construct. The latent construct in question could reflect the answers to a few question-statements related to the perceived amount of knowledge communicated, during a specific time interval, about the design of new car engines.

The theories should complement each other. In this precondition, complementing each other essentially means that the theories should add elements that enlarge a single causal model depicting the integrated theoretical framework. These elements can be new constructs or new relationships between constructs, in addition to the constructs and relationships of one or the other theory. The constructs here can be independent, intervening, moderating, or dependent; the relationships can be direct, indirect or moderating effects (Bagozzi 1980; Davis 1985; Kline 1998; Rosenthal and Rosnow 1991). Theories that are not complementary in this sense cannot be integrated, as they would lead to two or more separate causal models.

It should be noted that evolutionary and non-evolutionary theories that predict competing effects can still be seen as complementary, as long as the competing effects can be depicted in the same causal model. Let us assume that a fully evolutionary theory of electronic communication of knowledge predicts that electronic communication media in general decrease the performance in knowledge-intensive tasks of short duration. Let us also assume that a non-evolutionary theory developed to explain various aspects of electronic communication of knowledge about the design of new car engines predicts that electronic communication media in general *increase* the performance in knowledge-intensive tasks of long duration, such as the task of new car engine design. These two theories would still be complementary, because they can be combined in one single causal model, where the relationship between medium and task performance is moderated by task duration.

Integrating Evolutionary and Non-Evolutionary Theories in Practice: Richness Versus Naturalness of Electronic Media

This section provides a discussion and critical review of an evolutionary theorizing effort, and the integration of the resulting evolutionary theory with a non-evolutionary theory. The discussion starts with a review of media richness theory (Daft and Lengel 1986; Daft et al. 1987), and the identification of a theoretical gap associated with empirical findings that contradicted it. It then proceeds with the development of media naturalness theory (Kock 2004, 2005), in response to the theoretical gap left by media richness theory. The discussion then moves to recent attempts to overstretch the explanatory and predictive scope of evolutionary theorizing to overcome some limitations of media naturalness theory, and the proposal of a solution to overcome those limitations. That solution is the integration of media naturalness theory with a non-evolutionary theory, channel expansion theory (Carlson 1995; Carlson and Zmud 1999).

Media Richness Theory

Media richness theory (Daft and Lengel 1986; Daft et al. 1987) is an ingenious theory of organizational communication that makes predictions about behavior and outcomes in connection with various communication media. Electronic media are within the scope of media richness theory's predictions, even though the theory was originally developed well before the emergence of the Internet and the widespread use of electronic communication technologies that is seen today. Media richness theory is one of the most widely cited theories in the field of information systems (Dennis et al. 1999; Kahai and Cooper 2003; Kock 2005). In this theory, different media are classified according to their degree of richness, which varies depending on the degree to which media incorporate certain characteristics.

Four main characteristics define the richness of a medium, according to media richness theory. Two of them are given special prominence by Daft and Lengel (1986); they are the medium's ability to convey multiple communicative cues (e.g., facial expressions and voice intonations) and enable immediate feedback on the message being conveyed (a characteristic of synchronous communication). The other two are given less prominence by Daft and Lengel (see p. 560), who appear to imply that they either follow from or are related to the first two; they are the medium's support for language variety and personalization of messages. These four characteristics are evocative of unencumbered face-to-face interaction, although media richness theory does not explicitly use the face-to-face medium as a basis for richness comparisons. That is, media richness theory does not define rich media based on their degree of similarity to the face-to-face medium.

The notion of equivocal task is central to media richness theory. A task is equivocal when there are multiple interpretations of the problem that is being solved through the task (Daft and Lengel 1986; Daft et al. 1987). In equivocal tasks, complex knowledge, as opposed to simple pieces of information, must be exchanged in order for the task to be successfully accomplished (Speier et al. 2003). For example, the task of designing a new car engine with the goal of saving an ailing automaker plagued by decreasing revenues will most likely be an equivocal task. Conversely, the task of buying a commercially available metal pipe that will go into that new engine will probably not be an equivocal task.

In the context of equivocal tasks, media richness theory makes two main predictions (Daft and Lengel 1986; Daft et al. 1987). The first is essentially that effective communication media users will choose the richest possible media available to them. For example, an effective team developing a new car engine will probably, according to media richness theory, choose to communicate face-to-face instead of via e-mail if only these two media are available to them. The second prediction by media richness theory is that, when the choice of media is constrained (e.g., only e-mail is available), the use of a lean communication medium will lead to a corresponding degradation in task outcome quality. For example, if two teams are tasked with developing a new car engine and one communicates only face-to-face while the other communicates only via e-mail, then the theory's prediction is that the face-to-face team will develop a better car engine than the one developed by the e-mail team.

The above predictions may seem fairly intuitive and, at first glance, quite correct. However, there is a substantial amount of empirical evidence showing that individuals often choose lean media to carry out equivocal team tasks, and that the use of lean media often leads to the same or even better outcomes than if rich media were used (Bélanger and Watson-Manheim 2006; Burke and Aytes 2001; Crowston et al. 2007; Dennis and Kinney 1998; El-Shinnawy and Markus 1998; Hasty et al. 2006; Kock et al. 2006; Markus 1994a, 1994b; Ngwenyama and Lee 1997; Ocker et al. 1995). In other words, media richness theory has essentially been falsified multiple times.

In spite of the above, there is strong evidence that lean media do pose obstacles to communication in equivocal team tasks

(Burke and Chidambaram 1999; DeLuca et al. 2006; DeRosa et al. 2004; Graetz et al. 1998; Kahai and Cooper 2003; McKinney and Whiteside 2006; Simon 2006). This evidence is, to a certain extent, contradictory with the evidence that falsified media richness theory, and suggests the existence of a theoretical gap. Moreover, the finding that lean media pose obstacles to communication seems to be associated with a variety of different studies, and has even been reported in multicountry studies (Kock and DeLuca 2007; Tan et al. 1998; Wainfan and Davis 2004).

