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A Decade of Research Exploring Biology and Communication

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A Decade of Research Exploring Biology and Communication

The Brain, Nervous, Endocrine, Cardiovascular, and Immune Systems

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The study of communication has come a long way since Aristotle's conceptualization of persuasion in *Rhetoric* from the 4th century B.C. Today, scholars conceptualize communication in much more comprehensive ways than did those Greek Aristotelian philosophers. Still, much of the discipline of communication focuses on the way that messages have an impact on individuals or societies. Since the late 1970s a small group of communication scholars, greatly influenced by their peers in other social-science disciplines (i.e., psychology) began to direct their attention to the way that communication influences and is influenced by processes in the human body.

During the early 1990s, a group of researchers proposed a set of meta-theoretic axioms leading to the goal that specific theories could be generated related to the ways that the human body influences communicative messages and behaviors (Beatty, McCroskey, & Pence, 2009). These researchers called this set of propositions a communibiological paradigm (see Beatty, McCroskey, & Valencic, 2001). While we are not going to belabor each of the major premises of this paradigm, it is important to recognize these propositions, as they relate to this review:

> Proposition 1: All mental processes involved in social interaction are reducible to brain activity.
> Proposition 2: Communicator traits and temperament characteristics represent individual differences in neurobiological functioning.
> Proposition 3: Individual differences in the neurobiological systems underlying communicator traits are principally (but not completely) inherited.
> Proposition 4: Dimensions of situations have only negligible direct effects on behavior. (Beatty et al., 2009, pp. 5-12)

For many scholars operating from social construction paradigms, these propositions seem rather controversial with allegations ranging from these being overly deterministic (Condit, 2000) to being based on inadequate analysis of prior research findings (Nelson, 2004). Nonetheless, the original communibiology scholars argue that these propositions are "an alternative to the purely situational paradigm that began to dominate behavioral science" (Beatty et al., 2009, p. 14) and that these propositions only illustrate that communication behaviors may be explained through both proximal or distal biological influences.

Based on these points, we present the following review of recent and relevant literature on the biological dimensions of human communication. To start our review, we examined every issue of the top 20 communication journals (according to the Thompson Reuters Social Science Citation Index) beginning with issue one in 2001 through the most recent issue of 2011. We identified those articles that deal specifically with communication and biology. It was important for us to only include articles that dealt with physiology and not self-reports (e.g., self-reports of stress were not included, but physiological analyses of stress hormones were). Studies within the communibiology paradigm either focus on the direct effects of communication on markers of physiological health, or utilize physiological outcome measures as indicators of psychological processes. For example, scholars may utilize measures of heart rate to suggest the direct effect of an interaction on cardiovascular health or they may use heart rate as a measure of arousal (indicative of increased cognitive processing of a message). In both cases, physiological measures are primarily employed as outcome measures in such studies. On rare occasions, communication scholars look at physiology as the independent variable where health (such as breast cancer diagnosis) affects the process and nature of peoples' communication (e.g., Manne et al., 2004). We have omitted cases such as these where researchers did not directly manipulate or measure biological or health variables. Nevertheless, we would be remiss if we did not note that there is an extensive literature exploring the direct effects of health on communication.

In Table 1, we have included a list of the journals we reviewed by year with a frequency count of the number of articles focused on communication and biology. From 2001–2005, the relative number of research articles in communication journals dealing with biology was low with many articles of this type found in other disciplines' journals. Due to a number of special issues of communication journals, the frequency count of articles increased greatly in 2006 and has remained relatively stable since that time. Despite that, relatively few communibiological research articles have appeared in exclusively communication outlets.

In preparing this review, we do not discuss every published research article related to communibiology; rather, we decided to select the most appropriate and representative research articles to illustrate the current state of the art of this paradigm. Importantly, we have also limited the scope of our review. In doing so, we mean not to highlight one communication domain over others, nor do we intend to say that any particular domain is more important than the rest. Furthermore, we have decided to limit the scope of body systems to four primary systems—brain/nervous, endocrine, immune, and cardiovascular, as they represent the corpus of literature from communication perspectives. Finally, we have attempted to limit our review of literature to those articles that are communication-based, broadly defined as dealing with symbolic message transmission and/or interpretation. Because of that, we have excluded articles in some related social science fields (most notably, psychology). With these points in mind, the present review is designed to explore contemporary elements of communication and biology. To do this, we will first provide background on four primary systems. We will then highlight relevant research applications across a variety of communicative contexts. We will conclude with a brief summary of some general themes and provide some potential suggestions for future research endeavors.

Journal name	**'01**	**'02**	**'03**	**'04**	**'05**	**'06**	**'07**	**'08**	**'09**	**'10**	**'11**
Communication Methods and Measures	-	-	-	-	-	-	2	1	-	1	-
Commmunication Monographs	-	-	-	-	-	-	-	3	-	1	1
Communication Quarterly	-	-	-	-	-	-	-	-	-	-	-
Communication Reports	1	-	1	-	-	1	1	-	1	-	-
Communication Research	1	1	-	-	-	-	2	-	1	-	-
Communication Research Reports	-	-	-	1	-	-	-	-	-	1	1
Communication Studies	-	-	-	-	-	-	-	-	1	-	-
Health Communication	-	-	-	-	-	-	1	-	-	-	-
Human Communication Research	-	-	-	1	-	1	2	-	1	-	2
Journal of Applied Communication Research	-	-	-	-	-	-	1	-	-	-	-
Journal of Communication		1	-	-	-	-	1	-	-	-	-
Journal of Nonverbal Behavior	-	-	-	-	-	2	-	-	-	1	-
Journal of Social and Personal Relations	-	-	-	-	2	9	2	1	2	2	1
Management Communication Quarterly	-	-	-	-	1	-	-	-	-	-	1
Media Psychology	-	-	1	3	1	9	2	1	3	2	1
Personal Relationships	-	-	-	-	-	1	-	-	1	-	9
Western Journal of Communication	-	-	-	1	-	1	-	-	1	-	-
Total	2	2	2	6	4	24	14	6	11	8	16

Table 1. Listing of communication journals with frequency count of bio-communication articles by year.

Note: The following journals had no qualifying articles to review, based on our criteria: *Communication Theory*, *Journal of Health Communication*, and *Southern Journal of Communication*.

2. The Brain and Nervous System

No review of anatomy or human physiology is complete without mention of the control center of the human body—the brain. The brain, a relatively small organ in the human body responsible for the regulation of all human body subsystems, has four major regions—the cerebrum, diencephalon, the brain stem, and the cerebellum (Floyd, Mikkelson, & Hesse, 2008). The nervous system, consisting of nerves and chemical compounds, acts to transmit messages between various body subsystems and the brain, making the nervous system a distinct but connected part of brain research.

The largest part of the brain, the cerebrum consists of major nerve cells including both gray and white matter. This part of the brain largely functions to control motor skills, sensory perceptions, learning and memory, and includes some important areas for speech and language skills (Duvernoy & Bourgouin, 1999; Floyd et al., 2008). The cerebrum separates into the left and right cerebral hemispheres, which are connected by a band of tissue that transmits information between the two hemispheres—the corpus callosum. Re-searchers also divide the cerebrum into four distinct areas known as the frontal, parietal, occipital, and temporal lobes, with each largely implicated in a variety of distinct behaviors (Duvernoy & Bourgouin, 1999). For communication researchers, the frontal and temporal lobes contain two of the most important areas in the cerebrum. Broca's area, located in the frontal lobe of the left hemisphere in most people, is responsible for aspects of language production, especially with respect to syntax, structure, and lexical insertion along with control of mechanical voice-structures (Grodzinsky, 2000). Individuals with damage to Broca's area tend to have difficulty with (or cannot manage) the production of grammatically-correct sentences. Another area in the cerebrum important in human communication is Wernicke's area, located for most, in the left temporal lobe. Wernicke's area allows humans the ability to understand language meaning and process spoken and written language (Price et al., 1996). Damage to Wernicke's area typically prevents an individual from being able to create meaningful sentences and expressions (Floyd et al., 2008).

While these brain structures have clear and direct connections to the process of human communication, other major brain structures have important implications for communication as well. One of those structures, the diencephalon , located right above the brain stem (Duvernoy & Bourgouin, 1999), includes the thalamus, hypothalamus, and the pineal gland. The hypothalamus forms part of the limbic system, which regulates stress, sex drive, pleasure, and pain; we will discuss this system in greater depth in our section on endocrinology. The brain stem, sometimes referred to as the reptilian brain because of its ancient history, controls most reflex and involuntary actions including pupil dilation, heart rate, breathing, and participates in many hearing processes (Floyd et al., 2008). Finally, the cerebellum, a small part of the brain near the brain stem (Duvernoy & Bourgouin, 1999), regulates information from sensory organs and "does not engage in any conscious activity" (Floyd et al., 2008, p. 23).

While each of these structures has an impact on the brain system, one specific structure of the limbic system, as discussed above, holds particular importance for communication scholars. Amygdalae, two almond-shaped nuclei located in the medial temporal lobe (Duvernoy & Bourgouin, 1999), send signals to the hypothalamus as a result of emotional stimuli, especially to activate the physiological responses to the emotion of fear (LeDoux, Cicchetti, Xagoraris, & Romanski, 1990). In fact, researchers have found through the use of positron-emission tomography (PET) scans differential amygdala activation when research subjects viewed photos of fearful or happy faces, demonstrating a direct link between the amygdala and emotional regulation and processing (Morris et al., 1996). Importantly, amygdala activation also relates to activation of the sympathetic nervous system.

Additionally, various nervous system processes activate based on our communicative encounters with others. To provide a simple hierarchy of the nervous system, we can first divide it into two primary systems—the central nervous system and the peripheral nervous system (Floyd et al., 2008). The central nervous system includes the brain and the spinal cord while the peripheral nervous system, which helps regulate sensory input and motor functions, includes the somatic nervous system and the autonomic nervous system (Haase, 2010). Within the autonomic nervous system (ANS), two specific divisions exist. The sympathetic division is responsible for arousal and excitement, while the parasympathetic division is responsible for bringing the body back to rest (Floyd et al., 2008; Haase, 2010; Hubbard, 1974). Because these two subsystems of the nervous system easily yield to measurement and show more visible reactions (e.g., heart rate increases and sweating), communication scholars more commonly study them as dependent variables.

