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Neuroimaging in Environmental Communication Research

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Environmental communication comes in many forms, from news reports about natural disasters, verbal and visual communication about the effects of deforestation or climate change, to campaign messages promoting environmentally conscious behaviors. Despite this variety, the effectiveness of all environmental messages hinges on one simple fact; they must all pass through the human brain, the biological organ of communication. When a message reaches a recipient's brain, the kind of processing it undergoes will determine its fate: whether it will be attended to, comprehended, perceived as personally relevant, whether it will be remembered or forgotten, and whether it can spur action or go unheeded. All this depends on specific mechanisms that are instantiated in the human brain.

A growing number of studies have thus begun to examine how messages impact brain activity and how message-evoked brain responses relate to subsequent outcomes (Falk, Cascio, & Coronel, 2015; Schmälzle, Renner, & Schupp, 2017; Weber, Mangus, & Huskey, 2015). To date, most of this work focused on brain responses to health prevention messages or within marketing-related fields, but environmental communication topics are clearly on the rise. In this chapter, we will first introduce the goals and methods of Communication Neuroscience, an approach that seeks to describe, explain, and predict communication phenomena from a neural perspective. We will then give examples of how neuroimaging can be used to examine (1) the valuation of nature, (2) risk perception and risk communication, and (3) studies of pro-environmental messages.

COMMUNICATION NEUROSCIENCE

The goal of Communication Neuroscience is to examine communication phenomena from a neural perspective. By producing images of brain function and anatomy, neuroimaging methods provide a window into the human brain that allows for insights into the biological processes that underlie perception, cognition, emotion, and action (Turner, Huskey, & Weber, 2019; Weber, Mangus, et al., 2015). Different neuroimaging methods exist, such as EEG (electroencephalography), fMRI (functional Magnetic Resonance Imaging), or fNIRS (functional Near-Infra-Red-Spectroscopy),

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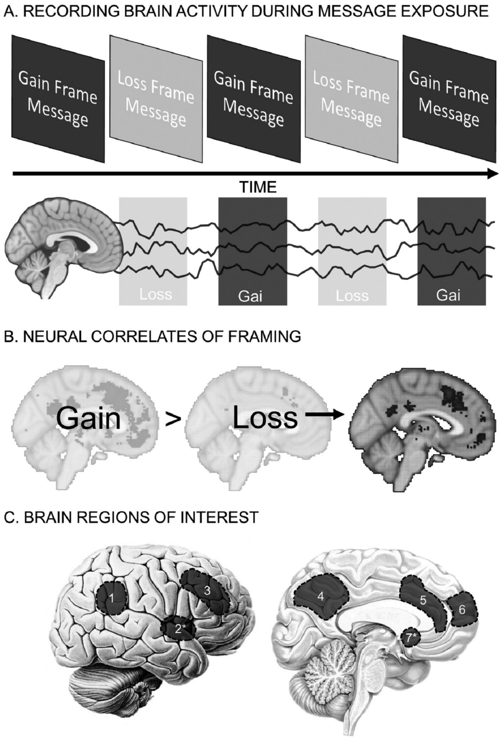
each with their own set of advantages and disadvantages, but the general approach is the same for most methods. The examples below will mainly focus on research using fMRI, but the principles can be applied to any method, including psychophysiological measures.

In brief, fMRI detects changes associated with cerebral blood flow metabolism, which can be used to measure regional changes in brain activity (Huettel, 2008). In a typical fMRI experiment, participants view different messages in an MRI scanner while the machine records their brain response throughout the reception process (see Figure 26.1). To examine some communication process of interest, researchers often use experimental and control conditions or manipulate the participant's task in the scanner, such as instructing them to generate counterarguments or attend to particular message features. To give one example, half of the messages shown to participants could feature a particular persuasive technique, such as framing, and the other half could represent control messages (Figure 26.1). Brain activity would be recorded throughout the study and the researcher would then compare the brain activity during each condition to identify differences between conditions or task manipulations. The results would then be used to draw inferences about the phenomenon of interest, in this case message framing and its neural basis.