Media Naturalness Theory

Media naturalness theory (Kock 2004, 2005) is an evolutionary theory that was developed to address theoretical problems with media richness theory, which were brought to light by many focused empirical tests. One of those problems is that there is solid evidence that electronic media that suppress face-to-face communication elements do seem to pose communication obstacles in equivocal team tasks (DeLuca et al. 2006; Graetz et al. 1998; Kahai and Cooper 2003; Simon 2006). This finding may be seen as supporting media richness theory. However, media richness theorists provided an explanation for it, namely low medium richness, which is not well grounded on fundamental psychological mechanisms. The proponents of media richness theory seem to have assumed as a postulate that what they refer to as rich media present certain characteristics that make those media particularly well-suited to support communication in the context of equivocal tasks.

A simple thought experiment highlights this fundamental problem that plagues media richness theory. Let us assume that the human species evolved in an ancestral environment without light. If that were the case, modern humans would all be blind, and therefore a communication medium's ability to convey facial expressions and body language would be irrelevant for effective communication. Conversely, a medium's ability to convey smell might be fairly important for effective communication. This illustrates the fact that one cannot define a medium's ability to support effective communication without taking into consideration characteristics of the communicators. Of these, biological characteristics often have an evolutionary basis. (Since those biological characteristics are hypothesized to present a high degree of similarity across different people, one can call them media naturalness characteristics, even though they are not tied to the media, but rather to the biological design of humans. In this sense, one could argue that "media naturalness theory" is a misnomer, even though the theory is normally referred to in this manner; see Simon 2006.)

The problem highlighted by the thought experiment has been vital to the development of media naturalness theory. The lack of a solid scientific basis for media richness theory's predictions was akin to that created by the explanation that objects fall to the ground because they are attracted to it, which was consistent with the geocentric view of the universe proposed in the first century by the great mathematician and astronomer Ptolemy. This explanation would in fact be consistent with many observations of objects falling to the ground, perhaps in most modern everyday situations. However, this explanation would fail to account for some exceptions, relatively rare in modern everyday life, such as the behavior of objects in a free-falling airplane. It would also fail to explain more general cases that are not part of most people's daily routines, such as the observation of planetary orbits. In other words, even though it would be wrong, the explanation would appear intuitive and correct to most people.

More modern explanations of the phenomenon of objects falling to the ground, now known as gravitational attraction, were later provided by Isaac Newton and Albert Einstein. Those explanations were consistent with the behavior of objects in free-falling airplanes and with astronomical observations. The search for a more fundamental explanation to the phenomenon associated with the communication obstacles posed by non-face-to-face media led to the development of media naturalness theory, similarly but certainly on a vastly smaller scale than the theoretical developments by Newton and Einstein.

A relatively simple argument is at the core of media naturalness theory. The argument is that since our Stone Age hominid ancestors communicated primarily face-to-face, evolutionary pressures likely have led to the development of a brain that is consequently designed for that form of communication (Kock 2004, 2005). Other forms of communication are too recent and unlikely to have posed evolutionary pressures that could have shaped our brain in their direction (Boaz and Almquist 2001; Wilson 2000). Using communication media that suppress key elements found in face-to-face communication, as many electronic communication media do, thus ends up posing obstacles to communication. This is particularly the case in the context of equivocal tasks, because such tasks seem to require more intense communication over extended periods of time than non-equivocal tasks (Kock 2004).

As illustrated in Figure 4, it appears that the face-to-face medium has been the primary communication medium used during over 99 percent of the hominid evolutionary history that led to the emergence of the human species (Boaz and Almquist 2001; Cartwright 2000). During that time, our