Communication scholars have explored the way that the brain and the nervous system have affected communication for a long time. In fact, during our review, we discovered a research article published almost a century ago in the *Quarterly Journal of Public Speaking*, which discussed the ways that environmental stimuli activated reflex processes in the brain and thereby resulted in some expression of behavior (Gaylord, 1916). While this article did not directly measure brain activity, it counts as one of the first to propose similar propositions to our working knowledge of a communibiological perspective. Indeed, Gaylord (1916) may rank as one of the first to publish neuropsychological research in a communication venue. Beatty and Lewis (2009) argue that much of communication researchers' understanding of neurology comes directly from the fields of cognitive neuroscience and neuropsychology. In a cognitive neuroscience perspective, researchers explore how social interactions and behaviors involve the brain. Specifically, cognitive neuroscientists may invite individuals to engage in some communicative act and map their brain activity using medical imaging equipment through positron emission tomography (PET), electroencephalogram (EEG), or magnetic resonance imaging (MRI) techniques (Floyd et al., 2008). For instance, McNealy, Mazziotta, and Dapretto (2010) used functional MRI (fMRI) to distinguish the neural pathway differences between children and adults from seeing words to listening to long patterns of language. In this example, the researchers could determine specific brain functions through these complex imaging techniques.

One area of brain research that communication scholars have focused on involves the study of brain hemispheric dominance, typically involving measures of handedness (right or left hand), familial handedness, and immune issues as markers of standard, anomalous, or mixed dominance (Floyd et al., 2008). Hemispheric dominance simply refers to which side of the cerebrum (left or right) dominates in acting for a specific behavior. For most people, the left hemisphere is dominant in verbal communication, while the right side is dominant in interpreting nonverbal communication (Beatty & Lewis, 2009; Floyd et al., 2008). Therefore, standard dominance includes people who process logical issues primarily in the left hemisphere and process emotional cues in the right hemisphere. However, classifications also show individuals as having either anomalous dominance (those who process these cues primarily in the opposite hemisphere) or mixed dominance (those who possess both standard and anomalous dominance). Individuals more likely fall into the anomalous dominant category if they (or family members) are left-handed. Therefore, researchers use that particular marker (coupled with a variety of other items) as an indicator of hemispheric dominance (Floyd et al., 2008). Many communication-based research articles focus on these issues (see Beatty & Lewis, 2009; Bodary & Miller, 2000; Floyd & Mikkelson, 2003; Mikkelson, Farinelli, & La Valley, 2006); we will discuss them with greater detail in context later.

While a variety of methods exist to measure brain activity ranging from the complex to the simple, the nervous system is rarely simplistic in terms of measurement. Communication scholars tend to focus, for example, on one subsystem in the nervous system: the adrenal medulla of the sympathetic division in the autonomic nervous system (typically abbreviated SAMS). The limbic region of the brain which consists of the thalamus, hypothalamus, hippocampus, amygdala, and the anterior cingulate which translate limbic system messages about a stressor into physiological responses to stress stimulate the SAMS (Zautra, 2003) while the brain stem stimulates the sympathetic division (SNS) (Brown, 2007). Stimulation of the SNS occurs through the spinal cord causing the release of norepinephrine (see sections on the endocrine and cardiovascular systems, later) in target organs and the release of epinephrine and norepinephrine (by the adrenal medulla) directly into the bloodstream (Brown, 2007). A series of measurement procedures can assess the SAMS directly, but researchers judge these measurements as generally too invasive and costly for social scientific research.

One easy-to-administer and minimally-invasive measure of SNS activation is salivary alpha amylase (sAA). Salivary alpha amylase, an enzyme secreted directly by the salivary glands, functions mainly to digest starches and carbohydrates as well as to clear bacteria from the mouth (Granger et al., 2006). Research suggests that sAA levels are associated with plasma catecholamine levels and can thus act as an indirect marker of SNS activity (Granger et al., 2006). Researchers can also assess the SNS through measures of heart rate variability (Appelhans & Luecken, 2006) though we will turn to this and other cardiovascular measures of the SNS in greater detail in a later section.

Some communication researchers have explored the impact of SNS activation on certain communication variables. For instance, Afifi, Granger, Denes, Joseph, and Aldeis (2011) explored parents and children in a study of 118 parent and adolescent child pairs. In this study, they found that adolescents with parents who reported greater amounts of communication skill tended to have greater SNS recovery after a stressful laboratory activity. These researchers also explored how certain SNS profiles (over-reactors or under-reactors) affected reports of relationships between parents and adolescents. The value of this study lies in the application of sAA to specific communicative functions. Indeed, measuring both brain function and the nervous system may seem like complicated methodologies for many social scientists, yet their relative explanatory value is useful in understanding the physiological underpinnings of communication behavior. Next, we will explore other major body systems that affect and are affected by communication. As a basic assumption of communibiology, we stress that all communication behavior originates in the brain, but other underlying biological systems can provide more specific correlates to communication behavior.

3. The Endocrine System

The body's endocrine system produces a series of chemical products that travel throughout the body to affect human functioning (Floyd et al., 2008). The endocrine system has two parts. The first consists of the primary body systems that actually produce these chemicals. These systems called glands are located throughout the body and brain (van de Graaf, Rhees, & Palmer, 2010). Unlike other systems in the body, the glands of the endocrine system do not physically connect to one another and therefore, their outputs (hormones) function as chemical messengers to communicate with other parts of the body (Floyd et al., 2008). Complicated processes (often in a specific cascade fashion) coordinate the body's glands in response to various stimuli to produce these output chemicals (van de Graaf et al., 2010).

The primary glands involved in endocrine function include the pituitary gland, the pineal gland, the hypothalamus (all located in the skull), the thyroid and parathyroid glands (both located in the neck), the pancreas and adrenal glands (located in the abdominal region), and the ovaries, and the testes (located in the pelvic region). The thymus, stomach, duodenum, placenta, and the heart also have an endocrine function (van de Graaf et al., 2010).

The second part of the endocrine system consists of the hormones produced by these glands; these hormones can only act on the specific parts of the body (known as target cells or target organs) that have receptors for that hormone (Floyd et al., 2008; van de Graaf et al., 2010). The endocrine system is thus highly varied with multiple glands producing a large number of hormonal outputs, all of which have different functions.

Researchers classify hormones by either their chemical composition or by the way that they bind to target cells and organs. Catecholamines, characterized by an amine group (NH_2), include epinephrine and norepinephrine. Glycoproteins such as Leutinizing Hormone (LH) and Human Chorionic Ganadatropin (HCG) are characterized by large proteins combined with carbohydrates. Steroids, lipids derived from cholesterol, include cortisol, estrogen, and testosterone. Finally, fatty acid derivatives such as prostaglandins are composed of long hydrocarbon acid chains (van de Graaf et al., 2010). Lipid soluble (group 1 or lipophilic) hormones such as the steroid hormones bind intracellularly and can cross cell membranes whereas water soluble (group 2 or hydrophilic) hormones such as the catecholamines bind to surface receptors and are able to stay in extracellular fluid (van de Graaf et al., 2010).

One system of glands and hormones of particular interest to communication researchers is the Hypothalamic-Pituitary-Adrenal (HPA) Axis which is stimulated by the limbic region of the brain (Dickerson & Kemeny, 2004; Zautra, 2003). Appraisals made in the limbic region cause the hypothalamus to release corticotrophin releasing hormone (CRH; Pollard & Ice, 2007). CRH release stimulates adrenocorticotrophic hormone (ACTH) secretion by the pituitary gland. Finally, ACTH causes the adrenal cortex to secrete cortisol into the bloodstream (Dickerson & Kemeny, 2004). The hypothalamus in particular is believed to be crucial in translating neural activity in response to stress into the specific response elicited by HPA activation.

The end product of HPA activation, the steroid hormone cortisol, serves a series of functions. First, cortisol aids in metabolism to provide much needed fuel for the body to respond to a stressor. Specifically, it assists in breaking down fats and proteins in tissue and converts amino acids to glucose in the liver (Dickerson & Kemeny, 2004). Additionally, evidence exists that cortisol acts as a natural anti-inflammatory by inhibiting proteins that regulate inflammation. Cortisol also interacts with other bodily systems such as the cardiovascular system and the SNS in order to mount an adaptive response to various stressors. Finally, some evidence shows that cortisol shuts down reproductive function (possibly to conserve and reroute energy; Pollard & Ice, 2007).

We would like to note though, that only certain stressors trigger HPA activity (Dickerson & Kemeny, 2004). This may result in part from the fact that the HPA system is a much slower acting system than is the SAMS (Pollard & Ice, 2007). Much research suggests that the body activates HPA in times where self-preservation and particularly social self-preservation is the primary goal. Dysregulation of the HPA axis is associated with both hypercortisolism and hypocortisolism, an increased cortisol awakening response (CAR), increased cortisol reactivity to an acute stressor, and a variety of other related syndromes and illnesses (Dickerson & Kemeny, 2004; Nicolson, 2008; Pollard & Ice, 2007). In the absence of dysregulation, cortisol follows a specific diurnal rhythm (Nicolson, 2008). Cortisol levels appear highest upon wakening, generally peaking approximately 30 to 40 minutes after awakening and slowly declining throughout the day, reaching their lowest levels between the hours of 10 p.m. and 4 a.m. with the exception of a moderate spike during lunch time (Nicolson, 2008). A flattening of this slope usually indicates HPA dysregulation.

Communication researchers can measure cortisol in blood, urine, or saliva (Pollard & Ice, 2007), but because venipuncture can cause stress in and of itself, and because of the fact that researchers largely find it impractical to collect blood and urine samples in the field, they use salivary cortisol as the preferred measure for many communication studies. Because cortisol passively diffuses into saliva, it is independent of and unaffected by SNS induced changes in salivary flow rate and produces a reliable measure of HPA activation (Nicolson, 2008; Pollard & Ice, 2007).