Key advantages of neuroimaging are that measurements are taken over time, from multiple regions, without overt questioning, and that they can simultaneously tap into multiple processes (e.g. related to perception, reasoning, and social cognition). Another advantage of neuroimaging methods is that they are particularly suited to tap into implicit and affective processes. These processes are essential to most theories of persuasion, but they are difficult to study using self-report methods because they are difficult to accurately verbalize (Cacioppo, Cacioppo, & Petty, 2016; Falk & Scholz, 2017). Moreover, neural approaches are attractive as we move from exploration and explanation of communication mechanisms to prediction of communication outcomes. Logically, brain activity must always precede behavior as well as more proximal outcomes, such as whether a message is remembered, affects attitudes, or impacts intentions. Indeed, research shows that neural measures have potential to predict outcomes like memory, volition, and behavior change in individuals as well as larger populations (Falk, Cascio, et al., 2015; Gabrieli, Ghosh, & Whitfield-Gabrieli, 2015; Knutson & Genevsky, 2018).

However, potential disadvantages of neuroimaging are that it demands a one-person-at-a-time approach and that studies are carried out under laboratory conditions at the expense of ecological validity. The sample sizes also tend to be smaller and less consideration has been paid to issues of culture and applicability – although this is currently changing (Falk et al., 2013; Gabrieli et al., 2015; Losin, Dapretto, & Iacoboni, 2010). Although not direct limitations, it is also important to clarify that current techniques cannot accomplish mind-reading (i.e. reading out the content of someone's conscious thought), contrary to common expectations from those unfamiliar with neuroimaging. Similarly, some people assume a simple mapping between psychological processes and regional brain activity (e.g. that fear is equivalent to amygdala activation and vice versa), but this is also not the case (Cacioppo, Tassinary, & Berntson, 2007; Poldrack, 2011).

Despite these caveats, neuroimaging creates new opportunities to study core communication processes. Perhaps the most obvious benefit is that – as the term neuroimaging implies – it turns the famous black box of the human brain into an observable aquarium (Plassmann, Venkatraman, Huettel, & Yoon, 2015). For example, in the hypothetical study of gain- vs. loss-framed messages (Figure 26.1), one would derive insights into the hidden brain processes that underlie framing effects, which advances the study of the fundamental biological mechanisms that facilitate these effects (see De Martino, Kumaran, Seymour, & Dolan, 2006 for an example of a neuroimaging study on framing in economics, and Casado-Aranda, Sánchez-Fernández, & Montoro-Ríos, 2017 for an example on gain vs. loss framing of ecological messages).



A. RECORDING BRAIN ACTIVITY DURING MESSAGE EXPOSURE

B. NEURAL CORRELATES OF FRAMING

C. BRAIN REGIONS OF INTEREST

Figure 26.1 Schematic example of a neuroimaging study to examine the neural correlates associated with gain/loss framing. (A) Principle of data collection: Participants are exposed to messages that are manipulated (e.g., independent Variable: gain- vs. loss-framing) and brain activity (dependent variable) is measured from different regions and throughout the reception process. (B) Neural correlates of message framing can be exposed by comparing the average activity evoked by gain-framed messages to that evoked by loss-framed messages. Note that the data are hypothetical. (C) Anatomical location of selected regions discussed in the review: (1) temporo-parietal junction (TPJ), (2) insula, (3) dorsolateral prefrontal cortex (dlPFC), (4) precuneus/posterior cingulate, (5) anterior cingulate cortex (aCC), (6) dorsomedial prefrontal cortex (DMPFC), (7) ventral striatum (VS). * indicates that structures are more medially located than shown on the image

Environmental communication researchers can adapt the example study on message framing to any other communication variable of interest, and the same principles can be used to study receiver-sided differences (e.g. self-construal, Zhang & Hawk, 2019; level of risk perception, Schmälzle, Häcker, Renner, Honey, & Schupp, 2013; personal relevance, Chua, Liberzon, Welsh, & Strecher, 2009). In conclusion, the integration of neuroimaging and communication research deepens our understanding by describing and explaining how messages are processed by the human brain, and how message effects at the brain-level relate to subsequent outcomes.

