Media Neuroscience

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Abstract

Media neuroscience offers a unique window into how the complexities of human behavior emerge from the dynamic interaction of adaptive brain structures in response to environmental inputs. Rather than treating these dynamics as a black box or measuring them only indirectly through self-report or behavioral observation, neuroimaging studies are uniquely able to provide theoretical insight into underlying brain processes and their evolutionary basis. This essay provides an overview of foundational research in the area of media neuroscience, evaluates key critiques of that research, and provides an outlook for how emerging trends may develop in the near future.

INTRODUCTION

Media neuroscience is emerging as a transdisciplinary research field. Scholars from an expansive constellation of disciplines, including psychology, communication, pedagogy, and cognitive and computer sciences, are employing the tools of neuroscience to cultivate a deeper understanding of media use, its influence on individuals, and its implications for society at large. In some of these disciplines, the integration of neuroscientific reasoning in the study of the mind is long-established; in others, including the discipline of communication and media research, neuroscientific perspectives have emerged only recently as a significant line of inquiry.

As with any transdisciplinary endeavor, the development of sophisticated research and fruitful collaborations will require that researchers establish common ground, interrogate latent assumptions, and craft programs of research that can be mutually beneficial to scholars across disciplines. In pursuit of these goals, this essay provides an overview of foundational research in the area of media neuroscience, evaluates key critiques of that research, and provides an outlook for how emerging trends may develop in the near future. In the process, we attempted to address four major questions: (i) *What* has extant media neuroscience research contributed to scientific knowledge? (ii) *How* can tools from neuroscience be applied to the

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study of media, and, conversely, how can media be useful in the study of neuroscience? (iii) *Why* should we study media neuroscience—or, perhaps, *why not?* (iv) *What's next* for media neuroscience?

FOUNDATIONAL RESEARCH

Neuroscience has been well established as a field for decades, and an overview of its foundational studies and major discoveries could easily fill an entire textbook (see, e.g., Gazzaniga, 2009). Rather than attempt to provide a comprehensive general overview, we instead concern ourselves here with the emergence of media neuroscience as a specific area of study, the development of which can be traced historically through the evolution of research on mass communication. In particular, two major transitions at different points in that history have laid the foundation for media neuroscience.

The first inflection point was the development of mass communication as a scientific discipline during the middle of the twentieth century. Of course, scholarly interest in communication as the art of rhetoric is much older—systematic approaches to rhetoric date back to at least ancient Greece. However, the sweeping impact of new electronic media, as well as the widespread use of propaganda during World War II, motivated a substantial number of researchers to begin studies of mass communication as a scientific, psychological, and social phenomenon in the 1940s and 1950s (e.g., Hovland, Janis, & Kelley, 1953). The pioneering persuasion studies of the Yale School initiated the bifurcation of communication science as a field distinct from the humanistic art of rhetoric and established media as a central focus of that field. This transition provided the basis for the *media* and *science* components of media neuroscience.

This originary work arose during an era in which studies were heavily influenced by positivism and environmental determinism. As a result, even in the present day, many communication theories purport to explain behavioral and social outcomes as products of environmental stimuli only. However, such theories are necessarily incomplete because they fail to account for the interaction between environmental inputs and the evolved physiological mechanisms that enable cognitive processes, traits, and behavior. Recent attempts to address this shortcoming have provided the second key transition toward media neuroscience: the development of a neurophysiological perspective, which incorporates theoretical ideas from evolutionary psychology and methodological tools from cognitive science (Weber, Sherry, & Mathiak, 2008). It is this body of research that has put the *neuro* in media neuroscience.

Media neuroscience is based on the belief that the brain is the center of cognition and must therefore play a pivotal role in processing media messages. Philosophical questions about the nature of the mind notwithstanding, only the physically observable world is amenable to scientific study, and mental processes can be most clearly explained through studying how physical events in the brain are linked to attitudes and behaviors. Furthermore, media neuroscientists subscribe to the view that the brain itself is a product of evolutionary processes, which have selected for modules that enable specific tasks (e.g., motor control, understanding language, recognizing faces) and have thereby yielded the emergence of complex cognitive phenomena (Barkow, Cosmides, & Tooby, 1992).