The second set of hormones often studied in the social sciences involve the amine hormones epinephrine and norepinephrine (catecholamines) which the body releases as a result of sympathetic arousal (see section on the nervous system above). Both epinephrine and norepinephrine interact with the cardiovascular system to increase blood pressure through constriction of the blood vessels, to dilate respiratory passages, and in concert with the musculoskeletal system, to increase muscle efficiency (van de Graaf et al., 2010). Because the body releases epinephrine and norepinephrine as part of the fight-or-flight response of the SAMS, these two outputs are often examined as markers of the body's immediate response to stress (Brown, 2007).

Other endocrine outputs studied by communication scholars include the sex hormones (androgens and estrogens), growth hormone (involved in cell, bone, and muscle growth), prolactin (involved in lactation), follicle stimulating hormone (involved in reproduction), luteinizing hormone (involved in ovulation and production of progesterone), oxytocin (involved in pain reduction and pair bonding, notably during childbirth and sexual intercourse), and vasopressin (involved in water regulation as well as in pain and stress reduction) (van de Graaf et al., 2010). By no means an inclusive list of the hormones produced by the body, this serves rather as a brief overview of the primary hormones referenced in research on human communication. Whereas researchers can measure some endocrine outputs non-invasively, they must measure other hormones intravenously; therefore these measurements require complex protocols (see Luecken & Gallo, 2008). As a result, much as our review of endocrinology focuses disproportionally on cortisol, much of the communication literature also targets cortisol as a primary hormone of interest.

4. The Cardiovascular System

The cardiovascular system consists of the heart (a four chambered organ consisting mostly of smooth muscle) and the veins, arteries, vessels, and capillaries comprising the vascular system (van de Graaf et al., 2010). In its *primary* function, the cardiovascular system transports oxygen and removes carbon dioxide and other waste from cells in the body (Uchino, Cacioppo, & Kiecolt-Glaser, 1996) as well as transports hormones (see endocrine system above) to target cells and organs (van de Graaf et al., 2010). Nevertheless, cardiovascular functioning also serves as an important marker of the body's ability to mount a stress response. Furthermore, cardiovascular functioning acts as an important outcome measure of long-term exposure to stress (Goyal, Shimbo, Mostofsky, & Gerin, 2008).

A healthy human heart circulates the body's entire blood volume, approximately 7% of a person's body weight, or on average about 10 pints, around the body every minute (van de Graaf et al., 2010). Human blood is composed of erythrocytes (also called red blood cells or RBCs), leukocytes (also called white blood cells), various proteins, molecules, ions, and thrombocytes (or platelets) suspended in plasma (Floyd et al., 2008; van de Graaf et al., 2010).

Blood plasma consists mainly of water (approximately 91% of total plasma composition), as well as of proteins such as albumins and globulins, electrolytes, nutrients (such as glucose, lipids, cholesterol, amino acids, and vitamins), hormones, dissolved gasses, and waste products (van de Graaf et al., 2010). Cholesterol's presence in the blood holds particular interest for social scientists as they can easily and reliably measure it through a minimally invasive finger stick procedure, a method that requires limited training and no formal medical certification (Floyd et al., 2009).

The body produces the lipid cholesterol primarily in the liver although dietary factors also have a significant impact on blood lipid levels. Cholesterol assists in the metabolism of certain vitamins, acts on cell membranes, and (among other functions), serves as the metabolic precursor of the steroid hormones in the body (see endocrine system above; Floyd et al., 2008). Cholesterol consists of high density lipoproteins (HDL) and low density lipoproteins (LDL), known as "good" cholesterol and "bad" cholesterol, respectively. The buildup of bad cholesterol in the body and an imbalance of HDL:LDL can lead to plaque buildup in the arteries and subsequent coronary diseases such as hypercholesterolemia, hypertension, and heart attack. As such, some health interventions proposed by communication scholars aim specifically at lowering cholesterol with the intent to directly decrease risk for heart disease and death (Floyd et al., 2009).

The heart's function is controlled primarily by the sinoatrial (SA) node, which functions as a pacemaker determining the rate at which the heart contracts and thus circulates blood throughout the body. The SA node is innervated by both sympathetic (SNS) and parasympathetic (PNS) branches of the autonomic nervous system (Appelhans & Luecken, 2006).

Activation of the SNS exerts an excitatory influence on the SA node, increasing the rate at which the heart contracts, whereas parasympathetic activation inhibits SA activity, decreasing the rate at which the heart contracts, and thus the two systems function in an antagonistic fashion to control heart rate. This means that heart rate can result from either SNS induced activation *or* PNS induced inhibition of the SA node (Appelhans & Luecken, 2006). Although heart rate varies considerably depending on a person's activity level, an average resting heart rate ranges from 70–80 beats per minute (Floyd et al., 2008) and BPM serves as a common measure of cardiovascular health (Floyd et al., 2008). At rest, the PNS system dominates and serves as the primary mechanism that regulates heart rate (Appelhans & Luecken, 2006).

The SNS and PNS "rely on different signaling mechanisms with different temporal effects" (Appelhans & Luecken, 2006, p. 230). Whereas the SNS relies on transmission of norepinephrine, the transmission of acetylcholine regulates PNS. As a result, the influence of the PNS on the heart is much more fast-acting than that of the SNS. Thus, a measure such as respiratory sinus arrhythmia (associated with inspiration and respiration of air in the lungs) serves as a direct measure of the PNS as it is the only system possessing a rapid enough latency of action to mediate heart rate associated with respiration (Appelhans & Luecken, 2006). In addition to respiratory sinus arrhythmia and heart rate, researchers have used a series of other measures to index the cardiovascular system as the efficiency with which the cardiovascular system responds to stressors indicates one's ability to regulate emotion and also indicates overall health (Appelhans & Luecken, 2006; Goyal et al., 2008).

Aside from cholesterol, heart rate and blood pressure are two of the most common measures of cardiovascular health. Assessments of the cardiovascular system generally involve taking either baseline measures of blood pressure or heart rate (generally an average of several readings), cumulative cardiovascular load over a certain period of time, heart rate or blood pressure variability over a period of time, or reactivity to laboratory induced or naturally occurring stressors (Appelhans & Luecken, 2006; Gerin, Goyal, Mostofsky, & Shimbo, 2008; Goyal et al., 2008; Janicki-Deverts & Kamarck, 2008).

Researchers can assess heart rate noninvasively with an electrocardiogram (ECG), which can also measure heart rate variability in response to various stressors (Appelhans & Luecken, 2006). Alternatively, blood pressure monitors typically also provide a heart rate reading (Goyal et al., 2008). Blood pressure measures the force with which blood hits arterial walls and is usually measured as mean arterial pressure. Typically, measurements record both systolic (SBP) and diastolic (DBP) pressure (though this can lead to an increase in Type I error). Systolic pressure is associated with contraction of the ventricles and DPB is associated with relaxation of the ventricles (Gerin et al., 2008). Elevated heart rate and blood pressure are associated with a series of adverse health outcomes including heart, brain, kidney, and liver damage (Gerin et al., 2008).

Researchers can also assess blood pressure intraarterially and though this provides the most accurate measurement form, its invasive nature makes it impractical for social scientific research. The most common system of blood pressure monitoring involves encircling the upper arm with a cuff containing an inflatable bladder and then assessing the pressures at which the heart contracts and relaxes. Trained researchers can perform these measurements manually, or an ambulatory blood pressure monitoring device can accomplish the task automatically. Participants can wear the devices continuously for a predetermined period of time to assess changes in blood pressure under the participants' normal living conditions in the context of daily life (Janicki-Deverts & Kamarck, 2008); such devices therefore aid considerably when ecological validity holds particular importance.

5. The Immune System

Another area of burgeoning research in communibiology explores how the immune system reacts to social interactions. The immune system, a critical body system, functions to protect humans from foreign antibody generating organisms (antigens), which include viruses, bacteria, fungi, and parasites. The system itself consists of a complex network of "integrated cells and soluble molecules that work in concert to protect the body from foreign agents" (Prather & Marsland, 2008, p. 236). When scientists conceptualize the immune system, they propose two specific divisions—natural and acquired immunity (Wise & Carter, 2002). Present at birth, natural immunity does not require any particular recognition of antigen properties (Prather & Marsland, 2008); it consists of skin and mucous membranes (Wise & Carter, 2002). Natural immunity also includes natural killer cells and granulocytes that can detect and destroy certain invading organisms. Cells involved in the natural immune response have fast response latency and can attack a wide variety of different pathogens (Segerstrom & Miller, 2004). The natural immune response leads to inflammation due to the action of macrophages and neutrophils, as well as the release of pro-inflammatory cytokines. Additionally, the natural response involves the action of natural killer cells which protect the body against viral infections during initial stages of viral invasion (Segerstrom & Miller, 2004). Acquired immunity rests entirely on the system's ability to recognize antigens that the system has already encountered in some fashion (e.g., by infection or through immunizations). This system further subdivides into active (adaptive) and passive immunity (Wise & Carter, 2002). An active immune response is specific to an antigen and the system will not respond in the same way to another antigen. A passive immune response relates to human interference with the immune response, when the body has not actually encountered the specific antigen, such as when a person receives an immunization to guard against tetanus (Wise & Carter, 2002). We could consider the acquired response specific immunity, an immune response targeted to a specific cell. The specific immune response has a slower response latency and the specialization (as the name implies) to attack certain pathogens. Lymphocytes involved in the specific response have receptors specific to a particular invader which bind to that invader and that invader only. Once the body detects the invader, the cells proliferate to mount the body's response to that pathogen. The specific response also leads to the production of antibody proteins that function to neutralize toxins, prevent viruses from entering cells, and serve a variety of other functions including aiding in the natural immune response (Segerstrom & Miller, 2004).