ENVIRONMENTAL COMMUNICATION AND NEUROIMAGING

In the following sections, we will give examples of how neuroimaging can be used to advance research on environmental communication. We will discuss selected studies of (1) the neural valuation of nature, (2) risk perception and risk communication, and (3) studies of pro-environmental messages. Our selective review draws from work in neighboring fields, like environmental psychology, health communication, and consumer decision making.

Extrapolating from how these fields have embraced neural approaches, we expect that the number of environmental communication studies in this area, which is still small, will undergo rapid expansion over the coming years. Though neuroscientific studies are still mainly geared toward advancing basic science, the combination of neuroimaging and environmental communication science is a fertile ground for use-inspired basic science (Stokes, 1997).

ENVIRONMENTAL NEUROSCIENCE AND THE NEURAL VALUATION OF NATURE

The umbrella term environmental neuroscience refers to an interdisciplinary field that is concerned with how the environment affects and interacts with the brain and behavior (Berman, Hayes, & Krpan, 2015; Berman, Kardan, Kotabe, Nusbaum, & London, 2019). This includes multi-level, integrative studies on the effects of being raised in maladaptive environments (pollution, noise, crime) on physiology (epigenetics, brain function and structure, physiology of stress), or various other interactions between bio-behavioral and social-environmental levels of analysis. Much of the research in environmental neuroscience goes beyond the scope of this chapter, but a subset that is relevant for environmental communication focuses on the effects of experiencing nature – either directly or in mediated forms – on physiological processes.

Intuition suggests that being in touch with nature improves health outcomes and numerous studies support this notion. It is commonsense that a day at the beach or a walk in the woods can reduce stress and promote positive emotion. Humans also actively choose to surround themselves with elements or symbols of nature. Plants, sunlight, fireplaces, and photos of beautiful landscapes all feature prominently in living rooms and offices, and these nature-elements have been shown to enhance well-being and productivity. These data strongly suggest an intimate connection between nature and core physiological motivational circuits, which aligns with evolutionary perspectives (Barkow, Cosmides, & Tooby, 1992).

Various psychophysiological studies have thus examined which biological mechanisms mediate these effects (measuring cortisol levels, heart rate, and skin conductance while people are exposed to nature media). Since the advent of neuroimaging, several studies have focused particularly on reactions to nature imagery and sounds in regions involved in reward, such as the nucleus accumbens (cf. Henderson, Larson, & Zhu, 2007; Kim, Song, & Jeong, 2012; Sawe & Knutson, 2015). Amazing landscape views also prompt what is known as motivated attention, or a widespread increase in brain activity in regions involved in processing perceptual and emotional stimulus aspects (Lang, Bradley, & Cuthbert, 1997; Schupp, Flaisch, Stockburger, & Junghöfer, 2006). The results support the notion that consuming nature is intrinsically rewarding, explaining at least in part why and how nature scenes attract attention, evoke positive experiences such as inspiration (Dale, Raney, Janicke, Sanders, & Oliver, 2017), and promote health more broadly (Bratman, Hamilton, & Daily, 2012; Ross & Mason, 2017). This, in turn, helps to explain the strong effects that elements of nature have on choices, which commercial advertising has long recognized and exploited to generate positive emotional product associations.

To provide one particular study example, Sawe and Knutson (2015) sought to characterize the processes underlying the economic valuation of environmental resources, a topic with clear policy implications. They conducted a combined behavioral and neuroimaging study in which participants made decisions about donating money for protecting natural park land. While lying in the scanner, participants responded to requests for real money donations to specific causes, which were manipulated regarding the park iconicness (high vs. low) and the proposed land use (destructive vs. non-destructive) that participants' donation was supposed to avert (e.g. donating $5 to avert destruction of a part of Yosemite from a planned mining project). Results showed that viewing iconic parks prompted positive subjective arousal and nucleus accumbens activity, and viewing destructive land uses prompted negative subjective arousal and anterior insula activity. The latter predicted choices to donate. Also, the size of the anterior insula effect covaried with the strength of pro-environmental attitudes. Overall, this study illustrates how neuroimaging can be used to disentangle different affective components of the valuation process and predict behavioral choices. Such work not only provides a more detailed picture of the value humans place on nature and how they become motivated to prevent its destruction, but it also illustrates how their valuations can be influenced by the kinds of information they are presented with, which is, in turn, relevant for environmental communication.