The primary theoretical value of media neuroscience lies in the nested levels of explanation demanded by a neurophysiological perspective on communication. Tinbergen (1963) famously argues that a complete explanation for behavior must address four distinct questions: ontogeny, phylogeny, causation, and function. Ontogeny and phylogeny place a given behavior in historical perspective, explaining how the trait develops during the life span of an individual organism and how its evolutionary history has unfolded at the species level, respectively. Both causation and function, on the other hand, address the operation of that behavior at a given point in time: causation provides the proximate mechanism by which the behavior operates, and function provides the adaptive utility of that behavior in evolutionary terms. Given that communicative behavior is an evolved adaptation, media neuroscience seeks to provide mechanistic explanations of *how* the behavior operates and can facilitate improved functional explanations for *why* such behavior is adaptive.

It is important to note that the rise of the neurophysiological perspective is not about a shift from "nurture" to "nature" as the driving explanatory force, but rather the dynamic interplay of both. This approach foregrounds a process-driven view of communication. Media effects research has often relied on static, population-level input–output models, which tacitly assume that the impact of a message occurs as a singular event and frequently gloss over the details of the individual differences and internal psychological processes driving media effects. By contrast, a process-oriented perspective argues that natural systems require a constant state of flux to adapt to changing environments and therefore foregrounds the dynamical nature of media effects (Lang, 2013). In keeping with this view, media neuroscience researchers aim to develop biologically driven explanations that demonstrate how media selection and effects occur as a result of processes that combine evolved physiological capacities with environmental inputs over time.

All types of communication between individuals is necessarily mediated, since the electrochemical signals in a sender's brain must be encoded in a format that can be transmitted to and processed by a receiver. At the most basic level, this takes the form of bodily movement that manipulates the local environment. Speech, for instance, uses the atmosphere as its medium: the vocal tract generates vibrations in air, which can be heard and understood by others. Over time, humans have developed many mediation technologies capable of extending the spatial and temporal transmissibility of a message. For example, writing encodes spoken language as symbols that could be recorded on a particular physical object, such as indentations in a clay tablet or ink on a sheet of paper, which can then circulate to other locations and persist over time. More recently, digital media have been developed to encode messages as numbers that, using electromagnetic fields for storage and transmission, can reliably propagate almost instantaneously over long distances and be broadcast to multiple receivers at minimal cost. Differences in how particular electronic media technologies—for example, text messages versus video calls—are processed by the brain is an active area of research with considerable value; however, this essay takes a broad perspective that foregrounds the content of mediated messages (e.g., auditory and visual information) rather than a particular technology of transmission (e.g., broadcast television vs streaming video on the Internet). We focus on audiovisual electronic media such as video and virtual environments not because other types of mediation are uninteresting, but rather because these media are uniquely able to encode multimodal, dynamic stimuli that most closely emulate the actual experience of reality.

Several studies exemplify early media neuroscience research and provide the foundation for the area. These studies can be broadly divided into two groups: those which use media to investigate neuroscience phenomena, and those which use neuroscience to investigate media phenomena.

First, media can evoke naturalistic responses in studies, which might otherwise struggle with ecological validity. A variety of brain imaging experiments have used mediated stimuli to simulate actual reality for participants during brain scans (Bartels & Zeki, 2004, 2005; Golland *et al.*, 2007; Hasson, Nir, Levy, Fuhrmann, & Malach, 2004; Mathiak & Weber, 2006; Spiers & Maguire, 2006a, 2006b). There is good reason to believe that these mediated stimuli can emulate real-world observations and interactions, despite the fact that participants are alone inside a brain imaging scanner. Research on the mapping principle suggests that individuals map virtual worlds to their experiences with nonmediated reality and, therefore, tend to behave in ways that parallel actual behavior (Reeves & Nass, 1996; Williams, 2010; Williams, Contractor, Poole, Srivastava, & Cai, 2011).