A concept inextricably linked to immunoresponse is that of inflammation. Externally, inflammation appears marked by redness and swelling due to increases in blood flow at the site of infection. A similar response occurs internally in the body, as blood flow increases to deliver more antibodies to the infection in order to destroy the pathogen. With this reaction come a variety of biological substances that circulate in the bloodstream (Dunn, 1991). One of those class of chemicals that mediate inflammatory response, cytokines are secreted in nucleated cells and act as signaling modulators for immune response (Dunn, 1991). Some cytokines include Interleukin-1 Alpha and Beta (IL-1α, IL-1β), Tumor Necrosis Factor Alpha (TNFα), and Interleukin-2 (IL-2). Each of these cytokines results in increasing local or general inflammation, stimulating lymphocyte production, or activating other elements of immunoresponse. Additionally, other ancillary markers of inflammation have been used successfully in research endeavors, including C-Reactive Protein (CRP), a marker of overall systemic inflammation (Danesh et al., 2004). Elevated CRP has links to various psychosocial stressors including post-traumatic stress disorder, burnout, and low socio-economic status. Elevated CRP also predicts future cardiovascular disease and thus serves as an important marker of immune dysregulation (McDade, 2007). Due to the immune system's complex network of interactive components, including some of the components discussed above, researchers have not found a single measurement of immune function available to them (Prather & Marsland, 2008). Therefore, it becomes increasingly important for researchers to identify some particular element of immune system function to study.

Some measures are enumerative (i.e., quantification of white blood cells, immunoglobulins, or cytokines) while others evaluate functional measures of the immune system such as looking at specific antibodies (McDade, 2007; Segerstrom & Miller, 2004). Many studies assess immune function by looking at lymphocyte proliferation where reduced proliferation (blastogenesis) associates with decreased immune functioning. Other studies may examine natural killer cells' ability to attack infected or cancerous cells (McDade, 2007). One particularly useful method to evaluate communication influences on the immune system is to evaluate viral antibodies by using blood. In one famous study, Cohen, Doyle, Turner, Alper, and Skoner (2003) had participants (N = 334) complete questionnaires about their social interactions with others and subsequently quarantined them for five days exposing them to a particular type of Rhinovirus (the virus that causes the common cold). Those individuals with the lowest measures of sociability had the greatest instances of cold symptoms on objective criteria. Cohen and colleagues concluded that individuals with larger social networks tended to have more robust immune systems, thereby resisting the development of the common cold.

Another area of research that communication scholars regularly use to evaluate immune system function and reactivity is to determine antibodies associated with latent virus (instead of exposing someone to viruses). For instance, the Epstein-Barr virus (EBV), a virus common in many adults, can be studied in this context. In fact, by the age of 40 years nearly 80% of adults have been infected with EBV (Jones & Straus, 1987), the virus associated with mononucleosis. When reactivated, the virus releases specific antigens that increase levels of antibodies associated with the virus capsid antigens (Prather & Marsland, 2008) allowing researchers the ability to evaluate whether or not some stimulus activates antibody production. When individuals experience chronic stress, including psychological stress, cellular immunity is typically suppressed, causing viruses such as EBV to release additional antigens. One example of this method comes from Glaser and colleagues (1991) who found that medical students who underwent a psychologically stress inducing activity had increases in their EBV antibody titers. More recently, Floyd, Hesse, Boren, & Veksler (2012) also used EBV antibodies to evaluate immunosuppression due to affectionate communication. In both of these cases, researchers used EBV antibodies as a marker of immune system function.

6. Biological Communication Research Applications

So far, we have provided some framework for the study of human communication and biology through a discussion of four major body systems. In the next section, we will discuss research endeavors utilizing measures of these systems across a variety of communicative contexts. In doing so, we have explored relevant, but not all, areas of research utilizing a communibiological approach.

A. The brain and nonverbal communication

Our bodies can have subtle and sometimes subconscious effects on the way that we communicate. One such way that our bodies affect us at a subconscious level comes from the impact of brain activity on interpersonal attraction. For example, women find voices either medium or low in average fundamental frequency more attractive than voices high in average fundamental frequency (Riding, Lonsdale, & Brown, 2006). Evidence from biological studies even suggests a halo effect due to the way the brain processes vocalizations. As a result, a marked "what sounds beautiful is good" bias reflects that "ratings of vocal attractiveness correlate with phenotypic markers of health and reproductive fitness" and that "listeners also attribute more positive personality characteristics to persons with attractive voices" (Bruckert et al., 2010, p. 118). Direct manipulation of vocal cues provides one method to examine the effect of the nonverbal function of speech on human attraction. While voice can signal attractiveness and genetic fitness leading to attraction, attraction in and of itself can lead to perceptible alterations in one's use of one's own voice. Hughes, Farley, and Rhodes (2010) found significant differences in vocal pitch when people spoke to attractive versus unattractive others and had greater physiological reactivity (measured by galvanic skin conductance) when speaking to an attractive individual. Taken together these findings suggest non-conscious physiological reactions to attraction that communication researchers can directly measure.

Gender differences exist as well. Some research suggests that women have greater interpersonal/emotional expressivity and sensitivity than men do (Mikkelson et al., 2006; Riggio, 1986). That is, women are more capable of encoding and decoding nonverbal affect, making them better at emotional communication. This superiority, then, has a direct effect on gender differences in interpersonal communication (Riggio, 1986). One biological explanation for differences in nonverbal decoding ability between the biological sexes relies on hemispheric dominance (Floyd & Mikkelson, 2003; Mikkelson et al., 2006), which exposure to testosterone in-utero affects, though not necessarily determines (Galaburda, Corsiglia, Rosen, & Sherman, 1987).

According to research by Floyd and Mikkelson (2003), women and men who have anomalous hemispheric dominance exhibit similar accuracy in decoding facial affect (a nonverbal cue), and women with mixed hemispheric dominance demonstrate more accuracy than women who are primarily right or left dominant. Furthermore, Bodary and Miller (2000) found that hemispheric dominance also affects communicator style preferences such as relaxed, friendly, and open communication, thus indicating that brain lateralization plays a role in how people enact emotion in addition to how they interpret it. In all cases, biological sex and hemispheric dominance interact to produce varying levels of emotional sensitivity (Bodary & Miller, 2000; Floyd & Mikkelson, 2003; Mikkelson et al., 2006).

While Floyd and Mikkelson (2003) argue that social and developmental factors obviously contribute to one's emotional communication competence and social skill, this research suggests that we should not overlook neurological factors as they may have an important effect on communicative behavior. These findings illustrate some of the underlying assumptions of communibiology, especially from a cognitive neuroscience perspective. Of course, the brain affects more than nonverbal interpretation.

B. The brain and verbal communication

A variety of neurological processes play roles in planning a verbal message needed to accomplish an interpersonal interactional goal, though some situations (such as when a person employs a previously successful strategy), may prove less cognitively taxing than others (Beatty & Heisel, 2007). Beatty and Heisel (2007) directly examined the cortical processes involved when interaction plans go awry. They used an

EEG to measure the electrical activity in the dorsolateral region of the prefrontal cortex (DLPFC), an area of the brain involved in information processing. In theory, more complex rational thought should increase demand on the DLPFC as evidenced by increased activity measured by the EEG. As predicted, accessing stored messages (previously employed means for accomplishing an interactional goal) did not cognitively tax the brain as much as having to revise the messages in the face of failure. For example, the task of retrieving $50 lent to a friend became more cognitively challenging when the friend rebuffed the initial request (therefore requiring a modification of the original message). This then provides support for cognitive theories of communication that argue that successful interactions lead to the development of memory structures to facilitate future interactions.

C. Interpersonal communication research

An abundance of evidence supports the long held hypothesis that interpersonal relationships provide great joy and confer various psychological and physiological health benefits (Cohen et al., 2003; Seeman, Singer, Ryff, Dienberg Love, & Levy-Storms, 2002; Uchino et al., 1996). For example, "positive social interactions are related to reduced HPA activity and serve as a buffer against depression and anxiety" (Byrd-Craven, Granger, & Auer, 2011, p. 471). Unfortunately, these very same relationships can also cause distress and can lead to serious negative health outcomes (Kiecolt-Glaser et al., 1987; Klinetob & Smith, 1996; Miller, 1997; Robles & Kiecolt-Glaser, 2003). "For most of us, romantic relationships provide some of the most meaningful experiences of our lives. They are the source of our most intense joy and, for many, our most desperate pain" (Klinetob & Smith, 1996, p. 945). According to Rook and Pietromonaco (1987), "those close to us at times afford great comfort and at other times cause great frustration" (p. 2).

In fact, the potential for distress associated with interpersonal relationships has given rise to a large body of research on the so-called "dark side" of relationships (Miller, 1997; Spitzberg & Cupach, 1998). Thus, plenty of evidence supports the assertion that interpersonal relationships serve the dual function of protecting us against the damaging effects of stress and also act as stressors in and of themselves (Miller, 1997; Robles & Kiecolt-Glaser, 2003; Rook & Pietromonaco, 1987). A decade ago, Kiecolt-Glaser and Newton (2001) identified 64 studies pertaining to marriage and physiological health. Since that time, the research on this topic has proliferated exponentially, examining virtually every aspect of romantic interactions and the subsequent effects on human physiology. Therefore researchers have extended a variety of hypotheses to explain the mechanisms by which close relationships can both harm and hurt us; many of these begin in the biocommunicological paradigm. For example, some research suggests that certain interpersonal processes such as approach or avoidance motivations are modulated by the endocrine system (through testosterone and cortisol) rather than by conscious psychological processes (van Honk, Schutter, Hermans, & Putman, 2004). Therefore consistent with the primary argument of our review, evidence exists to support that the nature of interpersonal communication both affects, and is affected by, our physiology.

D. Children and families

Many researchers have focused on the ways that social relationships in familial units affect individual health. For instance, in a five-part study and review, Granger and colleagues (Granger et al., 2006) explored salivary alpha-amylase (sAA) as a dependent variable in children and parent relationships. They found associations between alpha-amylase levels and social/behavioral variables. As an example, in one study, they found that mothers had alpha-amylase reactivity when they watched their infant child perform a challenge task. In addition, they found conflicting patterns between cortisol and alpha-amylase reactivity across many of the five studies, underscoring the need to explore both HPA and SNS systems in research on children and families. In a related study, Afifi and colleagues (2011) measured both HPA (with cortisol) and SNS (with sAA) response patterns of 118 parent-adolescent dyads after discussing a stressful relational topic in a laboratory setting. They found that adolescents "who think their parents are more communicatively skilled are more likely to recover from a stressful interaction than adolescents who think their parents are less skilled" (p. 290). Taken together, both of these studies underscore the interaction between individuals in a family unit, potentially causing underlying body systems to respond as a function of communication.

