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The Psychobiological Model: Towards a New Theory of Computer-Mediated Communication Based on Darwinian Evolution

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This article reviews theories of organizational communication with a special emphasis on theories that have been used to explain computer-mediated communication phenomena. Among the theories reviewed, two—social presence and media richness—are identified as problematic and as posing obstacles to future theoretical development. While shortcomings of these theories have been identified in the past, some of these theories' predictions have been supported by empirical evidence. It is argued that this theoretical dilemma can be resolved based upon principles derived from a modern version of Darwin's theory of evolution by natural selection and the application of those principles to the understanding of human evolution. A new theoretical model called the psychobiological model is developed, which predicts variations in cognitive effort in computer-mediated collaborative tasks. The model proposes that there is a negative causal link between the "naturalness" of a computer-mediated communication medium, which is the similarity of the medium to the face-to-face medium, and the cognitive effort required from an individual using the medium for knowledge transfer. The model also states that this link is counterbalanced by what are referred to as "schema alignment" and "cognitive adaptation." The schema alignment construct refers to the similarity between the mental schemas of an individual and those of other participant(s). The cognitive adaptation construct refers to an individual's level of schema development associated with the use of a particular medium. Finally, the model states that the degree to which the medium supports an individual's ability to convey and listen to speech is particularly significant in defining its naturalness, more so than the medium's degree of support for the use of facial expressions and body language. An example is offered of how the psychobiological model can be tested in the context provided by the customer support area of an online broker.

Key words: computer-mediated communication; communication media; media richness theory; schema theory; human evolution

Introduction

Some of the most significant turning points in human civilization have been marked by technological innovations that have increased our ability to store, transport, and communicate information and knowledge. From cave paintings to the printing press to e-mail, innovations in communication technologies have significantly changed how we interact with others and with whom we interact. Modern communication technologies that rely on the processing power of computers challenge conventional notions of media and its use. It is estimated that there are hundreds of millions of Internet users creating entirely new social situations and communication behaviors. The use of communication technologies for work is commonplace today. Computer-mediated communication (CMC) is becoming an integral part of our lives at work and at home.

The impact of CMC at work has been the target of intense research, particularly since the 1990s; this interest follows earlier studies that address communication in organizations (for excellent reviews see, e.g., Deacon et al. 1999, Trevino et al. 2000). Part of this research tradition has followed a theoretical orientation that would appear to be at odds with the increasingly widespread use of CMC. That theoretical orientation builds on the assumption that face-to-face communication possesses inherent characteristics that make it more appropriate than other media, particularly media that suppress too many of the face-to-face communication elements, for conducting a variety of collaborative tasks. This has led to the conclusion that the use of electronic communication media that usually do not incorporate all of the elements present in the face-to-face communication medium (e.g., synchronicity and ability to convey tone of voice and facial expressions) often leads to decreased quality of outcomes of collaborative tasks. Two theories aligned with this theoretical notion are social presence theory (Short et al. 1976) and media richness theory (Daft and Lengel 1986, Daft et al. 1987).

The Social Presence and Media Richness Theories

Short et al. (1976) proposed the social presence theory at a time when the Internet as we know it today was yet to be conceptualized, let alone implemented. In spite of that, the theory has influenced much CMC research over the years (Sallnas et al. 2000). This theory classifies different communication media along a one-dimensional continuum of "social presence," where the degree of social presence is equated to the degree of "awareness" of the other person in a communication interaction. According to social presence theory, communication is effective if the communication medium has the appropriate social presence required for the level of interpersonal involvement required for a task. On a continuum of social presence, the face-to-face medium is considered to have the most social presence, whereas written, text-based communication has the least.

Daft and Lengel's (1986) media richness theory, similarly to the social presence theory, classifies communication media along a continuum of "richness," where richness is based on the ability of media to carry non-verbal cues, provide rapid feedback, convey personality traits, and support the use of natural language (see also Daft et al. 1987). The conceptualization of "richness" can be seen as more elaborate than that of "social presence," which makes it appropriate to think of media richness theory as a refinement and extension of social presence theory (Dennis and Valacich 1999). According to media richness theory, matching media to collaborative tasks is based on the need to reduce discussion ambiguity (or "equivocality," in the terminology used by media richness theorists). The face-to-face communication medium is considered the richest and most effective medium for reducing discussion ambiguity (Daft and Lengel 1986). In contrast, electronic communication media in general are not considered very rich because of their inherent limitations in, for example, carrying non-verbal cues and providing immediate feedback to those involved in communication interactions (Daft et al. 1987, Lee 1994).

Theoretical Diversity and Polarization

With the emergence of low-cost computer networks and the Internet, CMC research has broadened its scope considerably beyond the original focus on managers, which had been emphasized by media richness theory. This led to an increase in the body of empirical research data on CMC, much of which could not be explained based on the notions of social presence or media richness alone. The growing body of data drove systematization attempts based on the development and refinement of theories that could be used to classify and explain empirical findings. Several new CMC theories and models emerged to explain media use behavior (Axley 1984; Contractor and Eisenberg 1990; Fulk et al. 1990; Kock 1998, 1999; Lee 1994; Markus 1990, 1994; Poole and DeSanctis 1990; Trevino et al. 1990; Walther 1992; Yates and Orlikowski 1992).

The theoretical variety of the 1990s, which led to the identification of new CMC behavior phenomena and their explanation, was accompanied by mounting concern regarding the social presence and media richness theories. While several past empirical findings in part supported the social presence and media richness theories (Daft et al. 1987, Fulk et al. 1990, Rice 1993, Rice and Shook 1990, Straub and Karahanna 1998), researchers raised key issues. Among the most important were those in connection with the proposed theoretical links between low social presence and low richness in communication media, respectively, and either avoidance by users to use those media for collaborative tasks or low-quality outcomes of collaborative tasks, if the users decided to employ those communication media (Daft et al. 1987, Lengel and Daft 1988). Empirical studies have suggested that these hypothesized theoretical links are wrong, particularly because other factors such as social influences and geographic distribution can both lead users to choose "lean" communication media and modify their behavior in ways that are independent of the degree of social presence or richness of those media and that compensate for problems associated with media "leanness" (Fulk et al. 1990, Lee 1994, Markus 1994, Ngwenyama and Lee 1997).

Several of the new CMC theories developed in the 1990s directly address the empirical evidence above. Some, like the social influence (Fulk et al. 1990) and social construction of reality theories (Lee 1994), emphasize the strength of social influences (e.g., peer pressure, cultural background, previously developed context-specific mental schemas) on behavior toward electronic communication media, arguing that these types of influences may have a stronger effect on individual behavior than communication media traits (e.g., media richness) do. Other theories, like the relationship development (Walther 1992) and channel expansion theories (Carlson and Zmud 1999), emphasize the influence of media use over time as a determinant of behavior toward and perceptions about electronic communication media. These theories have been developed to explain evidence that contradicted the social presence and media richness theories and have been successful at that. However, given their focus, they left a theoretical gap by not addressing evidence that supported the social presence and media richness theories. This, in turn, has led to countercriticism from advocates of the social presence and media richness theories, who still claim that those theories are to a large extent correct. As a result, the social presence and media richness theories continue to provide a foundation for our understanding of behavior toward electronic communication media (Allen and Griffeth 1997, Carlson and Zmud 1999, Kahai and Cooper 2003, Sallnas et al. 2000).

This theoretical polarization has led to productive debate but also to some problems. As the theories of social presence and media richness increasingly became the target of social theorists, they were often labeled in ways that were rather generic and that possibly created misleading perceptions about other theories that also appeared to fit the labels. One of these labels, and perhaps the most prevalent, is that of "rational choice" theories (Markus 1994, Webster and Trevino 1995). This label is arguably generic enough to include any theory that emphasizes the role of rational responses to technology in determining CMC behavior and that places little emphasis on the role of social influences. According to this point of view, rational choice theories are often presented as theories that take a technology-deterministic view of behavior toward technology, assuming that behavior is being strongly influenced by communication media traits defined by the CMC technologies that create those media.

As it becomes clear that rational choice theories provide an incomplete and somewhat flawed view of CMC behavior, the natural reaction from social theorists is to reject those theories entirely, as well as other theories that emphasize technological characteristics, often because they are viewed as examples of technological determinism. This is problematic for two reasons. The first is that rational choice theories seem to explain communication media perceptions and choice in a limited yet reasonably robust way under specific circumstances (Allen and Griffeth 1997, Daft et al. 1987, Graetz et al. 1998, Straub and Karahanna 1998), which provides justification for attempts (carried out more than 10 years after the original development of those theories) to expand and refine them (Carlson and Zmud 1999) as well as to combine them with social theories (Trevino et al. 2000). The second reason is that the 1990s have seen the development of theories that emphasize the influence of technology features—not social elements—on CMC behavior that have little to do with the social presence and media richness theories. Examples of these theories are the gains and losses model (Nunamaker et al. 1991) and the task-technology fit theory (Zigurs and Buckland 1998), which both have been supported by empirical evidence (Alavi 1994, Zigurs et al. 1999). This suggests that theories that emphasize technology can complement social theories. However, in spite of recent attempts to integrate rational choice and social theories (Trevino et al. 2000), convincing theoretical arguments have been put forth showing that rational choice theories cannot be effectively combined with social theories without radical revisions (Lee 1994, Ngwenyama and Lee 1997).