NEURAL PROCESSING OF RISK: INTUITIVE RISK PERCEPTION

If something is as existential and valuable as the environment, then the potential of its loss or destruction poses what we commonly call a risk. Risk has always been a core topic in environmental communication, from the seminal work by Slovic and colleagues on public reactions to nuclear power to the question of how to communicate the risks of climate change today (Slovic, 1987; Weathers, Maibach, & Nisbet, 2017). Risk perception is a central topic in this area because it is assumed that risk perception motivates behavior change (catalyst-function of risk perception) and influences how risk communication gets processed (filter-function of risk perception; Schmälzle, Renner, & Schupp, 2017). Several neuroimaging studies have thus complemented traditional approaches to reveal the neural processes of risk perception and responses to risk communication.

Perhaps the most difficult aspect of risk research is the difference between how technical experts define risk and how laymen think about risk. In brief, technical definitions of risk emphasize probability and severity as key variables, and experts strive to quantify these variables to objectively gauge the magnitude of risk posed by a hazard. However, when laypeople evaluate their personal risk, they are influenced by a number of variables that go beyond numerical calculations of probability and severity. For example, subjective estimates of the probability of a plane crash differ markedly between passengers in a plane depending on various individual-differences (e.g. familiarity and knowledge) and situation variables (e.g. boarding vs. runway; Myers, 2004). Similarly, when a natural disaster threatens to destroy a house, economic and emotional variables carry different weight for the owner, the tenant, or the insurer of the house, and each of these actors may perceive a different level of subjective risk.

What these examples make clear is that risk in people's minds and brains is not represented as a simple numerical quantity, and that the numbers used by experts to assess risk have little meaning for individuals. Again, especially advertisers for insurance policies and similar products have known this for a long time, and they regularly rely on drastic imagery and other non-numeric, but highly vivid and affect-rich material to make risk seem high.

If risk perception builds on affective processes, which is what models like the affect heuristic (Slovic, Finucane, Peters, & MacGregor, 2004) or the risk as feelings theory (Loewenstein, Weber, Hsee, & Welch, 2001) suggest, then neuroimaging methods are promising (Renner, Gamp, Schmälzle, & Schupp, 2015). Indeed, a number of EEG and fMRI studies have already examined how people evaluate various risks. For example, Qin, Lee, Wang, Mao, and Han (2009) conducted a study in which they presented phrases describing either risky or safe environmental or personal events (e.g. risky-environmental: tsunami, earthquake; safe-environmental: rainfall, tree-planting; risky-personal: smoking, bungee-jumping; safe-personal: playing-piano, reading), and several similar studies of hazard evaluations exist (Herwig et al., 2011; Qin & Han, 2009a, 2009b; Vorhold et al., 2007). Meta-analyses of risk neuroimaging studies (Knutson & Huettel, 2015; Mohr, Biele, & Heekeren, 2010) identify key correlates of risk which include the insula, the cingulate cortex, and the medial prefrontal cortex (see Figure 26.1). However, it should be noted that the definitions and operationalizations of risk in many of the analyzed studies vary due to the multidisciplinary nature of risk research. Nevertheless, key regions of the so-called risk matrix include the anterior insula and the anterior cingulate cortex, which are involved in various emotional functions and particularly negative affect (Craig, 2010; Kalisch & Gerlicher, 2014).

One potential criticism of these studies is that presenting words referring to risky hazards or operationalizing risk via gambling tasks may not be representative of risk perception in the real world (Schonberg, Fox, & Poldrack, 2011). Several studies examining health risk perception have thus tried to increase ecological validity, such as by conducting studies on risk perception related to sexually transmitted infections (STIs) in contexts that resemble online dating (Schmälzle, Imhof, Kenter, Renner, & Schupp, 2019).