Other lines of research on children and families look not at inherent family interaction; rather, they evaluate specific family dynamics on physiological outcomes. In a study with 112 parent-adolescent dyads, Afifi, Afifi, Morse, and Hamrick (2008) explored the impact of topic avoidance about divorce and adolescents' physiological arousal. Using skin conductance level (SCL) to assess physiological arousal as a variable in their path model, they found that adolescents experienced physiological arousal when their parents talked to them about their divorce.

These dynamics may have an impact throughout a person's lifespan. For instance, Luecken, Appelhans, Kraft, and Brown (2006) found that early family conflict had an effect on the way that children would manage emotional and cognitive responses to future stressful situations. Additionally, Merjonen and colleagues (2011) evaluated 819 children and adolescents over the course of 21 years to see whether genetic polymorphisms of serotonergic receptors moderated early caregiving on later-life hostility. They found that "non-nurturing environments may be a risk factor for later hostile attitudes in all children, but that carriers of a particular genotype might be especially sensitive to environmental exposures" (p. 192). In this case, much like Luecken at al., Merjonen and colleagues argue that the ways in which conflict communication functions in an early family environment may affect later life, but can also be a function of genetics and physiology. Finally, some work connects ongoing family communicative dynamics and health aspects. An example of this comes from research conducted by Lawler-Row, Hyatt-Edwards, Wuensch, and Karremans (2011) who demonstrated a link between state forgiveness due to a conflict episode and cardiovascular reactivity. They found that young adults who had higher state forgiveness in their families had a faster cardiovascular recovery from a stressful event. Interestingly, they also found that forgiveness acted as a key mediator between child-parent attachment style and health.

E. Process of human attachment

Another particularly fruitful area of research lies in the study of adult attachment (see Selcuk, Zayas, & Hazan, 2010 for a review). In particular, communication scholars have examined the role attachment plays in interpersonal interactions and the subsequent effects on relationship longevity and satisfaction, as well as on the physiological health of the relational partners. Marriage is the primary adult pair bond and the spouse is the primary adult attachment figure (Selcuk et al., 2010) although others have argued that individuals form attachments to dating partners as well (Powers, Pietromonaco, Gunlicks, & Sayer, 2006).

Powers et al. (2006) found a relationship between individuals' attachment styles and their HPA reactivity and recovery in response to an interpersonal stress task. Furthermore, Powers and colleagues argue that objective measures of stress such as HPA reactivity and recovery can differ from those elicited through self-reports and can provide greater insight into interpersonal processes than can self-report measures alone. Not surprisingly, insecure attachment is associated with a more pronounced physiological stress response (though the response patterns differ for men and women).

Kim's (2006) results indicate that individual attachment styles also affect cardiovascular functioning. A particularly interesting finding notes that attachment avoidance is associated with lower Resting Pulse Product (RPP; an inability to deliver oxygen to the myocardium) which may lead to cardiovascular events. This maladaptive physiological response to stress does not function to protect the person in the short-term thereby making interpersonal conflict particularly dangerous for these individuals. It appears, then, that insecure attachment correlates with heightened cardiovascular reactivity to interpersonal conflict. However, many methodological concerns can be raised in regards to this study, and therefore people should consider the findings and interpretations with caution.

Findings such as those discussed above shed interesting light on the argument that the desire to avoid physiological stress by avoiding conflict interactions may in part govern romantic partners' interactions. The idea that certain individuals, based on gender and attachment style, may be more conflict aversive due to the physiological discomfort associated with these discussions has implications for how couples communicate about their problems. For example, the findings of Powers et al. (2006) suggest that avoidant women experience physiological relief (as evidenced by faster HPA recovery) upon disengagement from conflict. In other words, these women quite literally feel better once they can end a conflict interaction. This may serve as a physiological motivation to engage in relationally harmful behaviors such as withdrawal (Caughlin, 2002). Furthermore, individual attachment styles appear to interact dyadically. For example, a woman's secure attachment functions to buffer her romantic partner against the physiological stress of engaging in a conflict interaction.

Finally, attachment not only plays a role in people's health when together, but also upon separation. Couples who separated from one another (e.g., to go on a short business trip) experience disturbed sleep, especially for those with high attachment anxiety (Diamond, Hicks, & Otter-Henderson, 2008). Those scoring high on attachment anxiety also showed heightened HPA activity during separation as compared with those scoring low on anxiety, indicating that physical separation leads to physiological stress.

F. Relational uncertainty

Much of the research on physiological reactivity to interpersonal discussions (as is the case with the studies reviewed below) focuses on conflict communication where the nature of the discussion topic often differentially affects men versus women because women more often react physiologically to intra-relational stressors than do men (Wanic & Kulik, 2011). Interestingly, when the laboratory task does not relate to conflict, the same physiological pattern does not necessarily emerge. Loving, Gleason, and Pope (2009) found that when dating partners discussed their potential for future transition from dating to marriage, no significant gender differences emerged in participants' cortisol reactivity. Nevertheless, the discussion about a novel relational state does elicit a physiological stress response where novelty of the topic correlates with greater HPA reactivity. In other words, the idea of confronting a significant, but not inherently negative, relational discussion proves stressful for both men and women and the relative novelty of the topic exacerbates this stress. Loving et al. (2009) do note that the HPA reactivity found in their study may not necessarily indicate a stress response but may simply occur as a byproduct of other physiological cascades such as those involved in falling in love (which also increase cortisol levels); therefore future research on the mechanisms involved in the cortisol reaction to this particular type of discussion is clearly warranted.

Priem and Solomon (2011) found a differential physiological response in reaction to a hurtful conversation depending on how much uncertainty a person experiencied. Specifically, they found that when experiencing uncertainty about a romantic partner's feelings for them, participants had a stronger cortisol reaction to the conversation than did those who experienced less partner uncertainty. Furthermore, partner uncertainty also correlated with less recovery from a laboratory induced stressful task (suggesting sustained HPA activation). These findings suggest that the experience of uncertainty in romantic relationships can prove stressful in and of itself, can have an effect on the physiological experience of other stressors, and can impact the strength of the ameliorative effect of supportive interactions with one's partner (Priem & Solomon, 2011). Notably, self-uncertainty led to a different pattern of findings than did other forms of uncertainty; this finding needs more in-depth study in future research.

G. Interpersonal conflict

Even though relational uncertainty can induce stress, it differs markedly from the experience and effects of actual conflict. Kiecolt-Glaser, Bane, Glaser, and Malarkey (2003) studied the physiology of newly married couples during their first year of marriage (time 1) and found that increased epinephrine during conflict discussions increased the probability of divorce at time 2, ten years later. Whereas epinephrine levels did not differ for satisfied and dissatisfied couples who remained married at follow-up, individuals indicating dissatisfaction with their marriages at follow-up had significantly higher norepinephrine levels during time 1 conflict interactions than did those who were satisfied at follow-up; women who were dissatisfied at time 2 had elevated ACTH levels during time 1 conflict. Additionally, epinephrine levels remained elevated throughout the day for couples who later divorced and both epinephrine and norepinephrine levels remained elevated at night for couples who later divorced.

These data indicate that elevated catecholamine levels are not limited to times when spouses engage in conflict but remain relatively sustained throughout the day and night for couples who later divorce. Taken together, these findings suggest a different pattern of endocrine functioning for couples who later report negative marital outcomes than couples who remain happily married. Interestingly these findings of differential endocrine functioning are independent of self-reports of marital satisfaction at time 1 suggesting that endocrine function can act as a harbinger of hidden relational danger. In other words, "stress hormones may function as a kind of bellwether in early marriage, reflecting emotional responses that individuals, particularly women, have not yet acknowledged consciously" (Kiecolt-Glaser et al., 2003, p. 187).

Age and relational duration can also affect the experience of conflict. Heffner et al. (2006) found that in older married couples perceptions of (rather than objectively observed) wife demand/husband withdrawal behavior during conflict increased cortisol reactivity for both husbands and wives. These findings suggest that perceptions of behavior over the course of a marriage may have effects on physiology during conflict episodes independent of what actually happens in a given conflict episode, thereby affecting health over the long-term. Kim (2006) found that relationship duration affected cardiovascular reactivity to a hypothetical relational stressor as measured by diastolic blood pressure (DPB) and rate pressure product (RPP). Men reacted more to stressful situations marked by negative affect. While the spike in RPP may prove adaptive in the short-term, this stress reactivity to communicative events may lead to negative outcomes in the long-term. These findings suggest that men may avoid interpersonal conflict due to a motivation to escape the negative physiological effects of encountering negative affect.

Finally, Loving, Heffner, Kiecolt-Glaser, Glaser, and Malarkey (2004) found that during conflict, relative marital power had an effect on both ACTH and cortisol levels and that consistent gender differences appeared in the way power discrepancies influenced hormone levels. For example, husbands appear to have heightened reactivity to conflict both when they are low in power and when couples share power in the marriage whereas wives who lack power in their marriages may be more susceptible to negative health outcomes.

Other research on couple conflict has involved experimentally manipulating hormones rather than simply measuring hormone levels as outcome variables. For example, Ditzen et al. (2009) administered oxytocin intranasally and asked married couples to engage in a conflict activity. Results indicated reduced post-conflict salivary cortisol levels in both men and women in the oxytocin (as opposed to control) group and that those in the oxytocin group had a greater duration of positive behavioral interaction relative to negative interactions.

H. Alcohol use and interpersonal interactions

In addition to conflict, sexual coercion and rape form another important topic in the realm of dark-side communication. Statistics vary widely, but generally indicate that unwanted sexual activity occurs more commonly than one might think. For example, in a recent study of college students (*N* = 351), Palmer, McMahon, Rounsaville, and Ball (2010) found that more than 30% of men and almost 35% of women surveyed reported experience with unwanted sexual activity. Clearly, as a matter of great importance communication researchers should seek to understand the often complex communication processes involved in the perpetration of sexual violence and in the experience of victimization. Palmer et al. (2010), consistent with prior research, found a large correlation between alcohol consumption and unwanted sexual activity.