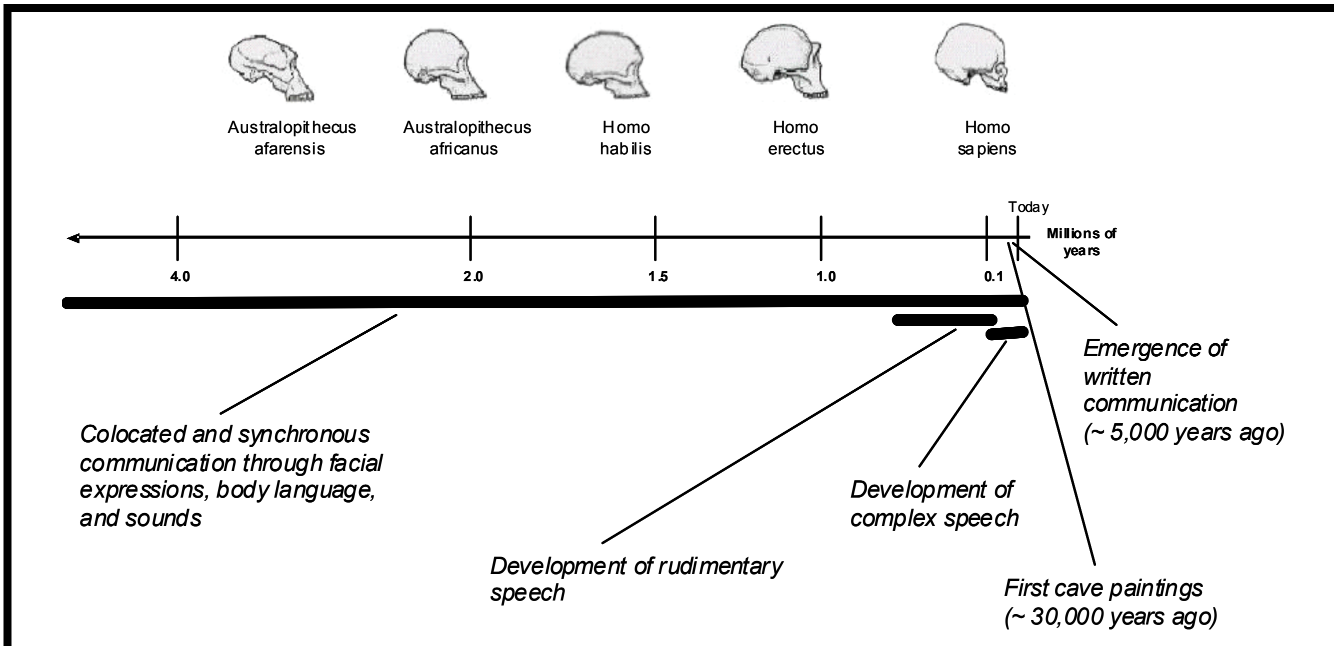

Figure 4. Communication Modes at Different Hominid Evolution Stages

ancestors developed several adaptations that seem obviously aimed at face-to-face communication employing speech and facial expressions. Among those adaptations are a larynx located relatively low in the neck and a customized vocal tract, which, combined with corresponding brain modules, allow us to generate the large variety of sounds needed to speak most modern languages (Laitman 1984; Laitman and Reidenberg 1997; Lieberman 1998). Another interesting adaptation is a very complex web of facial muscles, which allow humans to generate a large variety of communicative expressions, and whose main function seems to be primarily related to facial communication (Bates and Cleese 2001; McNeill 1998).

The naturalness of a communication medium is defined, in media naturalness theory, as the degree of similarity of the medium with the face-to-face medium (Kock 2004, 2005). The face-to-face medium is presented as the medium enabling the highest possible level of communication naturalness, which is characterized by the following five key elements: (1) a high degree of colocation, which would allow the individuals engaged in a communication interaction to see and hear each other; (2) a high degree of synchronicity, which would allow the individuals to quickly exchange communicative stimuli; (3) the ability to convey and observe facial expressions; (4) the ability to convey and observe body language; and (5) the ability to convey and listen to speech. (The ability to convey tactile stimuli or smell are not part of the definition of naturalness of a communication medium; some unique research results suggest that media naturalness theory could benefit from taking them into consideration; see, for example, Sallnas et al. 2000.)

Similarly to media richness theory, the main independent construct in media naturalness theory is the degree of naturalness of a communication medium. Unlike media richness theory though, the main dependent constructs of media naturalness theory do not refer to media choice or task outcome quality. They instead refer to the following attributes regarding the use of a medium to perform a collaborative task: (1) cognitive effort, reflected in perceptions regarding mental effort expended; (2) communication ambiguity, or the likelihood of misinterpretation of communication cues; and (3) physiological arousal, reflected in perceptions related to physical stimulation or excitement. Kock (2004, 2005) provides a detailed discussion of these constructs, and suggestions on how they can be measured. The main prediction of media naturalness theory is that, other things being equal, a decrease in the degree of naturalness of a communication medium leads to the following effects in connection with a collaborative task: (1) an increase in cognitive effort, (2) an increase in communication ambiguity, and (3) a decrease in physiological arousal.

Naturalness Versus Richness: Two Key Predictions

Some may feel inclined, based on the discussion above, to argue that media naturalness theory is too similar to media richness theory, even though it has a different theoretical basis and different dependent constructs. There are two key predictions, however, that illustrate the fundamental differences between the two theories. The first is in connection with the place of face-to-face communication in the naturalness or richness scale (Kock 2004, 2005). The second is in connection with what is referred to as the speech imperative proposition (Kock 2004).

The place of face-to-face communication. Media naturalness theory predicts that any electronic communication medium allowing for the exchange of significantly less *or more* communicative stimuli per unit of time than the face-to-face medium will pose cognitive obstacles to communication (Kock 2004, 2005). In other words, media naturalness theory places the face-to-face medium at the center of a one-dimensional scale of naturalness, where deviations to the left or right, so to speak, are associated with decreases in naturalness. Media richness theory, on the other hand, leaves the door open for the assumption that certain media can be higher in richness than the face-to-face medium. It does so because its focus is on the physical properties of the communication medium (Daft and Lengel 1986), and not on the biological constraints on the communicators using the medium, which is the focus of media naturalness theory. For example, a virtual reality medium that enables individuals to interact with more than one individual at the same time, without the interlocutors knowing, could be classified as richer than the face-to-face medium (Kock 2004), based on media richness theory.

Electronic media that enable the exchange of significantly *more* communicative stimuli per unit of time than the face-to-face medium are classified by media naturalness theory as having a lower degree of naturalness than the face-to-face medium (Kock 2005). As such, those media are predicted to be associated with higher cognitive effort; in this case due primarily to a phenomenon known as information overload (Kock 2004), which is characterized by individuals having to process more communicative stimuli than they are able. This phenomenon may also happen with the use of electronic media that are significantly simpler than virtual reality media. The electronic communication media created by group decision support systems, which are systems that allow groups of users to exchange large amounts of textual information without the need to share airtime as in face-to-face meetings, have been shown to induce a certain amount of information overload (see Dennis 1996).

The speech imperative proposition. Complex speech was enabled by the evolution of a larynx located relatively low in the neck (Laitman 1993; Lieberman 1998), which considerably increased the variety of sounds that our species could generate; this is actually one of the most important landmarks in the evolution of the human species. However, that adaptive design also significantly increased our ancestors' chances of choking on ingested food and liquids, and suffering from aerodigestive tract diseases such as gastroesophageal reflux (Laitman and Reidenberg 1997). This leads to an interesting conclusion, which is that complex speech must have been particularly important for effective communication in our evolutionary past, otherwise the related evolutionary costs would prevent it from evolving through natural selection. This argument is similar to that made by Zahavi and Zahavi (1997) in connection with evolutionary handicaps. If a trait evolves to improve the effectiveness in connection with a task, in spite of imposing a survival handicap, then the trait should be a particularly strong determinant of the performance in the task to offset the costs it imposes.