Second, media neuroscience can be used to examine the brain systems that are associated with particular media effects (Brefczynski-Lewis, 2011; Mathiak *et al*., 2011). The cognitive and behavioral effects of violence in media are one highly studied example, with numerous studies using both interactive (e.g., Klasen *et al*., 2013; Weber, Ritterfeld, & Mathiak, 2006) and noninteractive media (e.g., Mathews *et al*., 2005; Murray *et al*., 2006). Another major line of research has examined the persuasiveness of health-related messages (Falk, 2010; Ramsey, Yzer, Luciana, Vohs, & McDonald, 2013; Yzer, Vohs, Luciana, Cuthbert, & McDonald, 2011). The application of neuroscience to such questions can not only provide insight into the physical processes underlying media effects, but also serve as an important theory-building tool. For instance, the concept of flow has been used to explain media selection and enjoyment (Sherry, 2004). Weber, Tamborini, Westcott-Baker, and Kantor (2009) provide a neuroscientific reconceptualization of flow as the synchronization of attentional and reward networks in the brain, which has subsequently been tested using neuroimaging (Klasen, Weber, Kircher, Mathiak, & Mathiak, 2011).

These few selected examples of foundational research in media neuroscience have demonstrated that this emerging research area is bidirectional. Traditional cognitive neuroscientists stand to benefit from the increased ecological validity of media stimuli, the methodological possibilities enabled by virtual interactions, and the integration of solid media theory in neuroscientific investigations. Reciprocally, traditional media scientists stand to benefit from the empirical sophistication of brain imaging methods and the new theoretical trajectories that present themselves under an evolutionary neurophysiological paradigm. The bidirectional relationship between media science and neuroscience evinces the innate strengths of an abductive approach where theory and method evolve together, with innovations in one calling for further development of the other. In keeping with the notion that "there is nothing so theoretical as a good method" (Greenwald, 2012), media theory can drive new neuroscience methods, which can in turn yield data that demand revisions to media theory, and so on, in a mutually reinforcing cycle.

CHALLENGES AND CONTROVERSIES

While there seems to be a bright future for media neuroscience, this work remains in its infancy and is not without its critics. In this section, we provide a brief primer on neuroimaging for social scientists and consider some methodological, theoretical, and epistemological critiques of media neuroscience research.

Perhaps the biggest challenge for current work on media neuroscience is that only a relatively small minority of media scientists have the training necessary to execute or critically evaluate neuroscience research. Media scholars need to develop a basic understanding of brain anatomy and neuronal processes in order to design sound studies and engage in fruitful collaborations. Fortunately, there are a growing number of resources available for researchers to develop these skills and a number of excellent introductory textbooks (e.g., Frackowiak, Ashburner, Penny, & Zeki, 2004; Gazzaniga, 2009; Harmon-Jones & Beer, 2009). One of the most common technologies for neuroimaging is functional magnetic resonance imaging (fMRI). As is so often the case in scientific measurement, this technology has both advantages and disadvantages (Huettel, Song, & McCarthy, 2009). However, fMRI serves as a common measurement to observe the brain's activity and its wide use facilitates easy replication and collaboration (Brefczynski-Lewis, 2011).

One widely known methodological concern regarding neuroimaging is the problem of reverse inference (Poldrack, 2006). Suppose that a researcher observes that a certain stimulus tends to yield activation in a particular brain region, and that prior studies have associated that brain region with some well-known cognitive process. Frequently, the researcher will be drawn to make a reverse inference and assert that the stimulus engages that cognitive process. However, the available data can provide only limited support for such a claim—a given brain region may be activated by multiple distinct cognitive processes, so the fact that the region was active does not guarantee that the purported cognitive process took place.

This problem can be ameliorated in two general ways (Poldrack, 2006). First, certain brain regions exhibit highly selective responses that are consistently associated with one cognitive process but not others. Data sharing and replication are crucial to establish the selectivity of a region by observing trends across numerous studies. Though selectivity is beyond the direct control of the researcher, establishing high selectivity using prior research can strengthen the justification for the reverse inference. Second, brain imaging data can be combined with other behavioral measures, which can provide further evidence to help triangulate relevant cognitive processes. Social scientists can provide particular insight here, given their expertise in the development of behavioral measures for psychological processes.