A communibiological perspective provides one explanation for this phenomenon. The physiological effects of alcohol consumption decrease a person's ability to attend to certain behavioral cues (Lannutti & Monahan, 2002). This can lead to a perpetrator's inability to interpret cues that may indicate resistance to one's sexual advances (especially in the presence of conflicting cues), or the potential victim's inability to perceive coercive/dominant/forceful cues at the time of the interaction—a perspective known as Alcohol Myopia Theory (AMT; see Griffin, Umstattd, & Usdan, 2010 for a review).

Studies consistently indicate that alcohol consumption has a significant and perceptible effect on communication behavior (Lannutti & Monahan, 2002; Monahan & Samp, 2007; Samp & Monahan, 2009). For example, Lannutti and Monahan (2002) found that alcohol consumption affected participants' (*N* = 51), ability to interpret the nature of a sexually coercive situation. When presented with a communicative event marked by negotiation of sexual activity, sober participants could utilize multiple relational frames to understand a scenario marked by mixed cues (dominance and affiliation). On the other hand, when intoxicated, participants tended to expend less cognitive energy on interpreting the sexual interaction. In a different study, 44 dating couples engaged in an interaction discussing a hypothetical relational transgression (infidelity). Those consuming alcohol were less positive and more agitated than were sober individuals having similar discussions, suggesting that alcohol affects the nature of nonverbal communication during relationally relevant discussions (Samp & Monahan, 2009).

I. Affection exchange theory and the bright side

Whereas much of the research reviewed above focuses on the "dark side" of communication (e.g., conflict or relational uncertainty), research on the "bright side" of communication indicates that communication does have positive effects. In fact, positive communication can have a beneficial effect on both psychological and physiological health. Much of this research in communication has its roots in Affection Exchange Theory (AET; Floyd, 2001). According to AET, the exchange (acts of sending *and* of receiving) of affectionate verbal and nonverbal messages has developed as an evolutionarily adaptive behavior that contributes to survival and procreative success (Floyd, 2001). Whereas the stress buffering hypothesis (Cohen & Wills, 1985) argues that social interactions can indirectly affect health by protecting (or buffering) an individual from the physiological effects of a stressful event, AET argues that affectionate communication also has a direct effect on physiological health.

Research utilizing an AET framework has found support for both direct and indirect effects of affectionate communication. For example trait expressed affection correlates with average daily cortisol, waking cortisol, and diurnal variation of cortisol when controlled for affection received (Floyd, 2006); received affection (independent of sent affection) bolsters health by affecting morning, evening, and diurnal cortisol levels in married couples (Floyd & Riforgiate, 2008); writing down one's affectionate thoughts and feelings for a loved one significantly reduces total serum cholesterol over time (Floyd, Mikkelson, Hesse, & Pauley, 2007) and reduces salivary free cortisol in response to a stressful event (Floyd, Mikkelson, Tafoya, et al., 2007); increased frequency and duration of romantic kissing significantly decreases total cholesterol among cohabiting romantic partners (Floyd et al., 2009); and both state and trait affection affect oxytocin release in response to a stressful event (Floyd, Pauley, & Hesse, 2010). From a communication perspective, the finding that the actual communication of affection produces greater physiological benefits than does simply thinking about affection (a purely psychological act) holds particular importance (Floyd, Mikkelson, Tafoya, et al., 2007). While much of the research on the physiological effects of interpersonal relationships has its home in the psychological domain, it is of particular interest to our discipline that the *communication* of affection explains variance above and beyond that of experiential affection (Floyd, 2001).

An interesting modification of the affectionate writing procedure involved adding a condition where participants wrote a detailed account of a time when they engaged in deception in their expression of affection (e.g., telling a romantic partner she loves him when in fact she does not). Utilizing this method, Horan and Booth-Butterfield (2011) found no significant differences by writing condition (genuine affection, deceptive affection, or control) for systolic blood pressure, diastolic blood pressure, or heart rate suggesting that no physiological effect of lying about affectionate feelings exists. Furthermore, participants reported feeling minimal guilt or shame in response to expressing deceptive affection. Based on a methodologically sound and adequately powered full experimental study, Horan and Booth-Butterfield (2011) conclude that deceptive affection may not have emotional or physiological harmful effects (nor does it have beneficial ones) but rather may be a natural part of normal human interaction that is not particularly arousing. While expressing affection may have certain health benefits as suggested by the AET research reviewed above, communicating deceptive affection may have relational benefits independent of any direct physiological benefits to the actor. This topic calls for future research given the absence of significance in this particular study (Horan & Booth-Butterfield, 2011).

J. Social support and co-rumination

Social support, wherein close relational partners provide a means of reducing one's psychological and/or physiological experience of stress through communicative processes (Byrd-Craven, Granger, & Auer, 2011), offers another "bright" aspect of communication. The study of the process of social support has a long history in the communication discipline leading to the conclusion that the exchange of supportive messages has an effect on the psychological well-being of the interactants (Burleson, Albrecht, & Sarason, 1994). Researchers define social support as information, emotional messages, and material goods exchanged between individuals in a variety of contexts (Cohen & Wills, 1985; Goldsmith, 2004). For instance, in a family, many individuals comprise the social support network including spouses, children, and close relatives. Supportive networks also can include distant family and friends (Goldsmith, 2004). In either case, individuals can either receive actual support or perceive the size of their support network, with those people who have larger networks also reporting fewer health-related problems (for a review see Uchino, 2004).

However, a closely related concept, that of co-rumination, which focuses on the exchange of messages characterized by a focus on the mutual exchange of negativity such as "extensive problem discussion, rehashing of details of problems, speculating about the causes and consequences of problems, mutual encouragement of problem talk, and focusing on negative affect" (Byrd-Craven et al., 2011, p. 470), has been shown to lead to negative health outcomes. In both cases (social support, and co-rumination), interpersonal interactions have a direct effect on physiological health.

For women, interactions with close or "best" friends involving co-rumination have an effect on both salivary cortisol and sAA. Specifically, in a study of 44 female dyads, Byrd-Craven, Granger, and Auer (2011) found that 41% of people had a marked pre-task to post-task increase in sAA in response to a co-ruminative interaction marked by low negative affect. The HPA system on the other hand showed little activation in response to these interactions. Based on past research Byrd-Craven et al. (2011) suggest that this pattern of high SNS and low HPA activation indicates resilience to problem internalization. In other words, individuals whose HPA and SNS systems follow this asymmetrical activation show the lowest levels of negative affect focus during discussions of personal problems. At high levels of negative affect on the other hand, both the HPA and SNS activate in response to co-rumination about personal problems which may indicate the use of emotional rather than cognitive coping strategies. Furthermore, this pattern may suggest internalizing of problems and form one pathway through which co-rumination may be a maladaptive process.

Consistent with past research (Byrd-Craven, Geary, Rose, & Ponzi, 2008), Byrd-Craven et al. (2011) found that HPA activation occurs only in response to personal problem discussions and not in response to high negative affect discussions in the control condition (where discussions did not focus on personal problems/social stressors). These findings support the notions that the HPA is a body system particularly reactive to psychosocial stress (Dickerson & Kemeny, 2004) and that focusing on negative affect during interpersonal interactions can become a particularly stressful experience. Methodologically, both of these studies (Byrd-Craven et al., 2008; Byrd-Craven et al., 2011) contribute to the overall knowledge of co-rumination and social stress by measuring the physiological effects of an interaction, more closely mirroring those which naturally occur among friends by asking people to engage in a real co-ruminative interaction (rather than having participants watch a scenario or imagine a hypothetical interaction). The effect of this laboratory co-rumination induction therefore demonstrates improvements in ecological validity over more traditional stress induction procedures such as public speaking tasks (Dickerson & Kemeny, 2004) that seek to induce maximal stress responses without consideration of the likelihood of actually encountering these types of stressors in daily life.

K. Organizational communication research

While interpersonal scholars focus on micro level process (often limited to dyadic interactions), organizational researchers have long studied more macro level or hierarchical communication process such as the impact of manager-employee relationships, bargaining and negotiation, and organizational culture (Jablin & Putnam, 2001). Typically, these researchers have created complex theory based on their understanding of communication in organizations, but seldom evaluate actual communicative messages (Corman, 2006). Additionally, few organizational communication researchers explore the effects of organizational involvement and interaction on biology from a social scientific perspective. Not surprisingly, many researchers tend to focus on the impact of stress and wellbeing on body functions, which may result from complex or long working hours (Lundberg & Hellström, 2002), job demands (Schaufeli & Bakker, 2004), or other structural issues.

Some researchers have focused on particular behavioral elements in organizations and their effects on the body. For instance, some researchers have explored how workplace bullying affects the physiological stress response in both victims and witnesses of bullying events (Hansen et al., 2006; Kudielka & Kern, 2004). One other way in which relationships between coworkers tend to create a physiological or psychological change in an individual comes in the syndrome of burnout. Job burnout forms one of the most commonly reported responses to organizational strain, including those arising from poor coworker relationships (Maslach, Schaufeli, & Leiter, 2001). Maslach and colleagues defined burnout as "a psychological syndrome in response to chronic interpersonal stressors on the job" (p. 399). This syndrome can manifest itself due to the interpersonal strain of the workplace or can simply reflect "a crisis in ones' relationship with work" (Maslach, Jackson, & Leiter, 1996, p. 20). Typical evidence of burnout includes increasing levels of emotional exhaustion and cynicism toward the work environment and colleagues and a decrease in professional efficacy (Maslach & Jackson, 1981; Maslach et al., 1996; Maslach et al., 2001; Schaufeli & Bakker, 2004).