One noteworthy study of how the interface of (health) risk perception and risk communication can be studied with an eye toward the real world was conducted in the context of the H1N1 epidemic. During the peak of the H1N1 crisis, Schmälzle et al. (2013) scanned participants with either low or high pre-existing risk perceptions regarding H1N1 while they were exposed to a 30-minute TV documentary about H1N1. In the analysis, they assessed the similarity of neural processes evoked by the authentic documentary, finding that viewers with high pre-existing risk perception exhibited more similar responses in the anterior cingulate cortex (and at lower thresholds the anterior insula). These data further support the role of affect in risk perception and demonstrate a methodology for understanding how real-life risk communication is received by individuals.

Comparable neuroimaging studies on chronic divisive political issues are underway. To our knowledge, no studies exist on the reception of environmental risk communication, but researchers could adapt similar designs to study the reception of risk communication about nuclear energy, or the effects of messages from climate change skeptics (Greitemeyer, 2013).

NEURAL PROCESSING OF PRO-ENVIRONMENTAL MESSAGES

As indicated above, neuroimaging research focusing specifically on environmental messages is still relatively scarce. However, allied disciplines, such as behavioral economics, political and health communication, or marketing, create fertile ground for neuroscientific research on environmental messages. Several recent studies provide examples of how this endeavor can be advanced.

For instance, Casado-Aranda, Martínez-Fiestas, and Sánchez-Fernández (2017) examined the role of temporal framing on ecological persuasive messages. They presented participants with audio messages that were framed either in past or in future tense (temporal frame: future vs. past frame) and pronounced by either young or old voices (voice age: young vs. old age). Examples are messages like “If renewable energies are used, reserves of natural energy sources will increase” (future frame), or “If society had acted correctly, climate change effects would be lower” (of note, they only used gain framed messages, and messages were selected based on pretest ratings). The results revealed differences between future-framed and past-framed messages in auditory cortex, the precuneus, and medial frontal gyrus, which the authors interpreted with regard to the role of these regions in episodic memory and the so-called episodic future thinking. The innovative and therefore still exploratory nature of this research calls for follow-up work. However, it will be apparent to researchers working in this area that there is potential to illuminate long-standing topics related to psychological distance, which play a key role in environmental communication. A substantial neuroimaging literature exists on scenario- and future-oriented thinking (Szpunar & McDermott, 2009), and this work is highly relevant to studies of risk and to the construal level literature in psychology (Duan, Zwickle, & Takahashi, 2017).

Vezich, Gunter, and Lieberman (2017) presented another example of a neuroimaging study on environmental messages. They exposed participants to a series of green advertisements and standard ads, while they recorded brain activity during ad-viewing, and obtained self-report ratings of ad liking and perceived sustainability after each ad. The results showed that ratings were more favorable for green as compared to standard ads (a mere-green-effect), but fMRI showed greater activation in the ventromedial prefrontal cortex and the ventral striatum for the standard as compared to the green ads. In the fMRI literature, these regions are often associated with self-relevance and value, and the authors offer the interpretation that these results might explain, at least in part, why consumers' self-reported preference for green products does not match up with actual purchase behavior. However, the concrete study provided no evidence about decisions, and the issue of reverse inference needs to be considered when interpreting fMRI data (Poldrack, 2011). It thus stands to be determined whether brain responses to the ads would predict behavior better than self-report, but this hypothesis can be tested in future studies. Overall, these examples illustrate how researchers can use fMRI to examine the reception of environmental messages that have been manipulated regarding persuasion-related variables.

FUTURE DIRECTIONS

Taken together, neuroimaging can help environmental communication scientists unpack the chain of events that goes from a message to the brain activities associated with message reception, to subsequent message effects. The neighboring discipline of health communication provides a roadmap for how neuroimaging can be used productively to advance research on how these processes unfold as a causal chain from message characteristics, to brain activity, to message effects in individuals or populations. Substantial overlap exists between the concepts and methods used in health and environmental communication, and via the topic environmental health, the disciplines become factually merged.