Media naturalness theory builds on this evolutionary handicap conclusion to predict that the degree to which an electronic communication medium supports an individual's ability to convey and listen to speech is particularly significant in defining its naturalness (Kock 2004). Media naturalness theory predicts, through its speech imperative proposition, that speech enablement influences naturalness significantly more than a medium's degree of support for the use of facial expressions and body language. This prediction is consistent with past research showing that removing speech from an electronic communication medium significantly increases the perceived mental effort associated with using the medium to perform knowledge-intensive tasks (see Graetz et al. 1998). This prediction could not have been derived from media richness theory.

Overstretching the Evolutionary Argument

While media naturalness theory provides what one could call deep-level explanations for some key findings in the electronic communication literature, its predictions do not address task outcomes. This is a problem because predictions about task outcomes are often very relevant in information systems research, as they provide the basis on which practical implications for information systems users can be developed (Baskerville and Myers 2002; DeSanctis and Poole 1994; Easley et al. 2003; Fjermestad 2004; Straub and Karahanna 1998; Zigurs and Buckland 1998).

Let us take the case of online delivery of university courses as an example. Media naturalness theory allows for the prediction that students taking a course through an online delivery medium will have different, and possibly more negative, perceptions about their experience than students taking the same course face-to-face. Any online course delivery medium, even a very sophisticated one, will present a lower degree of naturalness than the face-to-face medium. Therefore, students in the online medium are predicted by media naturalness theory to experience higher levels of cognitive effort and communication ambiguity, and lower levels of physiological arousal.

What media naturalness theory cannot predict is whether the students taking the course online will learn less than, more than, or the same as the students taking the course face-to-face. This is an important type of prediction in the context of online learning (Summers et al. 2005), which like face-to-face learning is a highly equivocal task that involves intense communication and knowledge exchange over an extended period of time. At first glance, one could argue that more cognitive effort and communication ambiguity, combined with less excitement, is very likely to lead to impaired learning performance. Yet, media naturalness theory does not allow for that type of conclusion because there may be other influences that compete with naturalness and that contribute to improved learning performance (Kock 2005).

Even with the obstacles posed by electronic communication media in general, it is undeniable that the use of those media for course delivery is widespread and growing (Newlin et al. 2005; Summers et al. 2005). It would be surprising if that proliferation was taking place in spite of evidence that online delivery had a negative impact on student learning. In fact, much of the evidence from studies in which performance is measured through course grades obtained by students suggests that online delivery has no negative impact on learning outcomes (Newlin et al. 2005). The impact is not positive either; it seems to be generally neutral, which is still seen as an encouraging finding since online delivery allows students with time or geographic constraints or physical disabilities to attend university courses virtually. This has led to a rather optimistic view of online delivery of university courses that became known as the "no significant difference" perspective (Summers et al. 2005).

Since online learning is a task with peculiarities that make it rather different from ancestral learning tasks, the above findings would call for the integration of media naturalness theory with an appropriate non-evolutionary theory as a first step to better explaining them. In spite of that, media naturalness theory has not yet been integrated with any non-evolutionary theory that could have complemented it. Instead, it has been expanded to incorporate another phenomenon, namely that of compensatory adaptation (Kock et al. 2006, 2007), which is also presented as having an evolutionary basis.

Compensatory adaptation is presented as a general brain mechanism, or a mental meta-module, that is associated with the rewiring of the brain's neocortex whenever obstacles are posed to an individual carrying out a task. The evolutionary relevance of compensatory adaptation is presented on the basis that our hominid ancestors faced a number of task-related obstacles for which specialized adaptation would have been impractical. Therefore, a general mechanism such as compensatory adaptation should have been favored by natural selection (Cartwright 2000; Kock et al. 2007); particularly in the Pleistocene, the period in which *Homo sapiens* is believed to have emerged (Boaz and Almquist 2001).

While appealing and perhaps generally correct, the compensatory adaptation argument goes too far in a strictly evolutionary theorizing path in this case. Attempts to overstretch the limits of evolutionary theorizing may face some key challenges, such as that the tasks carried out by and task environments surrounding our hominid ancestors were often much different from the ones in connection with modern humans. Presumably natural selection shaped human morphology, physiology, and behavior to deal with tasks routinely carried out by our human ancestors. Those tasks involve mating, foraging, hunting, and socializing. Learning about computer topics (Kock et al. 2007) and developing new products (Kock et al. 2006) are too dissimilar from tasks performed routinely by our ancestors. Invoking general adaptive mechanisms, such as compensatory adaptation, to overcome this task dissimilarity problem is likely to only weaken the predictive and explanatory power of any related theoretical model. The reason is that such invocation and related hypotheses are difficult if not impossible to falsify.

The above argument can be illustrated through a critical review of the study reported by Kock et al. (2007), which was conducted in the context of an online learning task. The study builds on the analysis of mid-semester and final grades obtained by two groups of students taking the same course with the same instructor, with the difference that one group took the course online and the other face-to-face. One of the main findings of the study was that while grades at the middle of the semester were lower in the online than in the face-to-face condition, the difference disappeared at the end of the semester. Compensatory adaptation was invoked to explain that finding, even though the notion of compensatory adaptation is so general that it could also have been invoked to explain: (1) compensatory adaptive reactions leading to any increase in grades online between the middle and end of the semester, even if the increase had not led the online grades to catch up with the face-to-face grades at the end of the semester, and (2) a strong compensatory adaptive reaction that led the students in the online condition to obtain grades that were significantly better at the end of the semester than those in the face-to-face condition.

Integration with Channel Expansion Theory

A critical analysis of the compensatory adaptation notion suggests that it can be invoked to explain various changes in grades, including the change in grades observed in the study by Kock et al. (2007). In other words, compensatory adaptation theory is not very amenable to falsification in this type of context, which may impair its usefulness as a piece of a larger theoretical model addressing related information systems phenomena (Popper 1992).