Burnout has a variety of both psychological and physiological correlates and has been associated with dysregulation of the body's stress response system. In a study of 77 white-collar workers who experienced prolonged job stress, Rydstedt, Cropley, Devereux, and Michalianou (2008) found that long-term workload significantly affected morning stress levels. Moreover, hormonal samples collected during the work week and the weekend did not differ, indicating that job stress continuously affected the participants, regardless of day of the week. While the researchers had hypothesized that the weekend hormonal samples would differ from the weekday samples, the lack of variation indicates that chronic stress at work can have a prolonged effect on the body.

Other studies have found additional physiological effects of burnout; one discovered that in middle-aged working adults burnout showed significant association with greater waist-to-hip ratio and a less favorable metabolic profile (the biological indicators of heart disease and diabetes) in the participants, thereby indicating the prolonged impact of burnout on a worker (Lasikiewicz, Hendrickx, Talbot, & Dye, 2008). Similarly, a study of 66 public school teachers found that teachers who scored higher on a burnout measure manifested a suppressed physiological stress response compared with those teachers who scored low on burnout (Pruessner, Hellhamer, & Kirschbaum, 1999). Despite the fact that researchers typically regard burnout as a non-clinical psychological phenomenon, worker appraisal of being "burnt out" appears to dysregulate the body's stress response (Grossi et al., 2005). Researchers typically design studies exploring burnout with the organizational level interests in mind, especially in worker productivity. Further research in this area could explore the way that individual working relationships predict burnout, which could predict physiological health effects.

Indeed, social relationships in the workplace are both important and well-studied. In a famous longitudinal research study, Shirom, Toker, Alkaly, Jacobson, and Balicer (2011) examined over 800 employees over the course of 20 years. They particularly attended to the variables that would have predictive power on mortality. Interestingly, they found that risk of mortality was significantly lower for those employees who reported high levels of peer support while they were working. Through these data, they argue that peer support provides a protective factor against mortality. From a communicative perspective, supportive transactions tend to predict satisfaction with support networks, which tend to buffer the negative health effects of stress (Anthony & O'Brien, 2002; Ganster, Fusilier, & Mayes, 1986; Haber, Cohen, Lucas, & Baltes, 2007; Sosik & Godshalk, 2000). Because of these findings, many researchers have attempted to explore methods for integrating stress reduction or social-support induction programs in organizations to improve health (Boren, 2010).

In the workplace, stress management techniques and training have proven successful in reducing the negative effects of stress. In a study of 48 healthy adult men, Gaab et al. (2003) randomly assigned participants to one of four stress-management training conditions. Participants met in groups on two separate occasions and received training on stress inoculation and cognitive reframing techniques. This training instructed participants on both the skills and knowledge necessary to deal with complex daily stressors. During their next laboratory visit, researchers administered the Trier Social Stress Test (TSST) to elicit a stress response. Results indicated that the TSST did elicit a significant stress response; however, individuals who had participated in the stress inoculation and cognitive reframing training had significantly lower cortisol responses to the TSST and a faster recovery time. Vocks, Ockenfels, Jurgensen, Massgay, and Ruddel (2004) conducted a similar replication of this finding with blood pressure reactivity as the dependent variable. They found that individuals who participated in a cognitive-reframing stress-management training intervention had a significantly lower reactivity to the TSST than individuals in the control group. Despite these two studies on acute stress reduction, few studies have evaluated similar effects on chronic stress in the workplace.

In the case of organizational communication, researchers exploring the way that organizational variables impact performance and the human body occupy much of the research paradigm. Few researchers take a communibiological approach to these issues. Reasons for that may include difficulties associated with access to research sites and participants. Other researchers report that organizational decision-makers seldom seem open to allowing a researcher to study their employees without some sort of incentive on the organization's behalf (thereby creating potential conflicts of interest). Because of the notion that organizational involvement forms a ubiquitous part of human social life, future research projects exploring the impact of that social involvement, especially communicative interactions, could provide additional insight on the interface between individuals and organizations.

L. Mediated research applications

While much of our review thus far has focused on human interactions (narrowly defined), studied by scholars of interpersonal communication (e.g., dating relationships, marriages, parent-child relationships) and organizational communication, much of the research utilizing physiological measures lies squarely in the domains of mass communication, mediated communication, and new technologies (including human-computer interaction). Weber, Sherry, and Mathiak (2009) argue that mass and mediated communication research takes the perspective in which messages directly affect individuals. In this case, and through a discussion of a variety of media theories, they argue that "our mass communication behaviors and needs reflect a long process of evolution leaving us equipped for certain complex behaviors, but incapable of other complex behaviors" (p. 47). In this sense, they and others argue the core of message interpretation and impact lies with the study of neurophysiology (see Anderson, Bryant, et al., 2006).

As in the preceding sections, we exclude studies that do not directly measure human physiology. Nevertheless, we must briefly mention that researchers do conduct exciting work in the realms of mass/media communication on aspects of health, such as promoting HPV vaccination (Shafer, Cates, Diehl, & Hartmann, 2011), preventing HIV/AIDS (see Ratzan, 2006 for a review), curbing smoking (Primack, Sidani, Carroll, & Fine, 2009), as well as on assessing ways individuals obtain health information about various health promoting activities such as physical activity (Plotnikoff, Johnson, Karunamuni, & Boule, 2010) and about diseases such as cystic fibrosis (Dillard, Shen, Robinson, & Farrell, 2010). In fact, our review of the past decade of research led to the discovery that almost all of the articles published in the *Journal of Health Communication* and a large majority of the articles in *Health Communication* focus on these ends. Clearly, mediated and mass communication scholars conduct an abundance of health effects research and health promotion research. The focus of this review however remains on direct measures of the human system. As such we now turn our attention to recent research on the physiology of mediated and mass communication.

Media effects defines one popular area of study. In particular, communication scholars have long shown interest in how media interactions affect humans through the effects of entertainment media such as television and film (Simons, Detenber, Cuthbert, Schwartz, & Reiss, 2003); the effects of persuasive communication/advertising (Wang, Lang, & Busemeyer, 2011); the effects of human-computer interaction such as playing video games (Grimes, Bergen, Nichols, Vernberg, & Fonagy, 2004), creating and using avatars (Cheetham, Suter, & Jäncke, 2011), and exposure to pornography (see Allen et al., 2007 for a review). In particular, a large body of research by Lang and colleagues on the limited capacity model of motivated mediated message processing (LC4MP) has examined ways that mediated messages have direct effects on our cognitive process (see Lang, 2009; Sparks & Lang, 2010).

While communication researchers admit the difficulty of "seeing" emotions, we can tap into the emotional systems involved in media consumption through measurement of physiology. "Psychophysiological and neurophysiological research on emotion suggests that the autonomic and behavioral responses to emotional stimuli reflect the underlying neural and subcortical structures activated by the appetitive and aversive motivational system" (Wang et al., 2011, p. 72). In one study, Wang and colleagues (2011) had participants ($N = 125$) view film clips that differed on dimensions of arousal and valence while measuring heart rate, skin conductance, and activation of the zygomatic and currugator muscles. Zygomatic and corrugator electromyography measures facial representations of emotion. The zygomatic muscle (in the cheek) is responsible for smiling and the currugator muscle (above the eyebrow) is involved in frowning. Measurement of this muscular activation therefore provides an objective measure of the spontaneous expression of emotion. Consistent with past research, valence of the film clip elicited the expected (appetitive or aversive) reactions. Wang et al. suggest that people must expend increased cognitive effort as the stimulus becomes more arousing and at high levels of arousal the body prepares physiologically to approach or avoid pleasant or unpleasant messages, respectively.

Methodologically, Wang et al. (2011) argue for the importance of controlling stimulus duration in studies such as this (as the amount of input can have a dramatic effect on the output measures). Furthermore, they argue that in order to truly understand the long-term effects of media exposure, researchers must use more formal mathematical approaches to modeling data. Nevertheless, the findings they report contribute substantively to scholars' understanding of the role of arousal in media content. These findings can then apply to better understand how people learn from media or how they are affected by advertisements. For example, if media systems or messages engage individuals' appetitive systems, they may motivate people more to encode messages (Sanders-Jackson et al., 2011; Simons et al., 2003).

In terms of health promotion, scholars have long studied the utilization of mediated messages in order to make people healthier by encouraging behaviors such as quitting smoking (Sanders-Jackson et al., 2011). In a re-analysis of data from another study, Sanders-Jackson and colleagues (2011) examined smokers' visual tracking in response to messages that included smoking cues. "Eye tracking is a well-developed procedure that has been used effectively in research for more than a century (Duchowski, 2003). It allows researchers to determine how visual attention is allocated to a stimulus" (Sanders-Jackson et al., 2011, p. 276). In this study, Sanders-Jackson et al. found that including smoking cues in anti-smoking public service announcements (PSAs) may lead to greater resource allocation devoted to the message (due to appetitive activation). They do note, though, that this increased focus on the smoking cues may detract from other parts of the message (such as information provided about quitting).

M. Mediated message processing in the brain

Another area of research within this domain involves brain imaging research using functional magnetic resonance imaging (fMRI) to literally photograph the brain while individuals interact with media to gauge the effects media have on the brain (Weber et al., 2009). Another example involves measuring brain activity through EEG while watching either still or moving images (Simons et al., 2003). For some researchers, this line of work has proven very fruitful, leading to an understanding of the mechanisms for message processing (Anderson, Bryant, et al., 2006). For instance, Ravaja, Saari, Kallinen, and Laarni (2006) explored the role that state mood had on the processing of mediated messages. In their study, they used facial electromyography and cardiac ECG to explore underlying brain function related to a mood induction activity, whereas individual mood was related to positive or negative message valence.

Other studies have explored the impact of fear appeal messages on human physiology. Ordoñana, González-Javier, Espín-López,, and Gómez-Amor (2009) experimentally manipulated levels of threat in a message promoting the necessity to vaccinate against tetanus. They found that heart rate and skin conductance varied, based on threat level and efficacy range, indicating that message processing of a fear appeal did elicit a physiological response in individuals. Interestingly, auditory messages also create certain brain-level processing that result in physiological reactions. Both tempo (fast or slow) and genre (rock, swing, classical) resulted in differential heart rate and skin conductance numbers in two experiments ($N = 50$ total). Similarly, musical structural complexity also predicts physiological arousal along with improvements in memory and attention (Potter & Jinmyung, 2006). Collectively, these findings underscore the taken-for-granted assumption that our brains constantly process mediated messages in a way that creates activation of various physiological systems. That noted, one of the well-researched areas of mediated effects on biology comes from television research.