The Potential Contribution of an Evolutionary Perspective

It is reasonable to argue that the problems above will not go away or be solved by further studies that again show the existence of flaws in the theoretical frameworks proposed by the so-called rational choice theories. Many studies already exist that point to directions for theoretical development (Dennis and Kinney 1998, El-Shinnawy and Markus 1998, Kinney and Watson 1992, Lee 1994, Markus 1994, Ngwenyama and Lee 1997). What is needed is a new theory (or set of theories) that attempts to reconcile different views in as integrative a way as possible. Such theory should probe deeper than before into one key issue that was left out of the theoretical debate summarized above. Why is it that, as some evidence suggests, we seem to be somewhat predisposed toward the face-to-face medium? It is argued here that this issue is at the core of the debate, because evidence pointing at that predisposition is often presented as supporting the social presence and media richness theories. Even though the notions of social presence and media richness imply that the face-to-face medium is somewhat "better" than media that suppress face-to-face communication elements (as do many CMC media), the proponents of those theories never provided a convincing scientific explanation as to why that should be so.

This article argues that there is a missing element, rarely found in modern organizational theories, that can shed light on the underlying reasons why we seem to favor the face-to-face medium. The missing element is human "nature," that is, the genetic makeup that plays a key role in defining our biological communication apparatus (for a discussion of the limited use of this perspective in organizational studies, as well as an excellent illustration of its use, see, e.g., Pierce and White 1999). This missing element is present in many recent (i.e., 1990s and beyond) multidisciplinary attempts to unify different domains of knowledge that attempt to explain human behavior in general, which could arguably be viewed as models to be emulated in the unification of theories that explain human behavior toward CMC tools. Notable among those multidisciplinary attempts are those by philosophers such as Dennett (1991) in the areas of ontology and consciousness, psychologists such as Pinker (1997) in the study of communicative behavior and the nature of language, and zoologists such as Wilson (1998) in the study of human altruism and aggression. In spite of their Darwinian basis, these attempts try to explain behavior in terms of sets of constructs that are compatible with "socially sensitive" views of human behavior. For example, Pinker refers to social information-processing schemas, Dennett to social processes, and Wilson to social environment. In so doing, those attempts follow a modern evolutionary orientation whose importance was cogently highlighted by Plotkin (1998) and that often relies on epigenetic explanations of individual and group behavior—that is, explanations that emphasize the interaction between genes and environment.

The Evolution of Our Biological Communication Apparatus

According to the theory of evolution by natural selection, initially proposed by Darwin (1859), our biological communication apparatus has been developed through evolutionary adaptations over millions of years. It is important to understand the dynamics of this development here because of the influence that our biological communication apparatus and, ultimately, the genes that regulate its development have on our communicative behavior, of which behavior toward CMC tools is a subset. This point has been gaining increasing support recently, with calls coming from many researchers in different fields addressing human communication behavior (Beatty and Valencic 2000, Beatty et al. 1998, Bickerton 1990, Calvin and Bickerton 2000, Cappella 1996, Deacon 1998, Dunbar 1993, Ganger and Stromswold 1998, Kelly and Keaten 2000, Laitman 1993, Lieberman 1998, McCroskey and Beatty 2000, Pinker and Bloom 1992, Valencic et al. 1998).

The term "biological communication apparatus" is used here to refer to those elements of our brain and body that are used in communication interactions. It comprises what Lieberman (2000) calls the "neural functional language system" of modern humans, which is a set of brain circuits that are distributed over many parts of the human brain and that are responsible for the perception and generation of communicative stimuli. Our biological communication apparatus also comprises body structures that are controlled by our brain, both consciously and subconsciously, and that are used in communication interactions. These include structures that are primarily "expressive" (i.e., those used for expression of ideas, thoughts, feelings, etc.), such as our vocal tract and web of facial muscles, as well as "perceptual," such as our visual and auditory organs (Ackerman 1991, Bickerton 1990, Calvin and Bickerton 2000).

Darwin's Theory and Its Application to the Understanding of Human Communicative Behavior

The theory of evolution by natural selection, also known as the theory of evolution of species, was developed by Darwin (1859) at a time when the principles of genetics developed by Gregor Mendel were unknown to the scientific community (Edelson 1999). These principles, originally developed in the mid-1800s were "rediscovered" around 1900 independently by several researchers. Approximately three decades later, Dobzhansky (1937) developed a theoretical framework that unified the theories proposed by Darwin and Mendel. This theoretical framework was refined over the years and is now known as the "evolutionary synthesis" (Mayr and Provine 1998). Three theoretical laws make up the pillars of this evolutionary synthesis, namely the inheritance, mutation, and natural selection laws (Kock 2001b), which are summarized in Table 1.

Table 1 Fundamental Laws of the Evolutionary Synthesis

Law	Description
Inheritance	Offspring inherit a large proportion of their parents' biological characteristics through their genes. The similarity between the combined genetic code of the parents and that of their offspring is very high.
Mutation	When members of a species generate offspring, natural genetic mutations occur that lead the offspring to develop biological characteristics that are different from those of the parents. These genetic mutations are usually incremental and arbitrary.
Natural selection	Those offspring whose new biological characteristics give them an edge for survival and/or mating over other members of the same species are the most likely to pass the genes responsible for those biological characteristics to their own offspring.

The discipline of biological anthropology, which builds on evolution theory as well as social ethnography, argues that, as with all other living organisms, the human species also evolved according to the fundamental laws of the theory of evolution (Boaz and Almquist 1997, Campbell 1992). This process has led to the evolution of a set of biological adaptations that encompasses many traits of the human species, including those related to our biological communication apparatus. That is, over millions of years, gradual genetic mutations have led to the development of new traits in our biological communication apparatus, and those traits that increased the chance of survival and/or mating were selected and passed on to the next generations.

Biological anthropology findings suggest that during the evolutionary period between the emergence of *Australopithecus afarensis* and the extinction of *Homo erectus*, which comprised several millions of years, our ancestors communicated primarily in a colocated and synchronous manner through simple sounds (which later evolved into speech), facial expressions, and body language (Boaz and Almquist 1997, Lieberman 2000). This type of communication behavior, also found in modern primates and many other mammals, has been refined over millions of years, leading to a gradual improvement in our ability to express thoughts through facial expressions (which is suggested by an increasingly complex web of facial muscles) and the appearance of first some rudimentary forms of speech and later complex speech (Calvin and Bickerton 2000, Isaac 1993, Laitman 1993). Only very late in the evolutionary process that led to the human species is there evidence of cave paintings, which could be seen as early manifestations of written (or symbolic) communication had they not been found to be primarily associated with religious rituals aimed at ensuring successful execution of day-to-day activities such as hunting (Gombrich 1995, Janson 1997, Lloyd 1985, Myers 1967, Rice 1968).

Repeated Use and Brain-Body Coevolution

Two interdependent principles widely used by evolution theorists, *repeated use* and *brain-body coevolution* (Cosmides and Tooby 1992; Lieberman 1998; Lorenz

1970, 1983; Wilson 2000; Wright 2000), can be invoked to show, based on the discussion above, that our biological apparatus, which includes sensory and motor organs used for communication as well as brain functions associated with these organs, must have been designed primarily for face-to-face communication. These principles are used here with the goal of guiding the reader through a logically coherent reasoning process, which ultimately leads to key conclusions that provide the foundation for the psychobiological model. The principles are said to be "interdependent" in the sense that they should not be applied in isolation if one wants to reach valid conclusions regarding evolutionary adaptations. In fact, their use in isolation from one another could arguably lead to many misleading conclusions, as other simplifications of the theory of evolution did in the past (see, e.g., Gould 2002; Tattersall 1997, 2001). Some of those misleading conclusions, particularly in connection with early evolutionary psychology hypotheses, are also reviewed by Caporael (1991, 1997, 2001) and Caporael and Baron (1997).

The principle of *repeated use* argues that there is a general correlation between the degree of evolutionary optimization of a set of organs used for a certain purpose by a species living in a reasonably stable environment and the number of generations (or, generally speaking, the amount of time) in which those organs are repeatedly used for that purpose. If we employ this principle to understand the evolution of our biological communication organs in connection with the execution of collaborative tasks, then it becomes clear that this principle supports the notion that we evolved an increasingly sophisticated biological communication apparatus for communication using body language, facial expressions and, particularly, sounds. The principle somewhat dispels the possible assumption that our biological communication apparatus has been primarily designed for communication through graphic representations (or symbolic communication) in connection with collaborative tasks because this form of communication emerged very late in our evolutionary history.