One theory that is compatible with the change in grades observed in the study by Kock et al. (2007) is channel expansion theory (Carlson 1995; Carlson and Zmud 1999), a non-evolutionary theory. A key prediction of channel expansion theory is that continued use of a lean (or unnatural, in media naturalness theory's terminology) communication medium over time, with the same individuals and to perform the same task, will lead to an expansion of what is called the channel capacity of the medium. In their explanation of the channel expansion phenomenon, Carlson and Zmud (1999, p. 157) note that:

> As individuals develop experience communicating with others using a specific channel, such as e-mail, they may develop a knowledge base for more adroitly applying this communication channel ….For example, e-mail users may become aware of how to craft messages to convey differing levels of formality or of how to use channel-specific metalanguage to communicate subtleties. Similarly, these individuals are also likely to interpret messages received on this channel more richly because they can interpret an increasing variety of cues.

In order words, users of an unnatural medium are predicted to possibly become better at communicating through the medium over time to perform a specific task. This could explain the "no significant difference" effect in connection with the use of online course delivery media, since students normally have a full semester to adapt to an online delivery medium and the instructor's style of use of the medium for communication. Therefore, channel expansion theory can be seen as a good complement to media naturalness theory.

Channel expansion theory also allows for a much more specific prediction, which is that average grades in the online and face-to-face conditions would converge as the semester progresses. This is exactly what happened in the study by Kock et al. (2007). In fact, the grades at the end of the semester were on average lower than grades in the middle of the semester, for both the online and face-to-face conditions; the key change observed was that the differences in grades between conditions were significant in the middle of the semester and insignificant at the end of the semester. In this case, a non-evolutionary theoretical proposition (i.e., channel expansion) provides a better complement to an evolutionary proposition (i.e., media naturalness) than yet another evolutionary proposition (i.e., compensatory adaptation). The non-evolutionary theoretical proposition provides a better theoretical "glue," so to speak, with which one can integrate (1) predictions from a theoretical model developed based on ancient human behavior with (2) predictions about human behavior in connection with modern tasks.

The integration of the media naturalness and channel expansion theories is facilitated by channel expansion theory referring to media richness, or channel richness, in a way that makes it interchangeable with media naturalness. If channel expansion theory referred to richness in a way that implied that super-rich virtual reality media would be even more natural than the face-to-face medium, then it would be difficult to integrate the media naturalness and channel expansion theories in the context of use of such super-rich virtual reality media. An example of a super-rich virtual reality medium would be a medium that enabled individuals to interact with more than one individual at the same time, without the interlocutors knowing, thus potentially enabling the exchange of significantly more communicative stimuli than the face-to-face medium. According to media naturalness theory, such a super-rich virtual reality medium would be less natural than face-to-face communication. In this case, the integration would probably not be impossible, but one theory or the other would have to be amended prior to their integration.

Discussion

As can be inferred from the discussion above, the theories of media naturalness and channel expansion can be integrated to provide a more reasonable predictive and explanatory framework within which Kock et al.'s (2007) empirical findings can be understood. This section provides a conceptual link between the above discussion and the earlier discussion on information systems theorizing based on evolutionary psy-

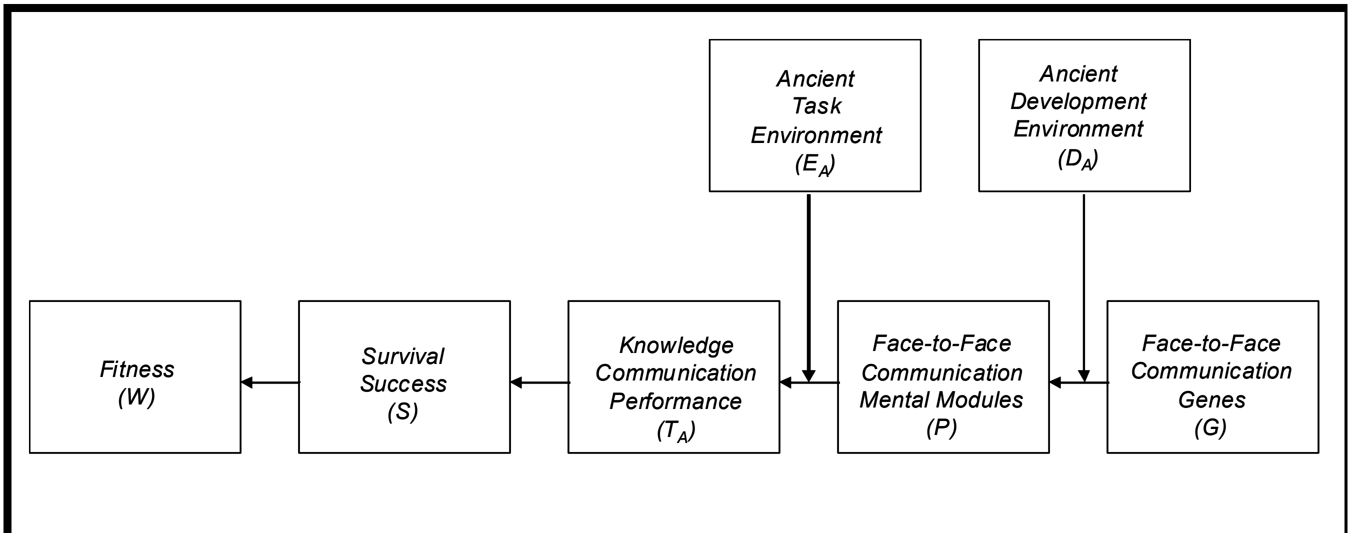

Figure 5. Evolution of Face-to-Face Communication Mental Modules Through Natural Selection

chology, the need to integrate evolutionary and non-evolutionary theories, and the four preconditions for integrating evolutionary and non-evolutionary theories.