N. Television research

Television research has deep roots in message effect research, making television an excellent medium to study physiological effects on individuals (Gibson, 2007; Lang, Chung, Lee, Schwartz, & Shin, 2005). In a laboratory experiment, Simons, Detenber, Cuthbert, Schwartz, and Reiss (2003) evaluated EEG reactions to either still or moving emotion-provoking television messages without sound. They found a quadratic relationship between arousal and valence, with both extremely positive and negative images creating physiological arousal. Importantly, they found that subjects rated moving images more extremely than they did still images; they experienced more cortical response (as measured by EEG) from moving images than still images, results that demonstrate the power of mediated television messages. Similarly Anderson, Fite, Petrovich, and Hirsch (2006) using video montages as the independent variable and actually imaging cortical activity through fMRI (as described earlier) found similar results. Whereas Simons and colleagues indirectly measured cortical activity, Anderson and colleagues imaged the brain to determine what parts were active while participants watched complex visual images. Collectively, these research findings underscore how individuals become engaged in mediated messages.

Engagement forms an important element of impactful mediated messages, as Smith and Gevins (2004) determined. Again using EEG, they exposed participants to 30-second commercials from broadcast television. They computed EEG readings continuously throughout the viewing of the commercials and asked the participants to gauge their interest and engagement in the commercials. Not surprisingly, they found that engagement and cortical activity were associated; indicating positive associations between cortical activity and interest, along with various design elements of the commercial themselves. These findings offer support in determining what elements of a commercial viewers actually find compelling, based on brain activity.

Finally, some have conducted research on the effects of television violence on brain activation. In an fMRI study, Murray and colleagues (2006) had children view violent and nonviolent television sequences. They argue that both of these should activate certain parts of the brain, which reflects prior research and those findings described, above. The children (aged 9–13 years) watched either two boxing scenes from the PG-rated movie *Rocky IV* or two nonviolent scenes from *Ghostwriter,* a PBS children's show. They found that heart rate significantly differed for violent v. nonviolent scenes and that certain parts of the brain, especially the limbic system and amygdala were active more frequently during violent scenes than nonviolent scenes. This does suggest that emotional processing and regulation may be associated with violence on television, at least for children. However, their study did suffer from low cell sizes, which make causality difficult to assume. Given these findings, many researchers have extrapolated knowledge about mediated violence from television to video games.

O. Video game research

As an interactive medium, video games provide a quite interesting research area. In contrast with a more passive medium like the radio or the television, video games allow researchers to assume that video games activate differential parts of the brain and perhaps do so in more complex ways. With that in mind, Ballard, Hamby, Panee, and Nivens (2006) had 41 adolescent children play video games during their three-week study. They measured heart rate and blood pressure during the video game period (15 minutes at a time). They hypothesized that participants would become desensitized to the video games over the course of a three-week period. Among these participants, continued video game play did not appear to desensitize them, indicating that the video games themselves may elicit similar physiological reactions across time. Of course, this study does beg the question whether a connection exists between lack of desensitization and other variables. At the same time, other researchers have found that video games can become highly physiologically rewarding to their players (Ravaja, Saari, Salminen, Laarni, & Kallinen, 2006)

To address that, Weber, Ritterfield, and Mathiak (2006) used advanced fMRI techniques to determine whether virtual violence in video games caused limbic activation and amygdalae suppression among young adults (ages 8–26) who played video games frequently. They found support for their hypothesis that there is a similarity in brain patterns (limbic activation and amygdala suppression) in regular players of violent video games and in those individuals who exhibit aggressive behaviors. In this case, regular play of violent video games suppressed affective parts of the brain. Barlett, Rodeheffer, Baldasaro, Hinkin, and Harris (2008) replicated this finding as they found in two separate experiments that violent video game play resulted in more hostile behaviors, aggressive thought, and higher physiological arousal than did nonviolent video game play. In another fMRI study, Hummer et al. (2010) examined the short-term effects of violent video game play with 45 adolescent volunteers. They found that "playing a violent video game for only 30 minutes immediately produced lower activity levels in prefrontal regions thought to be involved in cognitive inhibition" (p. 147) as compared to nonviolent game players. For their participants, a short violent video game activity resulted in diminished cognitive and executive functioning, as compared to individuals playing nonviolent video games. Taken together, these research findings demonstrate the effects of interactive media on brain and cognitive functions.

Of course, not all video game researchers explore the effects of violence on brain activity. Some researchers have evaluated, through the use of muscle and cardiovascular reactivity, the effects of video game opponent locations and shared physiological effects (Ravaja, 2009). Along with that, some researchers have explored the identity dimension of video games through the use of avatar selection and point of view in video games. In a factorial (avatar choice X point of view) study, Lim and Reeves (2009) found ability to select an avatar in a video game led to greater physiological arousal, more so than just point of view alone. This suggests one way that the interactive nature of video games could represent larger social mediated interactions.

8. Summary and Conclusions

Our primary goal with this summary of extant literature on biology and communication is to familiarize communication scholars with important research *currently* being conducted in various areas of the communication discipline. We started by providing a brief but thorough overview of each of the major body systems implicated in communication behavior (and indexed by the studies we discussed). To accomplish that, we focused our attention on the top 20 communication journals over the past 10 years as a starting point for this conversation. Taken as a whole, this body of literature led us to develop four primary themes that elucidate the underlying assumptions of communibiology. We will discuss each of these themes in context and then conclude with a few thoughts on the future direction for this research paradigm.

The first theme that emerged from this literature describes *recent methodological advances* in the study of communication. For decades, social scientists in psychology and physiology have utilized what communication scholars might call novel approaches to the measurement of communication. Moreover, these applications inject technological advances from traditional sciences, including medicine, to better understand the ways that communication functions within the body and how our bodies react to communication. This holds particular importance considering that the proponents of *communibiology* (Beatty, McCroskey, & Floyd, 2009; Beatty, McCroskey, & Pence, 2009; Beatty et al., 2001) argue that all communicative behavior can be reducible to brain processes. While some scholars may disagree (some vehemently), with this proposition, science follows the basic assumption of falsification. Therefore, having an actual measurement of those processes holds great importance for our understanding of communication from this perspective, for our ability to build theories of communication, and for our ability to test the propositions posited by communibiological scholars.

The second theme that emerged from this literature links inextricably to the first: a *focus on objectivity.* As a whole, communication researchers tend to focus on perceptions; self-reports of attitudes, beliefs, and behaviors; behavioral observations; retrospective recall; and surrogate markers of actual processes. Communibiology scholarship has accomplished adopting rigorous and objective scientific approaches toward the measurement and impact of communication. Whereas we recognize that bias will always play a role in the research process, scholars in this paradigm work toward designing methods that substantively reduce bias on the part of the participants. For example, few research participants could manipulate their physiological reactions as they might with their psychological perceptions. Furthermore, people find it much easier to modify their behavior than to modify their physiology in response to a research protocol or stimulus. Therefore, these methods allow for a focus on research objectivity in those situations where such a focus is warranted and necessitated.

The third theme pertains to the way that the *research is situated within the sciences*. Much of the research pertaining to communication and human physiology finds publication outside of the communication discipline. In fact, we argue that a significant majority of the articles pertaining to the very concepts discussed in this review appear in journals housed in academic disciplines outside of our own. We recognize that this represents a natural part of the growth of our discipline; nevertheless, we propose that communication scholars make a concerted effort to publish more of this research in our own journals. We do not mean to critique our discipline for the lack of published research; rather, we suggest a focus on ownership of research that is, by definition, of and about communication.

The fourth and final theme addresses the *increasing complexity in the understanding of communication*, as a concept. Throughout our history, people have often defined communication as a tool to accomplish a goal. For instance, in one of the most commonly cited models of communication, Shannon (1948) proposed a very linear model, commonly referred to as the Shannon-Weaver, or Mathematical model of communication. Clearly, our understanding of communication has changed significantly since this early conceptualization. Nevertheless, many disciplines outside of our own still view communication as only a goal-based activity. The value of a physiological and neurological view of communication lies in the very definition of that concept. These research articles represent a nuanced and complex view of communication as a concept and not necessarily a means to an end.

A. Future directions and conclusion

This research shines a spotlight on issues that our colleagues in other fields of study may not otherwise explore. Furthermore, in addition to the more specific recommendations for future research we have already made, we do believe that some other useful and important directions remain for researchers engaged in this paradigm. First, we propose that researchers integrate body systems through the measurement of multiple biological markers in the same study. For example, rather than studying cortisol as a measure of stress, researchers have now begun to realize that stress is a complicated process co-coordinated by various body systems. Therefore, a more comprehensive approach to the body's response to communicative stressors appears when scholars examine all of the body systems simultaneously. We can say the same about research on media effects. Much research has appeared examining neurological activation as a result of mediated messages, but perhaps exploring other sub-systems would continue to provide a more comprehensive look at mass communication.

Additionally, some deficits appear in research programs in areas such as organizational communication. Only recently have scholars begun to explore how body systems affect organizational communication. Based on other research areas, social strata, hierarchy, and interpersonal relationships have a profound impact on the body. Applying those ideas to the study of organizational communication would not only prove fruitful, but may also help develop useful interventions toward improving organizational life.

Finally, we do want to issue a word of caution when it comes to communibiological methodologies. People should not undertake these methods lightly, as they require considerable training and resources. Haphazard application of these methods could lead to false knowledge of the way that the body reacts to communicative interactions. We also recommend that consumers of this research vigorously securitize published methods to make sure they prove consistent with current standards for this type of research (see Luecken & Gallo, 2008).

In summary, we strongly believe in the notion that communication affects our biology and that in turn, our physiology affects our communication. We hope that this review has provided our readers with an understanding of the processes by which these phenomena occur, the methods that scholars in our discipline employ to study these processes, and some relevant and interesting findings.

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