A related challenge for neuroimaging in social science research also questions the ability to establish relationships between brain activity and cognitive processes, but from a slightly different perspective. Consider a distinction between research on *encoding* versus *decoding* brain states (Naselaris, Kay, Nishimoto, & Gallant, 2011). Traditionally, it has been generally cautioned that brain imaging cannot be a "mind-reading" technology:

experimenters present a stimulus designed to induce a given mental state and then observe the brain activity that encodes that state, but rarely has research reversed the procedure and used brain activity to decode mental states. This approach limits the utility of brain imaging, since it uses mental states to predict brain states, but not brain states to predict mental states.

However, there has been a recent groundswell of support for a new wave of decoding research supported by sophisticated Bayesian classifiers. For instance, the Gallant Lab at UC Berkeley has utilized a decoding approach extensively (Huth, Nishimoto, Vu, & Gallant, 2012; Naselaris, Prenger, Kay, Oliver, & Gallant, 2009; Naselaris, Kay, Nishimoto & Gallant, 2011), including decoding visual features of movies from brain activity (Nishimoto *et al*., 2011).

Similarly, Haynes and colleagues have conducted decoding studies focused around free will and hidden intentions, using brain activity to predict attentional salience and decision-making behavior (Bogler, Bode, & Haynes, 2011; Chen *et al*., 2010; Haynes *et al*., 2007; Soon, Brass, Heinze, & Haynes, 2008). These results have been one of the most remarkable emerging trends in neuroscience generally and media neuroscience in particular: "mind-reading" studies are now an extant, albeit nascent, area of research. It should be immediately evident that the ability to decode mental states using brain activity represents a major avenue for theoretical advancement using neuroimaging.

An additional critique of media neuroscience is that neuroimaging studies cannot predict real-world behaviors. This critique generally follows two lines of reasoning. First, ecological validity is a concern—brain scanning equipment is intrusive, and behavior during fMRI may not accord with real-world behavior. As argued earlier, though, media neuroscience can actually serve to enhance ecological validity by providing virtual environments within the experimental setting that can simulate actual experiences (e.g., Mathiak & Weber, 2006). Furthermore, brain imaging technology is constantly improving, and fNIR (functional near-infrared) technology capable of imaging prefrontal cortex is available in small, light, and comparatively unobtrusive packages (see, *inter alia*, Izzetoglu *et al*., 2011).

The second prong of this critique questions whether neuroimaging data can predict population-level effects. Given the time and expense associated with brain imaging, studies typically use as small of a sample as reasonably possible, often on the order of 10–20 participants. Moreover, the extensive use of convenience sampling from undergraduate participant pools calls into question the generalizability of research across the social sciences (Henrich, Heine, & Norenzayan, 2010). This is essentially an empirical question: do the results of neuroimaging studies allow us to predict behavior at the population level or not? Though it is impossible to provide a definitive answer to that question in its general form, recent publications (Berkman &

Falk, 2013; Falk *et al.*, 2013) have persuasively argued for a framework that combines neuroscience with population science, emphasizing representative samples, longitudinal analysis, and transdisciplinary collaboration. In one notable example, the application of neuroimaging using a brain-as-predictor approach doubled the explained variance in real-world health behavior compared to self-report measures (Falk, Berkman, Whalen, & Lieberman, 2011). Falk (2010) suggests that the future may bring "neural focus groups" whose brain imaging data are used to fine-tune persuasive messages. We believe that the use of the brain as a predictor of real-world behavior will be a crucial avenue of development for media neuroscience.