Figure 5 shows the elements involved in the evolution of face-to-face communication modules, and thus face-to-face media naturalness, in our ancestral past. The genotype *G* is indicated as "Face-to-face communication genes," which is the configuration of genes that coded for a brain design optimized for face-to-face communication. The genotype *G* coded for the general psychological trait *P*, indicated as "Face-to-face communication mental modules," which were the mental modules designed for face-to-face communication. The trait *P* positively influenced the ancient task performance T_A, indicated as "Knowledge communication performance," which was the performance in the high level task of communicating knowledge. The ancient task performance T_A positively influenced survival success *S*, which in turn positively influenced fitness *W*. Over many generations, the genotype *G* spread to the point of being largely observed among modern humans. So did the psychological trait *P*. The relationship between *G* and *P* was moderated by the ancient development environment D_A, and the relationship between *P* and T_A was moderated by the ancient task environment E_A.

Why was knowledge communication performance (T_A) positively associated with survival success (*S*) in our evolutionary past? The reason is that it enabled ancient humans to occupy what Pinker (2003) called the cognitive niche, which was as yet unoccupied by other species. Knowledge communication enabled our ancestors to make predictions about events that were likely to affect their survival without having to experience those events. This placed our human ancestors at a tremendous advantage compared with most other animal species, even those species with relatively large brains such as apes, because those other species had to generally live through or directly observe survival threats to learn how to avoid them (Pinker 1994; Wilson 2000). The ability to communicate knowledge, which is highly and uniquely developed in humans, allowed our ancestors to avoid survival threats, and also engage in survival-enhancing behaviors, simply by learning about them from other individuals. This likely coevolved with many socialization drivers that are believed to have also been the result of selection, and that led our ancestors to congregate in increasingly larger and more complex social groups (Boaz and Almquist 2001; Cartwright 2000). One of the most fundamental of those socialization drivers is the universal human instinct called reciprocal altruism (McElreath and Boyd 2007; Trivers 2002), without which our ancestors would be disinclined to share knowledge with one another.

Figure 6 shows how the evolution of face-to-face communication modules plays a role in the modern task of online learning investigated in the study by Kock et al. (2007). The genotype *G* is indicated as "Face-to-face communication genes"; *G* codes for the general psychological trait *P*, indicated as "Face-to-face communication mental modules." The relationship between *G* and *P* is moderated by the modern development environment D_M. The trait *P* negatively influences T_M, indicated as "Online learning performance," since the trait *P* is optimized for face-to-face communication.