The period since the appearance of the first cave paintings makes up less than 1 percent of our evolutionary history, starting with the emergence of the first hominids (e.g., *Australopithecus afarensis*). Moreover, that period does not include previous evolutionary paths that led to the human species, such as those taken by our earlier mammalian and reptilian ancestors (Lieberman 2000, Wilson 2000), the consideration of which would make the emergence of cave paintings an even more recent event in our evolutionary history. Finally, symbolic communication is significantly different from face-to-face communication, particularly so from face-to-face communication using complex speech, which seems to be the apex of the evolution of our biological communication apparatus from a morphological perspective.

Symbolic communication may have been developed as a result of another characteristic that emerged late in our evolutionary history—the ability to develop tools to solve problems (Lieberman 2000). Relying only on facial expressions, gestures, and speech to communicate limits our ability to make knowledge explicit and, more importantly, makes it impossible for us to create a record of it for future reference. This problem seems to have been solved by symbolic communication, which allows us both to record knowledge and to make it explicit, even though symbolic communication does not seem to be what our biological communication apparatus has been designed for.

The principle of *brain-body coevolution*, which underlies some of the key ideas in connection with the incipient field of evolutionary psychology (Buss 1999, Cosmides and Tooby 1992, Plotkin 1998, Tooby and Cosmides 1992), argues that body and brain structures coevolve in a closely matched way. This principle, when used in conjunction with the principle of repeated use, highlights one important fact about our evolutionary history. The gradual evolution of certain characteristics of our body, such as a complex web of facial muscles and complex vocal communication organs, has been accompanied by the evolution of specialized brain functions that process stimuli sensed by those organs and control their operation. For example, it is known that the development of a larynx located relatively low in the neck, a key morphological trait that differentiates human beings from their early ancestors (Laitman 1993, Lieberman 1998), considerably increased the variety of sounds that we could generate (and, at the same time, significantly increased our chances of choking on ingested food and liquids). According to the brain-body coevolution principle, the development of this "customized" larynx was necessarily accompanied by the development of specialized brain functions designed to control our larynx with great precision in order to generate the large variety of sounds used in normal speech. These brain functions are part of what is collectively referred to by Lieberman (1998) as the "neural functional language system" and illustrate the close match between brain functions and body functions associated with communication. Thus, using modes of communication that veer away from face-to-face communication is likely to put an extra burden on the brain (i.e., increase cognitive effort), as our brain, in addition to our body, has been designed for face-to-face communication.

A Brain Designed to Excel in Face-to-Face Communication

In summary, the combined application of the evolutionary principles of repeated use and brain-body coevolution, discussed above, leads to the conclusion that our biological communication apparatus, which includes sensory and motor organs associated with communication as well as brain functions associated with these organs, has been designed primarily for face-to-face communication. So how did communication aids that use symbols, such as the first forms of written language and (much) later text-based CMC tools such as e-mail, emerge and become so pervasive in society? Given the principle of repeated use, which virtually rules out the possibility that our biological apparatus was primarily designed for symbolic communication, the most logical explanation is that symbolic communication is a human development that has been enabled by the evolutionary development of increasing intelligence, as well as the possible parallel development of artistic abilities and tendencies, which, some researchers believe, might have been primarily sexually selected (see, e.g., Buss 1999, Miller 2000). These developments occurred somewhat concurrently with the development of a biological communication apparatus designed for face-to-face communication.

Another important conclusion can be drawn from the discussion above: Communication aids, like other tools (e.g., stone-shaping artifacts used to develop hunting tools), are largely a byproduct of higher intelligence and increasingly developed artistic abilities (Cartwright 2000). And, as with many other human inventions, communication aids may help us solve some problems (e.g., symbolic communication helps humans store knowledge for future use) yet not fit well with our biological communication apparatus. This is a particularly important conclusion because one of this article's key arguments is that certain characteristics of CMC tools, particularly those that make interaction less "natural" (i.e., less similar to face-to-face interaction), make them more difficult, or cognitively demanding, for human beings.

The Psychobiological Model

The preceding discussion on the evolution of our biological communication apparatus provides the basis for the development of theoretical propositions that can help us understand CMC behavior in ways that are inclusive of and yet significantly different from those presented by several of the theories reviewed earlier in this article, particularly the social presence and media richness theories. This section develops and discusses a set of such theoretical propositions.

Before moving on to the theoretical propositions, it is important to stress that saying our genes influence the formation of a "phenotypic trait" (i.e., a biological trait that defines a morphological, behavioral, physiological, etc. characteristic) is not the same as saying that the trait in question is "innate." Very few phenotypic traits are innate (e.g., blood type). The vast majority of those traits, including most of those in connection with our biological communication apparatus, need interaction with the environment to be fully and properly developed. The human eye, for instance, is a complex organ that was designed by evolutionary forces over millions of years. As with many other organs, the complex set of genes that guides the development of the human eye operates in conjunction with certain environmental conditions, without which malformations could occur. Those environmental conditions existed in our prehistoric past as well, probably in a recurrent way (Dawkins 1986, 1989). If the eye is not properly stimulated with light in the first years of life, for example, it will not develop properly, in some cases leading to severe eyesight problems and even blindness. The same goes for the human biological communication apparatus. Even though there is a significant amount of evidence suggesting that our biological communication apparatus is designed for face-to-face communication, there is also ample evidence that at least part of such apparatus (including parts of the neural functional language system) cannot be fully developed without a significant amount of practice (Pinker 1994).

The above conclusion does not invalidate the arguments made here, because we likely have strong instincts that induce us, from an early age, to behave in ways that are conducive to the development of a biological communication apparatus designed to excel in face-to-face communication. There is little doubt that a fully developed biological communication apparatus has been particularly important in terms of survival and mating for our prehistoric ancestors, as it is for us today (Boaz and Almquist 1997, Dunbar 1993, Miller 2000). Therefore, evolution must have developed mechanisms to compel human beings to use their biological communication apparatus, mostly in the form of instincts analogous to Pinker's (1994) language "instinct." These instinctive mechanisms are similar to those that compel animals to practice those skills that play a key role in connection with survival and mating, such as "play hunting," widely observed in mammal predators, and "play fleeing," widely observed in those animals on which mammal predators prey (Lorenz 1970, Wilson 2000). Analogously, human beings possess a set of instinctive mechanisms that lead them while infants to develop a language (Pinker 1994), usually that spoken by their parents and/or caretakers. Purposeful suppression of those instinctive mechanisms is almost universally avoided, as that suppression is seen as likely to lead to psychological disorders and a variety of developmental problems. As a result, the biological imperative to develop a communication apparatus well adapted for face-to-face communication "succeeds" in its role. Unfortunately, this success leads to an apparatus better designed for the solution of communication problems found in our remote evolutionary past than for those in today's world (which, incidentally, is the main point of this article).

The notion that culture and genes coevolve has been gaining increasing acceptance recently (see, e.g., Henrich 2004 and the responses published in the same journal issue), particularly among biological anthropologists. The notion posits that certain general cultural adaptations lead to changes in the gene pool of a population, which in turn may reinforce the cultural adaptations, and so on. For example, as groups of a particular species increase in size, cultural norms associated with respect for individuals in positions of authority may be developed to ensure group cohesion. It is plausible to expect that those individuals whose genetic makeup makes them more predisposed to respect authority will have better chances of survival in such a society, which will then help spread those genes throughout the population, providing a genetic reinforcement to the cultural norm.

The above culture-gene coevolution notion is consistent with this article's focus on collaborative tasks rather than on other facets of human behavior, such as, say, noncollaborative competition among individuals. It is likely that the evolution of our biological communication apparatus is closely linked with cultural adaptations related to a variety of collaborative tasks, such as hunting and gathering, food preparation and sharing, and territorial defense against predators. While many of the specifics about those culture-gene coevolutionary adaptations are still unknown, it is safe to assume based on the evidence discussed in the previous section that virtually all of those adaptations have occurred in the context of face-to-face communication. In fact, the evidence from our evolutionary past strongly suggests that many evolved adaptations in connection with face-to-face communication are aimed at helping us excel in collaborative tasks. A key reason for this is that hominids have not been historically endowed with the physical attributes necessary to allow them to survive in the presence of other species, including predators, without a great deal of intraspecific collaboration (Boaz and Almquist 1997, Wilson 2000).

The main goals of this section are to develop and discuss a set of theoretical propositions that is both internally consistent and falsifiable. This set of propositions is referred to here as the psychobiological model. An important feature of the proposed model is the use of cognitive effort (required to perform a collaborative task) as the dependent variable, which contrasts with the traditional emphasis on media choice and use behavior seen in media richness theory. Another important feature of the proposed model is that it is largely task independent within the scope of collaborative tasks, which does not imply that future refinements of the model cannot incorporate certain task attributes as moderating variables. Cognitive effort can in turn be associated with other downstream variables such as satisfaction, task outcome quality, and even media choice, paving the way for future theoretical integration. Media characteristics are introduced into the model by developing the notion of naturalness of the media to our biologically evolved communication capabilities. The model also incorporates our capability to adapt and develop mental schemas (Bartlett 1932, 1958; Cossete and Audet 1992; Lord and Foti 1986) associated with the use of different communication media.