A final critique of media neuroscience is that neuroimaging data are innately misleading, increasing the confidence that researchers are willing to place in research, even when the results are counter-intuitive or even apparently absurd. A well-known study by McCabe and Castel (2008) contends that images of the brain in and of themselves make research findings more persuasive to their audiences—the exact same data presented in text or chart form carry less persuasive force, they argue, because images exaggerate a bias toward reductive physicalist explanations. We object to this critique on three levels. First, methodological shortcomings and failed attempts at replication call into question the empirical validity of the supposed "seductive allure" of brain imaging (Farah & Hook, 2013). Second, many researchers show due restraint in presenting their results, hedging the implications of their work when appropriate, and including images of the brain only when they contribute information above and beyond what can be presented through other means. Third, if such a bias does exist, its impact should be dampened over time as more scholars become familiar with neuroscience research and develop the experience necessary to critically evaluate that research. If anything, then this critique should be seen as a call for more and better neuroscience research, not the abandonment of neuroimaging.

OUTLOOK FOR THE FUTURE

Though it is currently in its early stages, we anticipate that media neuroscience research will grow tremendously in the coming years. In this concluding section, we provide an overview of research areas that are likely to be core to media neuroscience going forward and offer general guidance for how we believe this research can be most successful. The task of predicting where innovation is likely to occur always involves inherent uncertainty, and there are innumerable lines of study that could generate valuable knowledge. Nonetheless, based on recent interest as well as practical and theoretical value, we choose to highlight three major areas of research that seem likely to remain on the cutting edge of media neuroscience.

First, the effects of violent media seem likely to remain a central vein of research for the foreseeable future. As one of the longest standing and most studied topics in media neuroscience, the literature on media violence is already considerable. Yet development has continued in recent years, expanding research to consider not only the details of brain mechanisms that might underlie direct effects of violent media on aggression (Guo *et al*., 2013; Porges & Decety, 2013) but also better explanations of how different individual traits might mediate that relationship (Swing & Anderson, 2014; Valkenberg & Peter, 2013), and how violence effects psychological states other than aggression (Madan, Mrug, & Wright, 2014). Future work in this area also should include further examination of the contested link between aggressive cognition during exposure to media violence and subsequent aggressive behavior. The use of neuroimaging data to predict population-level behavior could be especially valuable in addressing that important ongoing controversy.

Second, media neuroscience will continue to provide great contributions to the study of persuasion. The high-stakes area of health communication will likely play a major role here. Falk (2010) argued that the contributions of media neuroscience would likely proceed in three parts: identification of neural mechanisms underlying persuasive health messages, translation of brain imaging data examining those mechanisms into sound predictions about population-level behavior, and integration of those mechanisms into theories of persuasion. So far, this progression is well underway. The use of brain imaging data to make predictions about the real-world effectiveness of persuasive messages is an emerging trend with tremendous potential (Falk *et al*., 2011).

Third, we anticipate an increasingly close relationship between research on narratives as a means of communication and research on the neural substrates of moral reasoning. Hasson and colleagues have produced a fascinating program of media neuroscience research that examines communication as a process of brain-to-brain coupling (Hasson *et al*., 2004; Hasson, Ghazanfar, Galantucci, Garrod, & Keysers, 2012; Stephens, Silbert, & Hasson, 2010). A separate line of research has examined the evolutionary basis of moral intuitions (de Waal, 2013; Haidt & Joseph, 2004) and sought to identify the neural mechanisms of morality (Graham *et al*., 2011; Mikhail, 2007; Parkinson *et al*., 2011). Narratives can serve to communicate culturally significant moral norms, and future research on media neuroscience is poised to better understand how moral content promotes synchronous brain responses and affects the salience and popularity of narratives (Tamborini, 2011; Weber *et al*., 2006, 2007; Weber, Popova, & Mangus, 2012).

The success of these research programs—and media neuroscience overall—will demand innovation. Cross-disciplinary collaborations frequently suffer from differences in training and difficulties in communication. Neuroimaging research requires extensive planning and resources. Without a culture of data sharing and replication, methods will be inconsistent, predictions will be limited, and results will be uncertain. Students in communication and media science who intend to pursue this research will require training that currently may not be available in many departments. Nevertheless, we believe that these challenges can—and ought to be—overcome given the far-reaching benefits of media neuroscience research for revealing how complex behavior emerges from dynamic processes in the brain.

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