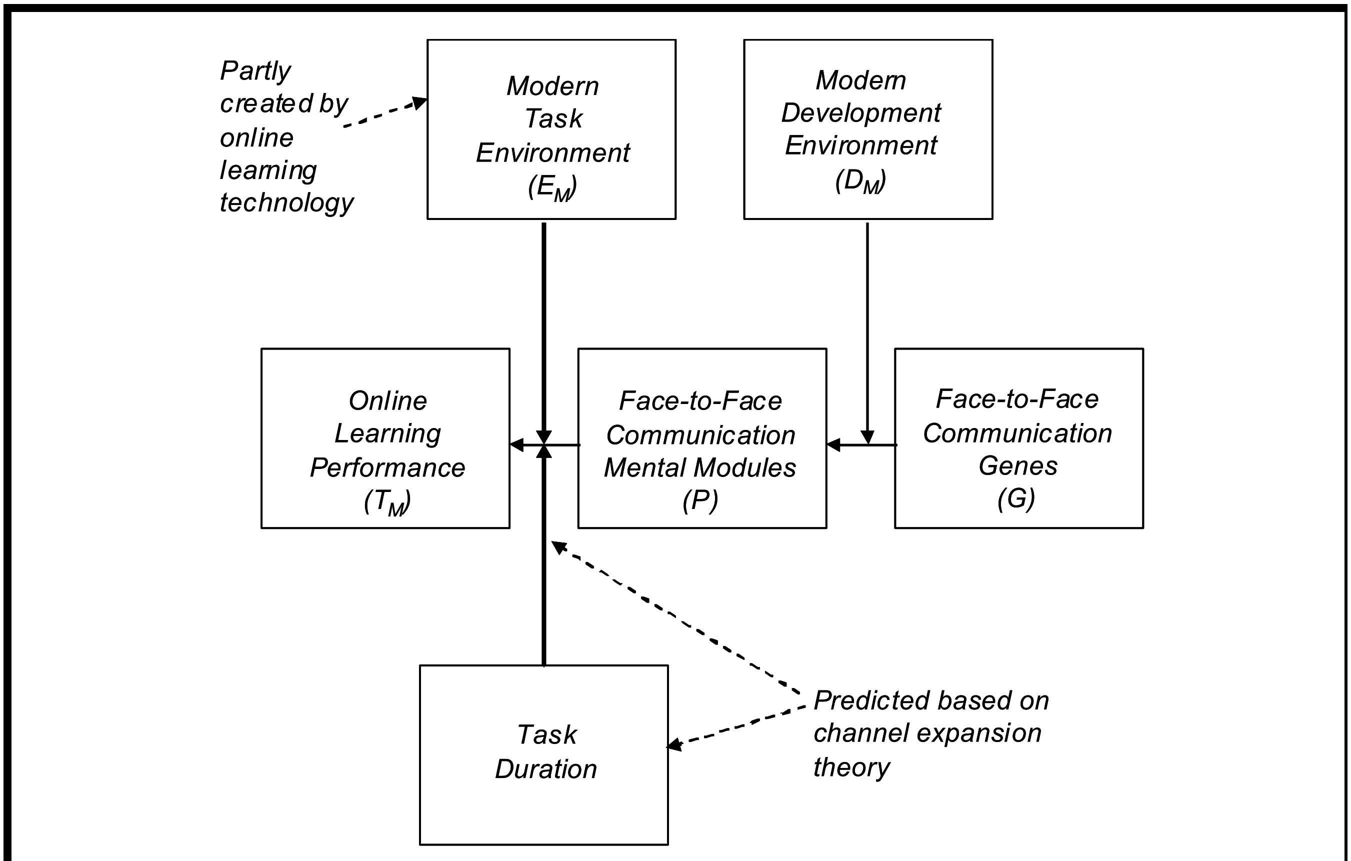

Figure 6. Evolved Face-to-Face Communication Mental Modules and Online Learning

The relationship between P and T_M is moderated by the modern task environment E_M, which is partly created by the online learning technology. The more the technology suppresses face-to-face communication elements, the stronger the negative relationship between P and T_M. The moderating effect predicted based on channel expansion theory is indicated at the bottom as "Task duration." Channel expansion theory allows for the prediction that the longer is the task, the weaker is the negative effect of P on T_M.

Table 1 illustrates how the media naturalness and channel expansion theories fit in terms of the four preconditions for integration discussed earlier. The two theories refer to the same general type of task, the task of electronic communication of knowledge; both theories allow for predictions regarding this general task. The two theories refer to the same general type of technology, electronic communication technology; both theories allow for predictions regarding this general technology. The two theories comprise at least one similar theoretical construct, namely media naturalness; channel expansion actually refers to media richness, but in a way that makes it interchangeable with media naturalness. Finally, the two theories complement each other. Media naturalness predicts that face-to-face communication modules (P) have the potential to negatively affect online learning performance (T_M). Channel expansion theory provides a moderating effect complement by supporting the prediction that this relationship between P and T_M is weakened as task duration increases.

The discussion above illustrates the integration of the media naturalness and channel expansion theories in the context of online learning. In different contexts, such as virtual new product development (Kock et al. 2006) and virtual team leadership (DeRosa et al. 2004), other non-evolutionary theories may be needed to complement media naturalness theory.

It is possible that the media naturalness and channel expansion theories will be subsumed within a broader evolutionary

Table 1. Integrating the Media Naturalness and Channel Expansion Theories

Precondition for Integration	Description	Explanation
Same general type of task	The task of electronic communication of knowledge	Both the media naturalness and channel expansion theories allow for predictions regarding the general task of electronic communication of knowledge.
Same general type of technology	Electronic communication technology	Both the media naturalness and channel expansion theories allow for predictions regarding the same general type of technology: electronic communication technology.
Similar theoretical construct	Media naturalness	Both the media naturalness and channel expansion theories refer to a similar theoretical construct: media naturalness. Channel expansion actually refers to media richness, but in a way that makes it interchangeable with media naturalness.
Theories complement each other	Task duration moderates the relationship between P and T_M	Media naturalness predicts that face-to-face communication mental modules (P) have the potential to negatively affect online learning performance (T_M). Channel expansion theory provides a complement by supporting the prediction that this relationship between P and T_M is weakened as task duration increases.

theory as the result of future theoretical efforts. This will happen as long as the phenomenon Carlson and Zmud (1999) called channel expansion can be fully explained from an evolutionary perspective. Once that is achieved, if it is achieved at all, the resulting naturalness-expansion theory can be used as a basis for integration with other non-evolutionary theories as needed, in a progressive process of theory development and integration (Popper 1992) that is not unlike that underlying the evolution of social theories (Stinchcombe 1968). Appendix I outlines a set of four sequential steps that information systems researchers may find useful in related theorizing efforts.

Conclusion

Hopefully the framework for information systems theorizing based on evolutionary psychology and theoretical integration put forth here will serve as a guide for information systems researchers, especially those interested in understanding how evolved brain modules and mechanisms may influence human behavior toward technology. The use of the framework was partially illustrated here through one main example in connection with theorizing about human behavior toward communication media. While much of the discussion focuses on electronic communication studies, one main contention made here is that the framework can be used in a wide variety of theory development efforts in the field of information systems.

The framework proposed here is likely to be particularly useful in efforts aimed at developing theories that explain and predict universal behavior of humans toward technology. The emphasis of the framework is on behavior that is likely to be observed in all human beings regardless of possible differences between subgroups, even small genetic differences (e.g., men and women). Media naturalness theory is a good example of this type of theory development effort. These theories would apply to both men and women, whose genetic differences are likely to influence certain types of behavior but not others. For instance, men and women have been shown to differ significantly in their mate search and selection patterns (Buss 1995; Miller 2000), which would naturally lead to different theoretical predictions regarding certain types of technology-related behavioral patterns such as those in online dating contexts.

The discussion of the integration of evolutionary and non-evolutionary information systems theories put forth here also opens up a new line of theoretical inquiry for information systems researchers. This new line of inquiry relates to the integration of different information systems theories into theoretical models that are amenable to rigorous empirical testing. Examples are provided in the context of communication media issues, which are issues that have been gaining increasing attention over the years, and are among the most intensely investigated among information systems researchers (Dennis et al. 1999; Te'eni 2001; Watson-Manheim and Bélanger 2007). With a few notable exceptions (for example, Trevino et al. 2000; Watson-Manheim and Bélanger 2007;

Webster and Trevino 1995), different communication media theories rarely have been integrated into testable models.

It may seem at first glance that the discussion presented here is only of academic value, but industry practitioners can benefit greatly (although indirectly) from theory development efforts conducted through the framework and related information technology developments. The emergence of the Internet and the global economy are two key reasons for that, because they create a central challenge for most organizations. The challenge is that of having to sell goods and services, using electronic interfaces, to buyers from a wide variety of backgrounds and cultures. The main common denominator among those buyers is their human nature. In spite of increasing efforts toward personalization of interfaces, many of which are undeniably successful, designing interfaces for electronic commerce that build on human universals is likely to be a fundamental part of the solution to the challenge of selling goods and services to geographically disperse and culturally diverse buyers.