The Media Naturalness Proposition

The media naturalness proposition, enunciated below, follows from the discussion in the previous section on the evolution of our biological communication apparatus and its apparent optimization for face-to-face interaction. In particular, it follows from the application of the brain-body coevolution principle to the interpretation of the historical evolution of communication in our species, which points at a concurrent optimization of body functions and related brain structures for face-to-face interaction (Laitman 1993; Lieberman 1991, 1998, 2000). Since our brain is to a large extent designed for face-to-face interaction, moving away from this form of interaction is likely to lead to extra cognitive effort, which is the key underlying assumption of the media naturalness proposition.

Media Naturalness Proposition. *Decreases in the degree of naturalness of a CMC medium lead to increases in the degree of cognitive effort required from an individual to use the medium for communication to accomplish a collaborative task.*

The media naturalness proposition states that the higher the degree of "naturalness" of a CMC medium, the lower the "cognitive effort" required to use it for communication. Underlying the media naturalness proposition are two key theoretical constructs, namely "medium naturalness" and "cognitive effort." The former construct refers to the similarity between a given CMC medium and face-to-face interaction. The latter construct refers to the degree of schema use, reconstruction, and development required to accomplish a certain task (Piaget 1971; Salomon 1979, 1981; Salomon et al. 1991).

Medium Naturalness. It is proposed here that the degree of naturalness of a CMC medium can be assessed based on the degree to which it incorporates five key elements of face-to-face communication: (a) colocation, which would allow individuals engaged in a communication interaction to share the same context, as well as see and hear each other; (b) synchronicity, which would allow the individuals to quickly exchange communicative stimuli; (c) the ability to convey and observe facial expressions; (d) the ability to convey and observe body language; and (e) the ability to convey and listen to speech.

What is being argued here is that, other things being equal, among several different CMC media that can be used to perform a collaborative task, the medium that incorporates to the largest degree as many of these five elements as possible is the one that possesses the highest degree of naturalness, other things being equal. Thus, if we compare two CMC tools such as an e-mail system and a video-conferencing system, we can say that the video-conferencing system provides a CMC communication medium that presents a higher degree of naturalness than the e-mail system, because it incorporates more of the naturalness elements found in face-to-face interaction (e.g., synchronicity, limited support for the use of facial expressions, support for the use of speech) than the e-mail system does. Similarly, between two CMC media that incorporate the same naturalness element, the one with the higher degree of naturalness is the one in which the naturalness element more closely approaches what is found in face-to-face communication, other things being equal. For example, between two similar video-conferencing systems, the one whose image quality more closely approaches that found in natural face-to-face communication would be the one possessing the higher degree of naturalness (with the caveat that this should also take into consideration our limitations in perceiving image granularity). The media naturalness proposition will be further qualified through a formative proposition, the speech imperative proposition, discussed in the next subsection.

Cognitive Effort. Cognitive effort refers to the degree of schema use, and, in the case of learned tasks that require cognitive adaptation, to the degree of schema reconstruction and development required to accomplish a certain cognitive task (Piaget 1971; Salomon 1979, 1981; Salomon et al. 1991). From a strictly biological perspective, the cognitive effort construct can also be seen as related to the degree of brain activity (i.e., neural connection firing) required to accomplish a certain cognitive task (Lieberman 1991, 1998). Cognitive effort is usually assessed indirectly through measures of perceived cognitive effort (Graetz et al. 1998, Karahanna and Evaristo 2001, Todd and Benbasat 1999), as direct measurement of brain activity associated with cognitive processes is often difficult to accomplish. In this sense, cognitive effort is usually associated with the perceived level of difficulty of using a medium for communication.

Kock (1998) developed the concept of "fluency," which is essentially the number of words that an individual can convey per minute over different media. Variations in fluency can also be used to indirectly measure cognitive effort, after the "typing-versus-speaking effect" is controlled for. The typing-versus-speaking effect refers to the fact that, from a purely mechanical perspective (Dennis and Kinney 1998), it is more time consuming to type than it is to read aloud a piece of text (for more details on this, see McQueen et al. 1999). Kock's (1998) study found that fluency is about 18 times higher face to face than over e-mail in complex collaborative tasks and about 10 times higher when the typing-versus-speaking effect is controlled for. This provides support for the media naturalness proposition. On the other hand, the study found that task outcome quality was better when groups interacted though e-mail, a result that led to the development of the notion of compensatory adaptation (Kock 1998, 2001a). That notion suggests that individuals seem to compensate for cognitive obstacles posed to them, in some cases (e.g., when appropriate social influences are present) overcompensating for those obstacles and achieving collaborative task outcomes of greater quality than if the obstacles were not present. This result is incompatible with predictions based on the social presence and media richness theories but perfectly compatible with the media naturalness proposition, as it has been shown empirically in the past and predicted by a theory known as symbol systems theory (Salomon 1979, 1981; Salomon et al. 1991) that higher cognitive effort sometimes leads to better task outcomes.

The Speech Imperative Proposition

A second level of categorization of the naturalness elements can be developed to better understand the influence of those elements from an evolutionary perspective and arguably to provide the basis for a more refined insight on media naturalness than would be possible based on the social presence and media richness theories. According to this second level of categorization, the naturalness elements can be broken down into two main dimensions (the letters used in the previous section are also used here): (1) the space-time dimension, which comprises the degree to which a medium supports (a) colocation and (b) synchronicity; and (2) the expressive-perceptual dimension, which comprises the degree of support for the use of (c) facial expressions, (d) body language, and (e) speech. These two dimensions appear to be fundamentally different when looked at through an evolutionary lens.

The speech imperative proposition, enunciated below, builds on the notion of evolutionary cost of adaptations in connection with specific processes (Zahavi and Zahavi 1997, Wilson 2000). That notion allows for the prediction that one of the elements of the expressive-perceptual dimension, namely the ability of a medium to support the use of speech, is likely to be significantly more important than all of the other naturalness elements within the expressive-perceptual dimension in defining the naturalness of a communication medium and thus enabling communication with low levels of cognitive effort. The evolutionary cost notion can be seen as a broad conceptual generalization of Zahavi and Zahavi's (1997) handicap principle but should not be confused with that principle. Zahavi and Zahavi (1997) argue that for animal "signals" to be "honest" indications of fitness, they must impose a cost, or handicap, on the signaler. The more costly a fitness indicator is, the higher its reliability is, and thus the greater its relative importance as a fitness indicator when compared to other indicators. For example, a set of large and symmetrical antlers (developed by an elk species so that males can signal good health to potential mates) would be more important for procreation than a less-costly fitness indicator, such as the color of the hair around the elk's neck. Therefore, as far as the procreation process is concerned, losing its antlers (a suppression of the ability to use a more-costly fitness indicator) would be more likely to relegate a male elk to bachelorhood than having its neck shaved (a suppression of the use of a less-costly fitness indicator).

What is proposed here as a formative proposition associated with the media naturalness construct, based on the evolutionary cost notion, is analogous to what was proposed by Zahavi and Zahavi (1997), in that it is suggested that what is costly to evolve from a communication perspective is also costly not to use. More specifically, it is argued here that the ability to convey and listen to speech through a communication medium is likely to have a higher relative importance than the other elements in the expressive-perceptual dimension because of its arguably higher evolutionary cost to human beings. This is formalized in what we call here the speech imperative proposition.

Speech Imperative Proposition. *The degree to which a CMC medium supports an individuals' ability to convey and listen to speech is significantly more important than the other elements of the expressive-perceptual dimension in defining the degree of naturalness of the medium.*

As mentioned before, the development of a larynx located relatively low in the neck (Laitman 1993, Lieberman 1998) considerably increased the variety of sounds that we could generate and thus allowed us to develop complex speech (a landmark in the evolution of the human species). However, that development also significantly increased our chances of choking on ingested food and liquids. Neither of the other naturalness elements in the expressive-perceptual dimension seems to involve the same level of evolutionary costs. The development of a complex web of facial muscles, necessary for effective communication with facial expressions, while somewhat costly from a protein development and allocation perspective, does not seem to have led to a fitness handicap analogous to that related to the development of speech. The related loss of facial hair, necessary for effective use of facial expressions (Bates and Cleese 2001), actually seems to have increased the area available for sweat glands to develop, which arguably increased fitness at a different level. The concentration of sweat glands on the human skin is one of the highest in the animal kingdom and is probably due to the fact that a large proportion of our evolution occurred in the hot African savannas, where we likely walked a lot and thus tended to overheat (Boaz and Almquist 1997, Wilson 2000, Zimmer 2001). This also explains why we have very little hair compared to our closest primate relatives and have been called the "naked ape."