Over the past decade, several neuroimaging studies on health messages have not only tackled very similar topics as we have outlined above (e.g. framing, risk, and message processing), but have also begun to approach others. These include the neural processes of counterarguing, self-affirmation, and various factors related to message success (e.g. argument strength, sensation value, and perceived effectiveness; Coronel, O'Donnell, Beard, Hamilton, & Falk, 2019; Falk, O'Donnell, et al., 2015; Imhof, Schmälzle, Renner, & Schupp, 2017; Schmälzle, Häcker, Honey, & Hasson, 2015; Wang et al., 2013, 2016). Although the work presented above has barely scratched the surface of what would be needed to paint a complete picture of how people respond to environmental messages, it is clear that such research advances our understanding of basic processes related to mass communication and persuasion, which can ultimately inform the practice of environmental communication as well as policies (Schmälzle et al., 2017).

Most notably, an influential series of studies advanced the brain-as-predictor framework, which uses neural data as predictors of the outcomes of messaging. For example, Falk et al. (2011) showed that brain activity in response to smoking messages predicted reductions in smoking among individuals who were scanned (also see Falk, Berkman, Mann, Harrison, & Lieberman, 2010; Falk, O'Donnell, et al., 2015; Weber, Huskey, Mangus, Westcott-Baker, & Turner, 2015).

This brain-as-predictor approach is particularly attractive because of its potential practical value and because it connects neuroscience laboratory studies to real-world outcomes. Clearly, the bulk of neuroimaging research in communication is more geared toward basic science and elucidation of mechanism. However, combining environmental communication and neuroimaging this way could be used, for instance, in the formative stages of campaign design.

Furthermore, there is evidence showing that the brain response to messages recorded in small groups can be used to predict aggregate-level outcomes, such as the call volume to smoking quit lines and other health campaign goals (Falk, Berkman, & Lieberman, 2012). Comparable work by Knutson and colleagues shows that neural data in response to charitable requests in kick-starter campaigns can predict real-world donation outcomes (Genevsky, Yoon, & Knutson, 2017; Knutson & Genevsky, 2018). Studies like the one on donations to national parks could be connected to this line of work.

A growing number of studies also focus on the social sharing of messages to understand decisions to share and what information to pass on (Meshi, Tamir, & Heekeren, 2015). This work has been carried out in social media contexts (Twitter, Facebook), and interpersonal contexts (Pei, Schmälzle, O'Donnell, Kranzler, & Falk, 2019; Scholz et al., 2017). Interestingly, media content depicting nature is more likely to evoke feelings of inspiration, and, therefore, more likely to be shared on social media than media not depicting nature (Ji et al., 2019). Collecting neural data may thus shed light on the importance of nature in making decisions to share messages about the environment, which, in turn, influence the public communication environment and social norms more broadly (Lapinski, Funk, & Moccia, 2015; Lapinski, Zhuang, Koh, & Shi, 2017; Takahashi, Tandoc, & Carmichael, 2015).

Methodologically, the trend toward mobile brain imaging will increase, and the costs for equipment are expected to fall. Although here we mainly focused on research using fMRI, methodologies like fNIRS and EEG are readily adoptable (Imhof et al., 2017). This development will make neuroscience much more adaptable to contexts beyond isolated laboratory environments, and it creates opportunities for researchers beyond North America, China, and European countries to engage in environmental communication using neuroscientific methods or even begin cross-cultural studies. Lastly, we can expect that neural process measurement will become more integrated with virtual reality, which has already been used to study environmental communication (Ahn, Bailenson, & Park, 2014; Bente et al., 2014; Markowitz, Laha, Perone, Pea, & Bailenson, 2018; Parsons, Gaggioli, & Riva, 2017).

SUMMARY

Here, we outlined the potential of neuroimaging to improve description and explanation of environmental communication processes focusing on studies on the neural valuation of nature, risk perception and risk communication, and neuroimaging of pro-environmental messages. Neuroscientific approaches to environmental communication issues are still rare, but a number of studies on valuation, risk perception/communication, framing, and future-oriented thinking contribute to this promising area of research. Future work can build on these seminal efforts to advance our understanding of communication and its practical effects.

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