In addition to providing a guide for researchers interested in developing new information systems theories based on evolutionary psychology, another obvious goal here is to stimulate this type of theorizing among researchers who have not considered it yet. However, a note of caution, already discussed as part of the framework, needs to be emphasized. Information systems phenomena are unlikely to be always fully explained based only on evolutionary psychology notions. Thinking otherwise would probably do more harm than good for the field of information systems, as it has been the case elsewhere.

History has taught us (on a much broader scale) that a blind belief in deterministic evolutionary explanations and predictions of human behavior can lead to many problems. After all, that blind belief was at the source of once influential schools of thought such as race-based eugenics and social Darwinism, which in turn formed the basis for the development of ideas that led to racism, wars, and genocide. Evolutionary explanations of behavior, including behavior toward technology, must be developed cautiously and fully tested before they are accepted and used in practice. Moreover, their results should be used only to the extent that they are compatible with the highest standards of ethics, morality, and concern for the well being of all human beings.

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About the Author

Ned Kock is a professor of Information Systems and director of the Collaborative for International Technology Studies at Texas A&M International University. He holds degrees in electronics engineering (B.E.E.), computer science (M.S.), and management information systems (Ph.D.). Ned has authored and edited several books, including the bestselling *Systems Analysis and Design Fundamentals: A Business Process Redesign Approach* (Sage Publications). He has published his research in a number of high-impact journals including *Communications of the ACM*, *Decision Support Systems*, *European Journal of Information Systems*, *European Journal of Operational Research*, *IEEE Transactions (various)*, *Information and Management*, *Journal of the Association for Information Systems*, *MIS Quarterly*, and *Organization Science*. He is the founding editor-in-chief of the *International Journal of e-Collaboration*, an associate editor for Information Systems for *IEEE Transactions on Professional Communication*, and an associate editor for *Journal of Systems and Information Technology*. His main research interests are biological and cultural influences on human–technology interaction, electronic communication and collaboration, action research, ethical and legal issues in technology research and management, and business process improvement.

MIS Quarterly

THEORY AND REVIEW

INFORMATION SYSTEMS THEORIZING BASED ON EVOLUTIONARY PSYCHOLOGY: AN INTERDISCIPLINARY REVIEW AND THEORY INTEGRATION FRAMEWORK[1]

By: **Ned Kock**
Division of International Business and Technology Studies
Texas A&M International University
5201 University Boulevard
Laredo, TX 78041
U.S.A.
nedkock@tamiu.edu

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 if 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 20^{th} Century. Hamilton conducted pioneering research based on the gene-centric view of evolution, also know 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 EES 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 EES 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 (EES). As noted above, the EES 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 the 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 posses 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 of 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; Nunnaly 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).

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

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.

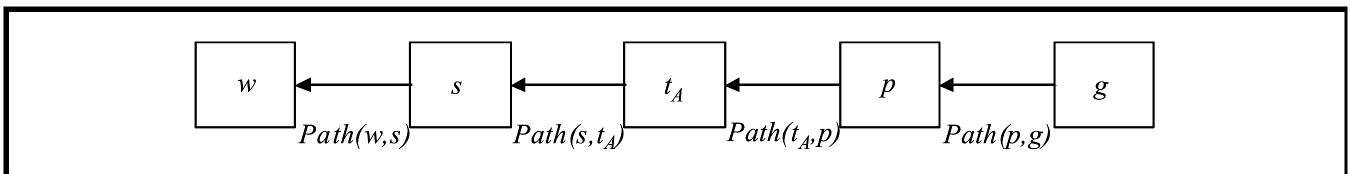

Figure F1. Path Model

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).

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

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).

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

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.ehbonline.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/

  M-Squared Research Group at McMaster University, Canada
  http://psych.mcmaster.ca/dalywilson/

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 mass, 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.

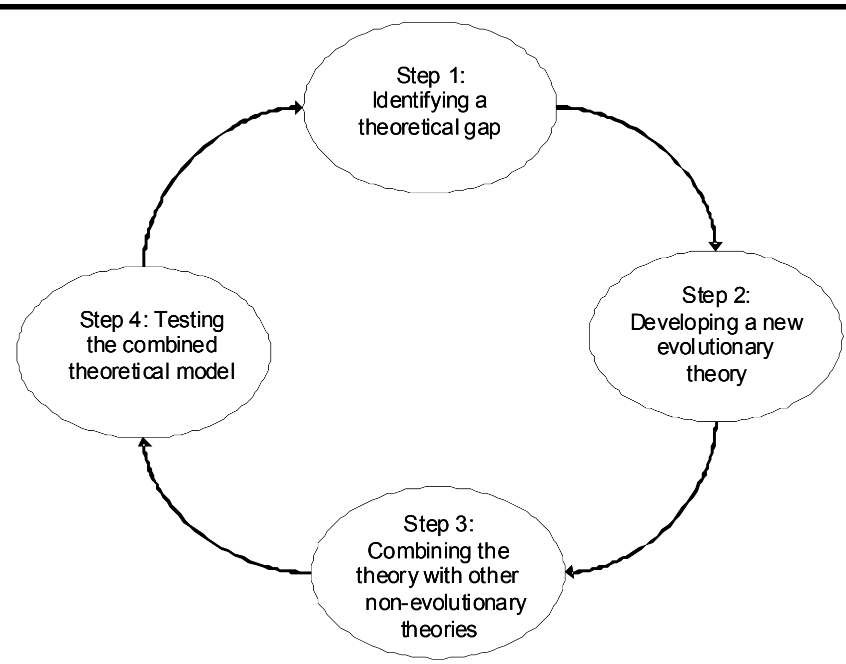

Figure I1. The Four Steps as Part of a Theory Development Cycle

This page is maintained by Jan DeGross (degro003@umn.edu). It was last updated October 28, 2008.