Similarly, communication through body language does not seem to have required any costly changes in our morphology or behavior for that matter, because the related motor adaptations are likely to have been inherited from as far back as our paleomammalian past and slightly modified over millions of years. Evolutionary cost is often associated with evolutionary speed. That is, very costly adaptations often emerge in relatively short periods, such as a few thousand years, as is the case with some fitness indicators used in sexual selection—for example, the peacock's tail (for more examples, see Miller 2000). Our paleomammalian ancestors likely shared many traits with modern rodents (Boaz and Almquist 1997, Wilson 2000), all of which employ a variety of body language elements for communication (as do most other animals).

The notion of evolutionary cost does not apply to the elements of the space-time dimension. Colocation and synchronicity were an integral part of life for prehistoric humans, as well as many other mammals, because prehistoric humans had no means by which to communicate in a non-colocated and asynchronous manner until the emergence of writing. Writing is too recent a development to have influenced the formation of our biological communication apparatus in any way that could be seen as very significant. Moreover, the elements of the space-time dimension were not evolved, so the notion of evolutionary cost makes no sense when applied. Nevertheless, it is important to take those two elements into consideration for the development of the psychobiological model, because modern CMC tools have the ability to selectively suppress them, thus leading to decreases in medium naturalness in comparison with the face-to-face medium.

The above discussion would suggest that suppressing the ability to convey and listen to speech would substantially affect the naturalness of a medium, more than suppressing the ability to use facial expressions and body language, which should in turn be observed in variables directly or indirectly associated with cognitive effort. This is interesting from a CMC design perspective, because it begs the question as to whether video-conferencing (or a similar technology, such as teleconferencing, which employs video together with audio) is much better than audio-conferencing alone in terms of cognitive effort required, particularly given the substantial technical difficulties and costs associated with adding a video component to an audio-only channel. According to the theoretical perspective proposed here, it should not be; this expectation has been supported in the past by empirical research (Galegher and Kraut 1990). Nor, according to the theoretical perspective proposed here, should face-to-face interaction be much better than video-conferencing (or teleconferencing and similar forms of interaction), as long as the audio channel is of good enough quality. At least one study (Graetz et al. 1998) comparing face-to-face, teleconferencing, and electronic chat groups provides unambiguous support for this conjecture. Graetz et al. found differences in "mental demand" (a measure used to assess cognitive effort) across those three different conditions. The means obtained for that measure were 8.14 for the face-to-face condition, 8.41 for teleconferencing, and 12.32 for electronic chat. Consistent with the evolutionary cost perspective presented here, the differences were statistically significant between the electronic chat and each of the other two conditions but not significant between the teleconferencing and face-to-face conditions.

The Cognitive Adaptation Proposition

Even though our genetic makeup gives the human brain a particular design, the characteristics of which can be inferred in part from evolutionary biology studies, it also makes the human brain the most "plastic" brain in the animal kingdom (Caramazza 1984, Eysenck and Keane 1990, Gardner 1985, Piaget 1971, Pinker 1997, Wills 1993). The plasticity of the human brain, which is itself a result of evolutionary forces (Dennett 1991), is illustrated by the unique capacity of human beings to learn (i.e., to develop new schemas) by modifying certain parts of the brain, notably the outer layer known as the neocortex (Kotulak 1997; Lieberman 2000; Pinker 1994, 1997). This also suggests that the design of our brain in connection with face-to-face communication is at least in part located in its inner layers (Lieberman 2000).

Our ability to develop new schemas, stored primarily on the neocortex, covers all kinds of schemas, including schemas related to CMC media use. Therefore, it is reasonable to conclude that we can develop CMC media use schemas (especially process-related schemas, also known as "scripts"—see, e.g., Lord and Foti 1986) that counter the negative link between medium naturalness and cognitive effort hypothesized in the media naturalness proposition. This notion of schema-related adaptation to CMC media is similar to that proposed by Carlson and Zmud (1999) in their channel expansion theory. In other words, we can develop schemas through repeated CMC media use that may counter the effect of instinctive schemas (i.e., schemas that are largely defined by our genetic makeup), which are biased toward face-to-face interaction. This is formalized in the cognitive adaptation proposition below.

Cognitive Adaptation Proposition. *Increases in the degree of cognitive adaptation to a CMC medium lead to decreases in the degree of cognitive effort required from an individual to use the medium for communication to accomplish a collaborative task.*

Learned schemas, that is, schemas that are developed through learning, are different from instinctive schemas (Cappella 1997, Kotulak 1997, Piaget 1971) in that they have to be acquired and reinforced by action, and thus their effect on behavior toward CMC tools can be considered in isolation from and concurrently with the effect of instinctive schemas.

Cognitive Adaptation. The cognitive adaptation construct refers to the level of schema development associated with the use of a particular CMC medium to perform collaborative tasks. The degree of cognitive adaptation of a user to a certain CMC medium can be assessed directly based on the user's amount of training and repeated use of the CMC medium for collaborative tasks or indirectly based on perceptions about self-efficacy (Compeau and Higgins 1995) and ease of use (Davis 1989) in connection with the CMC system being used. A high degree of cognitive adaptation to a CMC medium is expected to be particularly associated with repeated use of the CMC medium for collaboration (Knowles 1984). For example, a group of geographically distributed users who employ e-mail intensely and repeatedly over many years for work-related collaboration will be more cognitively adapted to using e-mail for work-related collaboration than a group of users who, during the same period of time, engaged in work-related collaboration primarily face to face (Carlson and Zmud 1999).

The Schema Alignment Proposition

The development of a large and flexible brain, whose plasticity and memorization capacity far surpasses that of other animals, is the main evolutionary "trick" that allowed us to develop tools and processes (i.e., technology) as well as to retain, refine, and communicate knowledge about those tools and processes, generation after generation. Still, a large and flexible brain practically guarantees that learned schemas (i.e., schemas that are not instinctive) differ from individual to individual, even though instinctive schemas are very similar across different individuals (Pinker 1997, Wills 1993, Wilson 2000). In particular, it has been shown that individuals who come from different cultural backgrounds, for example, are likely to have different learned schemas, which in turn may influence their behavior toward CMC tools in different ways (Tan et al. 1995, Watson et al. 1994).

A fundamental notion in organizational communication studies that is relevant to the theoretical model presented here is that the degree of schema misalignment (or lack of schema alignment) between individuals engaged in communication is positively correlated with the amount and intensity of communication necessary to accomplish collaborative tasks and reach a shared understanding of concepts and ideas needed to complete tasks (Boland and Tenkasi 1995; Galbraith 1973, 1977; Weick 1969, 1995; Weick and Bougon 1986). This notion is relevant here because it is reasonable to expect that the degree of schema alignment between two or more individuals engaged in communication will have an impact on the degree of cognitive effort required from each individual to use a CMC medium to collaborate with the other individuals. This leads us to the schema alignment proposition below.

SCHEMA ALIGNMENT PROPOSITION. *Increases in the degree of schema alignment between any two individuals using a CMC medium lead to decreases in the degree of cognitive effort required from each individual to use the medium for communication to accomplish a collaborative task.*

Schema Alignment. The degree of schema alignment between two individuals can be assessed based on knowledge and skill tests associated with the specific task they intend to perform collaboratively. The higher the similarity between test scores, the higher the degree of schema alignment between the individuals. The schema alignment proposition incorporates the notion of shared schemas in connection with a task and thus allows us to make the psychobiological model a task-independent model within the general scope of collaborative tasks. This is seen here as a preferable alternative to incorporating the task construct into the model, because task-specific schemas can and will often vary from individual to individual, and the unit of analysis of the psychobiological model is the individual, as opposed to the group (or pair) of individuals engaged in communication interactions. Deriving predictions based on the psychobiological model at the group level of analysis can be accomplished by aggregating predictions about the individuals who make up a group.

Developing a theoretical model whose main unit of analysis is the individual allows for a high level of granularity in predictions, both at the individual and group levels of analysis. Predictions at the individual level of analysis can be useful in connection with CMC behavior. An application of the schema alignment proposition that highlights this usefulness can be illustrated by considering the case of CMC-based user-expert communication interactions at an information technology help desk. Often a solution is achieved by the expert at the help desk transferring knowledge and information to the user about how to solve the problem. In this case, the schema alignment proposition allows us to hypothesize that those users whose degree of schema alignment with the help desk experts is low (e.g., computer-illiterate users) will experience more cognitive effort in conjunction with the use of CMC media of low naturalness. The main reason for this is the fundamental notion, discussed above, that a lack of schema alignment between individuals leads to an increase in the amount and intensity of communication required to accomplish collaborative tasks and reach a shared understanding of concepts and ideas needed for the tasks.

Suggestions for Further Empirical Research

The usefulness of a new theoretical model can be assessed based on two important attributes (Popper 1992). The first is the degree of testability of the model, or the extent to which the model is falsifiable. The second is the relevance of the model to practice. In the case of a CMC model, relevance to practice may be associated with the model's ability to predict CMC behavior that managers can use to improve their organization's relationship with customers. This section addresses issues in connection with these attributes by illustrating the application of the psychobiological model in a particularly business context, showing how the model can be tested and making related construct measurement suggestions.

How Can the Psychobiological Model Be Tested?

The context-specific hypotheses below have been developed based on an action research study involving one mutual fund management firm and two online brokers. The focus is on a generic customer-support process involving a customer and the customer-support area of an online broker. It is argued here that a test of the hypotheses developed below would constitute a valid attempt at refutating the psychobiological model, attesting to the falsifiability of the model (Popper 1992). The actual test of the hypotheses, as well as the development of other hypotheses based on the psychobiological model for different contexts, is beyond the scope of this article.

The main goal of the customer-support area of an online broker is to help customers buy investment products online. Those products usually include money market instruments, stocks, bonds, mutual funds, and derivatives (Rose et al. 1999), for whose sale the online broker receives a transaction fee. The customer-support process involves communication between two main entities, the *customer* and the *customer-support area* of the online broker.

Let us assume that three different types of CMC media implementations are used by the customer-support area of the online broker to provide advice to its customers: (a) a web-based video-conferencing implementation, whereby customers and online broker representatives interact through a desktop video-conferencing application; (b) a web-based audio-conferencing implementation, whereby customers and online broker representatives interact through a desktop audio-conferencing application; and (c) a web-based chat implementation, whereby customers and online broker representatives interact through a web-based desktop chat application.

Let us assume that customers can be classified according to their cognitive adaptation to the different CMC media used by the online broker into two main categories: *beginners*, who have used similar CMC media for trading investment products in the past for no more than three months; and *skilled*, or those who have used similar CMC media for more than three months. Similarly, let us assume that customers can be classified according to schema alignment with online broker representatives into two main categories: *novice*, those who have been trading investment products for no more than three months; and *seasoned*, those who have been trading investment instruments for more than three months.

Table 2 shows four hypotheses as well as an indication of the conceptual basis on which they have been developed. The key unit of analysis to which the hypotheses refer is the *customer*. The hypotheses are expected to be tested based on analyses of communication interactions associated with investment product trading activities between the customer and the customer-support area of the online broker.

Not only do the hypotheses summarized in Table 2 allow for a test of the psychobiological model in a specific business context, they also depict conceptual relationships that are relevant to industry practitioners in the online brokerage industry. Previous CMC studies that investigated perceived cognitive effort and satisfaction (Graetz et al. 1998, Nunamaker et al. 1991, Todd and Benbasat 1999) provide the basis on which to assume that increased perceived cognitive effort is likely to lead to increased customer dissatisfaction with the service provided by the online broker (as hypothesized in the fifth hypothesis in Table 2) and thus increased likelihood of using the services of a competing online broker. This is compounded by the low cost associated with opening an account at a competing online broker and the weak bond that ties providers and customers in the online brokerage industry (Spiro and Baig 1999). Previous empirical studies of the financial services industry and in particular customer-provider relationships in that industry (Macdonald 1995, Walkins 1992) allow us to conclude that the impact of each communication interaction will be both incremental and cumulative in most cases. In the case of consistent dissatisfaction with the communication interaction, this cumulative effect will eventually lead to the decision by the customer to use the services of a competing online broker.

Given the considerations above, one key finding would provide a valid refutation of the psychobiological model when customers with the same level of cognitive adaptation to different CMC media and the same level of schema alignment were considered. The finding would be that a higher degree of CMC medium naturalness is not associated with a lower degree of perceived cognitive effort and thus satisfaction with the customer-support interaction. Of course, this assumes other things are equal. For example, it is not easy to imagine a high medium naturalness condition leading to greater dissatisfaction than a lower media naturalness condition, if the higher medium naturalness condition is associated with a high incidence of severe and annoying technical problems. This situation is not at all uncommon, since higher medium naturalness is more often than not associated with greater technical implementation challenges. With time this is likely to become less of a factor, as more natural and less technically problematic CMC implementation solutions become available to organizations.

Recent trends in the use of communication media in the online brokerage industry provide support for the context-specific predictions above as they suggest a link

Table 2 Context-Specific Hypotheses Developed Based on the Psychobiological Model

Basis	Hypotheses
Media naturalness proposition	1: Decreases in the degree of naturalness of the CMC medium used by the customer (from video to audio to chat) will lead to increases in the degree of perceived cognitive effort required from the customer to use the medium for communication with the online broker's customer-support area.
Speech imperative proposition	2: The difference in perceived cognitive effort between the chat condition and either of the other two CMC conditions (audio or video) will be significantly greater than the difference in perceived cognitive effort between the audio and video conditions.
Cognitive adaptation proposition	3: Increases in the degree of cognitive adaptation of the customer to the CMC medium used (from beginner to skilled) will lead to decreases in the degree of perceived cognitive effort required from the customer to use the medium for communication with the online broker's customer-support area.
Schema alignment proposition	4: Increases in the degree of alignment between the schemas of the customer and those possessed by members of the customer-support area (from novice to seasoned) will lead to decreases in the degree of perceived cognitive effort required from the customer to use the CMC medium for communication with the online broker's customer-support area.
Empirical literature on cognitive effort effects	5: Increases in the degree of perceived cognitive effort required from the customer to use a CMC medium for communication with the online broker's customer-support area will lead to decreases in the degree of satisfaction experienced by the customer with the customer-support interaction.

between customer satisfaction and loyalty and the use of electronic media with a high degree of naturalness to support customers (Dodson 2000). The above predictions are also consistent with the relative commercial success of sophisticated text-based chat tools that add synchronicity to online business-to-consumer interactions, making it easier for customers to obtain information about products and services (Eichler and Halperin 2000, Gilbert 1999).

Construct Measurement Suggestions

The psychobiological model can be tested through empirical investigations that build primarily on either qualitative or quantitative data collection and analysis methods or that employ a combination of qualitative and quantitative methods (Creswell 1994, Gallivan 1997, Jick 1979, Maxwell 1996, Rosenthal and Rosnow 1991). From a quantitative methods perspective, some tests, such as that illustrated by the customer-support example above, would not require the use or development of validated instruments for all constructs. For instance, cognitive adaptation and schema alignment could be seen as factors varying along treatment conditions, similar to what was suggested in the example, in an analysis of variance study (Creswell 1994) or a study employing nonparametric techniques for comparison of means (Siegel and Castellan 1998). Other tests, particularly those relying on more sophisticated quantitative analysis techniques, such as multiple regression and structural equation modeling (Kline 1998, Rencher 1998, Schumacker and Lomax 1996), would require the use of validated instruments for construct measurement. With that in mind, below are some suggestions of measurement approaches that could be adapted for future tests of the model. The focus here is on multi-item perceptual measures that have been tested for reliability and validity in contexts relevant to CMC.

Cognitive Adaptation. The degree of cognitive adaptation of a user to a certain CMC medium can be assessed based on perceived competence, experience, and comfort with the CMC system that creates the communication medium. Carlson and Zmud (1999) discuss the development and validation of a six-item instrument to measure the perceived competence, experience, and comfort with e-mail, which apparently can be easily adapted to address most CMC systems. That instrument has been developed based on the literature on computer self-efficacy (Compeau and Higgins 1995) and ease of use (Davis 1989) and used in the context of a study of the impact of cognitive adaptation and other variables on perceptions about media richness (Carlson and Zmud 1999).

Cognitive Effort. One of the most widely used multi-item instruments for measurement of cognitive effort is the National Air and Space Administration (NASA) Task Load Index, which measures "mental workload" via a weighted average of six distinct dimensions: mental demand, physical demand, temporal demand (i.e., time pressure), operator performance (how satisfied one is with own performance), effort, and frustration level (Karahanna and Evaristo 2001). Hart and Staveland (1988) provide a detailed discussion of the instrument and its development. Karahanna and Evaristo (2001) provide a detailed discussion of the instrument vis-à-vis other measures of mental workload. Graetz et al. (1998) provide an excellent example of use of the measurement instrument in the context of a study of the impact of CMC media on cognitive effort. Based on a review of this literature in light of the psychobiological model, it is suggested here that, among the six dimensions of the NASA Task Load Index, the two dimensions that best reflect what is referred to here as cognitive effort are the mental demand and temporal demand dimensions. These two dimensions can be combined into a two-item measure of cognitive effort that is likely to yield high reliability and validity coefficients in most CMC study contexts.

Schema Alignment. As for the schema alignment construct, the recommended approach here is analogous to the one adopted in the business communication and news media literature for the assessment of schema-related issues (Cappella 1997, Faris and Smeltzer 1997). It consists in developing multi-item tests in connection with the collaborative task under consideration. A measure of intersubject agreement (e.g., Pearson correlation) or intersubject reliability (e.g., Cronbach alpha) should then be used to quantify the level of schema alignment between the individuals involved in the communication process. The higher the intersubject agreement or reliability is, the higher the schema alignment between the different subjects (or individuals) is. The empirical literature on schema development and assessment, which are recurrent topics in the areas of business communication and news media research, can be used for some ideas on how to develop multi-item tests in connection with specific collaborative tasks. Good examples are the empirical studies conducted by Cappella (1997) and Faris and Smeltzer (1997).

The Theoretical Contribution of the Psychobiological Model

While the theoretical basis of the psychobiological model differs from those of the other CMC theories reviewed in this article, the model's most fundamental proposition, the media naturalness proposition, may be seen as similar to the key proposition of the social presence theory and particularly of the media richness theory. The psychobiological model, however, differs considerably from the social presence and media richness theories. Some differences have been discussed previously in this article. Three other key differences are discussed below.

Moving Beyond the Notions of Social Presence and Media Richness

The first key difference between the psychobiological model and the social presence and media richness theories is that these theories argue that different communication media present certain characteristics that are inherent to them and are static, that confer to them different degrees of social presence or media richness, respectively. That is, the main focus of the social presence and media richness theories is the communication medium. In contrast, the focus of the psychobiological model is our biological communication apparatus.

The second key difference between the psychobiological model and the social presence and media richness theories is that the psychobiological model does not relate low medium naturalness with certain types of behavior (e.g., medium avoidance) but with high cognitive effort, which in turn may or may not lead to certain types of behavior. Therefore, the psychobiological model is perfectly compatible with individuals perceiving a CMC medium as posing cognitive obstacles for effective communication yet deciding to use the medium for collaboration. Moreover, outcomes of a quality comparable to or better than what would be achieved face to face are a result that is also compatible with the psychobiological model.

The third key difference is that the social presence and media richness theories classify different communication media according to a continuum of social presence and media richness, respectively, based primarily on communication media features. This opens the door for the conclusion that communication media such as virtual reality–based media, for example, that incorporate more of those features that increase their richness (or social presence) will be even "better" than face-to-face interaction. The psychobiological model, however, argues that the face-to-face medium is the one likely to lead to the least cognitive effort during communication, which implies that a super-rich virtual reality–based medium will also lead to increased cognitive effort, most likely because of information overload (see Figure 1).

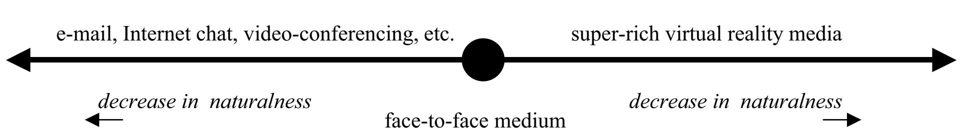
The term super-rich virtual reality is used here to refer to a type of technology that would allow for the use—for expression and/or perception—of substantially more communicative stimuli than the face-to-face medium. Since the psychobiological model places the face-to-face medium at the center of a one-dimensional scale of naturalness where the distance from the center could be seen as a measure of decreased naturalness, it can be concluded that anything "less" or "more" than face-to-face communication, so to speak, is likely to lead to increased cognitive effort. A super-rich virtual reality medium would be on the "more" side of the scale.

Filling an Explanatory Gap and Providing a Theoretical Alternative

The psychobiological model provides a scientific basis for the existence of a communication media scale (i.e., a naturalness scale) that explains previous empirical results supporting in part the social presence and media richness scales (Daft et al. 1987; Fulk et al. 1990; Kahai and Cooper 2003; Markus 1990, 1994; Rice 1993; Rice and Shook 1990; Sproull and Kiesler 1986; Walther 1996). Based on the psychobiological model, one can understand why the highest point has been consistently found to be around the face-to-face loci in the social presence and media richness scales. It is important to stress that while these theories present ingenious and well-structured conceptual frameworks on which they built their communication media scales, they never provided an underlying reason for their existence. They had to be accepted based on the implicit and intuitive assumption that the face-to-face communication medium is somehow better than other media because of characteristics inherent in that medium.

As mentioned before in this article, there has been mounting empirical evidence pointing to the flaws of the social presence and media richness scales (Lee 1994, Kinney and Dennis 1994, Kinney and Watson 1992, Kock 1998, Rheingold 1993, Walther 1996, Weisband et al. 1995, Weisband 1994). That mounting empirical evidence suggests the need for a new theory that can replace those theories. However, no alternative theory has gained acceptance within the organizational communication and information systems research communities that could explain previous empirical results supporting in part those theories (Daft et al. 1987; Fulk et al. 1990; Markus 1990, 1994; Rice 1993; Rice and Shook 1990; Sproull and Kiesler 1986; Walther 1996)—that is, the existence of a scale with a highest value around the face-to-face medium—and at the same time move beyond

Figure 1 The Media Naturalness Scale



Note. The highest degree of naturalness is found at the center of the scale.

the flaws identified based on empirical evidence against the theories. The psychobiological model, it is argued here, does that by isolating the influence of instinctive schemas (or biology) from learned schemas (which include socially learned schemas) on CMC behavior.

However, arguing that the psychobiological model can explain CMC behavior in its full complexity would be akin to proposing a modern-day version of biological determinism applied to CMC research. As with other theoretical models reviewed in this article, the psychobiological model is inherently limited and thus needs to be combined with other theoretical models to fully explain CMC behavior, an approach that has been taken by Webster and Trevino (1995) and later refined by Trevino et al. (2000).

Providing a Basis for Theoretical Integration

A detailed discussion of how the psychobiological model could be integrated with other theories is beyond the scope of this article and is suggested as future research. That integration could begin with the identification of theoretical constructs that are addressed by other theories and that are not fully addressed by the psychobiological model. Table 3 provides a summary, in approximate chronological order, of organizational communication theories subsequent to the social presence and media richness theories that have been used in the interpretation and understanding of CMC behavior. The main foci of those theories are shown in the second column.

The wide encompassing set of constructs addressed by the theories summarized in Table 3 represents some of the many different facets of CMC behavior that have been explored by researchers. They address concrete elements such as the communication medium, its technological features, and the geographic distribution of the individuals engaged in a collaborative task through a communication medium. They also address more abstract elements such as the collaborative task itself, the social environment surrounding the individuals engaged in the collaborative task, the social processes that guide individual behavior, and the social information-processing schemas that lead individuals to coconstruct the messages they receive.

The decision as to which theories to combine with the psychobiological model in order to better understand CMC behavior is likely to be contingent on the context in which CMC is used. Generally speaking, among technological theories, a strong candidate for this combination is the task-technology fit theory proposed by Zigurs and Buckland (1998) because of its comprehensive coverage of technological and collaborative task features and the fact that its theoretical basis is fundamentally different from those of the social presence and media richness theories. Among social theories, a strong candidate theory is the social influence model (Fulk et al. 1990) because of its comprehensive coverage of social influences on behavior toward technology. The combination of the theories per se is a complex task, which could then be followed by the development of hypotheses that are specific to the situation under study based on the propositions of the psychobiological model and the chosen complementary theories.

Conclusion

This article proposes a new theoretical model called the "psychobiological model," which states that there is a positive link between the "naturalness" of a communication medium—that is, how similar the medium is to the face-to-face medium—and the "cognitive effort" required from an individual engaged in a communication interaction using the medium. The model also states that this link is counterbalanced by what are referred to as "schema alignment" and "cognitive adaptation." The schema alignment construct refers to the similarity between the mental schemas of an individual and those of the other party in a communication interaction; cognitive adaptation refers to the level of schema development associated with the use of a particular medium for communication. Finally, the model states that the degree to which a medium supports an individual's ability to convey and listen to speech is particularly significant in defining its naturalness in the context of collaborative tasks and is more significant than the medium's support for the use of nonverbal cues in the form of facial expressions and body language.

This article also compares the psychobiological model with other theoretical models addressing CMC issues, particularly the social presence and media richness theories, which arguably address constructs that are similar to those addressed by the psychobiological model. It is argued, based on this comparison, that the psychobiological model can potentially replace those two theories with advantages in the context of CMC-supported collaborative tasks and be used in conjunction with other theories to provide a better understanding of CMC behavior.

The theoretical development presented in this article is fundamentally anchored on the notion that Darwinian evolution endowed modern humans with a brain that is ill adapted to CMC, because that brain has been designed, through recurrent use and evolutionary adaptation, for modes of communication that incorporate many of the elements associated with face-to-face communication. This is a notion the simplicity of which provides a solid foundation for a preliminary evolutionary understanding of CMC behavior and for the explanation of a certain amount of variation in that behavior in the context of collaborative tasks. The notion allows for a limited number of conclusions, which can be combined with those of other CMC theories so that a fuller understanding of CMC behavior can be obtained. Beyond this,

Table 3 Summary of Organizational Communication Theories Relevant to CMC

Theory	Foci	Key proposition(s)
Symbolic interactionism model	Geographic distribution, social environment	Contextual factors such as physical separation might constrain the choice of media available, making it necessary to use media that may not be the most appropriate for a given communication interaction. The choice of a medium may be also be driven by its symbolic value within a given social context (Trevino et al. 1990).
Social influence model	Social environment	Media use behavior is influenced by a variety of factors and is subject to social influence. Coworkers influence each other's media perceptions directly by discussing media and indirectly by making judgments about and interpreting different actions and events in the organizations in connection with the use of different communication media (Fulk et al. 1990).
Network theory	Social environment, social information-processing schemas	Communication media users actively coconstruct meanings of messages they receive. Not all communication is necessarily preplanned or has predictable outcomes; it will always be influenced by the social context of communication (Contractor and Eisenberg 1990).
Adaptive structuration theory	Technology features, social environment, social processes, social information-processing schemas	Communication technologies have two aspects: the "spirit," or the intent of the technology in promoting certain objectives and attitudes, such as democratic decision making, and the specific structural features designed to implement the spirit, such as anonymity in group decision-support systems. Structural features, although designed to promote the spirit, are independent of the spirit, and their use by different groups may vary considerably (Poole and DeSanctis 1990).
Gains and losses model	Communication medium, technology features, collaborative task	For many group tasks, gains outweigh losses when computers are used to support communication in task-oriented groups. For example, more ideas per unit of time (e.g., per hour) are generated in a meeting supported by a group decision-support system than an equivalent face-to-face meeting, because the system allows group members to contribute ideas without having to share "air time" (Nunamaker et al. 1991).
Communication genres model	Technology features, social processes	Communication genres in organizations—such as the memo, the report, and the meeting—are viewed as social institutions that both shape and are shaped by individuals' communicative behavior. A genre may encapsulate the communication medium used and also expand into other media, like the use of memos in e-mail (Yates and Orlikowski 1992).
Relationship development model	Social environment, social information-processing schemas	CMC media users, as users of other media, are driven to develop social relationships. Even though computer-based communication media have inherent limitations, users can adapt to them and effectively develop normal interpersonal relations, usually over a longer period of time than face-to-face or through face-to-face-like media (Walther 1992, 1996).
Social construction of reality model	Social environment, social information-processing schemas	Recipients of messages are active producers of meaning. In interacting with media such as e-mail, users transform data into information they find meaningful, based on their existing mental schemas. Users engage in a social construction of reality by joining a communication medium as "coprocessors" (Lee 1994).
Compensatory adaptation model	Communication medium, collaborative task	Better group task outcomes are possible with the use of "lean" media like e-mail as group members adapt their behavior toward technology in a compensatory way. Users of "lean" media generally tend to make more elaborate and better-quality verbal contributions in electronic meetings than they would in face-to-face meetings (Kock 1998, 2001a).
Task-technology fit theory	Technology features, collaborative task	The type of task and the characteristics of a CMC technology should present a high level of "fit" to enhance group performance. There are five main task types: simple tasks, problem tasks, decision tasks, judgment tasks, and fuzzy tasks. CMC tools are classified according to three key dimensions: communication support, process structuring, and information processing (Zigurs and Buckland 1998).
Channel expansion theory	Communication medium, social information-processing schemas	Certain experiences of media users are important in shaping their media richness perceptions, namely experience with the medium, experience with the messaging topic, experience with the organizational context, and experience with communication coparticipants. Through these experiences users develop associated social information-processing schema bases that may more effectively encode and decode "rich" messages (Carlson and Zmud 1999).

the psychobiological model provides a foundation on which to base promising further researcher by drawing on more specific evolutionary hypotheses and theories, which could also lead to a broader set of insights in connection with CMC behavior. Among those evolutionary hypotheses are the Machiavellian intelligence hypothesis, often associated with what is known as the "theory of mind" (Byrne 1995, Byrne and Whiten 1988), and the repeated assembly hypothesis (Caporael 2001). As it is shown below, not only are these ideas compatible with the psychobiological model, but they also have the potential to add new insights into CMC behavior that would arguably complement the model.

The Machiavellian intelligence hypothesis (Byrne 1995, Byrne and Whiten 1988) argues that human intelligence has been developed so that individual members of a group could learn how to best serve their purposes by manipulating other individuals without disrupting the overall social cohesion of the group. This would require that individuals be able to predict how other people would react to certain actions. That is, they would have to put themselves in those other people's shoes. Building on that hypothesis, Dunbar (1993, 1996) reached the conclusion that complex oral communication has been developed to a large extent to serve social grooming purposes. That is, individuals used social grooming to ensure favorable reactions toward them in the future. Dunbar (1993, 1996) argued that this conclusion is consistent with his general empirical observation that about 60% of the time in face-to-face communication is dedicated to gossiping. If this were correct, then it would be reasonable to hypothesize that face-to-face interactions present certain types of stimuli that would induce individuals to gossip; that is, those stimuli would trigger a "gossiping instinct." Such instinct could be counterproductive in situations where rational collaborative tasks had to be accomplished within a short time. This would lead to an interesting corollary: The suppression of face-to-face communication elements could also suppress the "gossiping instinct" and thus make CMC communication generally more focused and objective. While this effect does not invalidate the cognitive effort effect proposed by the psychobiological model, it seems to provide a counterbalancing and positive influence that could lead individuals to favor CMC media for some particular tasks. See, for example, Kock (1999) for an action research study of CMC-supported groups that provides some empirical support for this prediction.

The repeated assembly hypothesis (Caporael 2001) is based in part on the notion of multilevel selection, which unlike the more prevalent inclusive fitness theory (Dawkins 1989, Hamilton 1964, Williams 1966; this theory is sometimes referred to as "selfish gene" theory) assumes that selection occurs at multiple levels, not only at the gene level. According to Caporael's (2001, p. 617) repeated assembly perspective, "The objective of evolutionary psychology would then be to understand the system dynamics that result in variation, retention, and selection of the component parts of repeated assemblies." This perspective opens a new door for the study of communicative behavior in general, and thus CMC behavior in particular, by allowing researchers to hypothesize individual differences in behavior toward CMC technologies that could have emerged as an evolutionary reaction to cultural mechanisms developed and passed on from generation to generation to deal with specific problems. For example, as our species congregated in larger and larger social groups (Cartwright 2000, Dunbar 1993), new cultural mechanisms must have been developed to maintain a certain amount of group cohesion and social order. Those mechanisms in turn could have influenced the genetic evolution of subconscious behavioral traits by conferring higher survival and/or reproductive advantages to those individuals whose traits were better aligned with the status quo (Dunbar 1993, Miller 2000, Pinker 1997). That would lead to reinforcement of the original mechanisms and of the status quo, and so on, in a loop process similar to those found in some forms of sexual selection (Miller 2000). Such a process could have led to specieswide changes in a few thousand years, thus occurring relatively recently, as opposed to slower natural selection processes that require much longer time spans (Wilson 2000). Barkow (1992) suggested one example of such behavioral traits. We seem to have a general and subconscious compulsion to pay particular attention and give deference to individuals in positions of prominence and/or authority, which could be speculatively extrapolated to a general and sometimes counterproductive "subservience instinct." This instinct could, as many other instincts are, either be reinforced or be partially suppressed by environmental stimuli, particularly during an individual's upbringing. In the case of individuals whose instinct was not suppressed, one could argue that in organizational contexts where a variety of communication media of different naturalness were used, the instinct could lead to behavior that would have a subtle and complex but nevertheless significant effect on cognitive effort, an effect that would be cumulative to the effect already predicted based on the psychobiological model. For example, it is reasonable to expect that in interactions involving individuals at different points in an organization's hierarchy, those individuals higher in the hierarchy would tend to choose communication media that were more convenient for themselves (primarily based on rational expectations), whereas individuals lower in the hierarchy would subconsciously tend to choose communication media based on implicit (or explicit) preferences of those hierarchically above them (sometimes going against rational expectations). An employee may reply with a well-crafted e-mail to a request for information made over the phone by a director of the company, for example, based on the assumption that an e-mail reply would be more convenient for the director, when in fact a phone reply could be more effective for the discussion of the particular topic at hand. The repetition of these types of situations may ultimately lead, over many communication interactions, to a substantial shift in cognitive effort from senior managers to employees, as well as other problems, such as a decrease in the overall level of communication effectiveness in the organization (and related monetary losses). See Carlson and Davis (1998) for an empirical study that is consistent with this prediction.

The subservience instinct may also lead individuals at different hierarchical levels to use the same communication medium in different ways. Still using e-mail as an example, it would be reasonable to expect that e-mails from employees to executives would be reasonably well prepared and double-checked for typos and grammatical problems, whereas e-mails from executives to employees would generally be sloppily put together. See Florio (2001) for a nonacademic, industry-oriented, review of research supporting this expectation.

The above examples should be taken with caution, however, and so should related lines of research be pursued, because they hint at possible effects that are likely to be more contingent on situational factors than the arguably more universal effects predicted by the psychobiological model. A certain degree of universality has its advantages, at least in initial steps such as that taken through this article. The widespread use of CMC technologies today by individuals with often completely different social and cultural backgrounds and the still prevailing uncertainty about the effects of these technologies on humans warrant the search for theories that can help us predict CMC behavior based on elements that are shared by all human beings and that are relatively independent of social and cultural backgrounds. This article is a first step in that search and a small one toward the development of a grand theory that can be used to explain CMC behavior in its full complexity. Darwin's theory alone is unlikely to provide the basis for a grand theory of CMC behavior. Nevertheless, this article's ideas are presented with the hope that that theory will be instrumental in the development of some of the key aspects of a grand theory of CMC behavior.

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