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ORIGINAL ARTICLE

# Theory and Method for Studying How Media Messages Prompt Shared Brain Responses Along the Sensation-to-Cognition Continuum

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*When members of an audience are exposed to the same messages, their brains will, to a certain degree, exhibit similar responses. These similar, and thus shared audience responses constitute the recruitment of sensory, perceptual, and higher-level neurocognitive processes, which occur separately in the brain of each individual, but in a collectively shared fashion across the audience. A method called inter-subject-correlation (ISC) analysis allows to reveal these shared responses. This manuscript introduces a theoretical model of brain function that explains why shared brain responses occur and how they emerge along a gradient from sensation to cognition as individuals process the same message content. This model makes results from ISC-based studies more interpretable from a communication perspective, helps organize the results from existing studies across different subfields, and generates testable predictions. The article discusses how research at the nexus of media, audience research, and neuroscience contributes to and advances communication theory.*

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Imagine a speaker addressing a large audience, such as Dr. Martin Luther King giving his famous "I-Have-A-Dream" speech. The resulting one-to-many message could be characterized as communication science's cradle (Bizzell & Herzberg, 2000). Modern media create a similar one-to-many situation in which the same message is delivered to a large audience. A fundamental question is how similarly members of an audience respond to these messages. For instance, does a message evoke heterogeneous responses, or does it command similar responses that are thus collectively shared across the audience?

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Recent work has begun to reveal neurocognitive responses during message reception. This article is written in the general spirit of reviews that introduced biological methods as new ways to study communication processes (Falk, Cascio, & Coronel, 2015; Potter & Bolls, 2012; Schmälzle & Meshi, 2020; Weber et al., 2018). However, it deals with a new approach, called inter-subject-correlation analysis (ISC). As the name suggests, ISC analysis computes correlations between recipients' brain activities. This provides a way to assess whether, where, and how strongly brain responses are shared across audience members. Given that constructs like attention, elaboration, or involvement loom large in communication, but are hard to measure, an ability to identify shared responses in specific brain regions while people process messages is relevant to many communication theories. This includes theories about entertainment, persuasion, and all topics that deal with how audiences respond to communicative messages. In addition to these theoretical issues, the approach is also practically relevant because it allows to measure and possibly predict audience responses. However, the foundation of measuring shared audience brain responses has not been well explicated, and there exists confusion about how the ISC-technique relates to other methods.[1] Therefore, instead of providing another methodological review, this article focuses on the theoretical relevance of the approach and introduces a model of brain function that helps organize results from corresponding studies.

The article's organization is as follows: First, I introduce the rationale for measuring shared audience responses and discuss how to assess them via ISC analysis. Next, I discuss a model of brain function that provides a framework for understanding why the same messages prompt shared responses and how to interpret the results. I then discuss recent studies through this model's lens and point out research opportunities.

## Rationale for Measuring Shared Audience Responses

### Principle of the Inter-Subject-Correlation-Approach

During a public speech, words emerge from the speaker's mouth as sound waves and travel across the air towards the audience. When these signals arrive at each listener's ears, they are converted into neural impulses and analyzed along a gradient from sensation to cognition. Within a split-second, people in the audience understand and respond to the speech, such as when Dr. King's statement that "All men are created equal" prompts vigorous applause. An obvious question is whether the same message produces similar responses in peoples' brains ahead of these reactions, and if so, how, why, and in which regions effects arise? These questions focus fundamentally on how messages are received, processed, and responded to. As such, they are of great significance for communication science, and new methods that can help address them have the potential to promote method-theory synergy in our quest to explain communication processes (Greenwald, 2012). Moreover, moving from explanation to prediction, it would be relevant if one could predict outcomes based on brain activity data recorded during message exposure (Falk et al., 2015). To link back to our example, could we perhaps identify peak moments in Dr. King's speech based on convergent audience brain responses? A recently developed data-analytic method, ISC analysis provides answers to these questions by quantifying shared audience responses to the same messages.

The rationale behind the ISC approach is straightforward and laid out in Figure 1. Consider a situation in which different people process the same message and neuroimaging has been used to record their brain activity. In this example, we assume that functional magnetic resonance imaging (fMRI) has been used to record each individual's brain activity on a moment-to-moment basis, and simultaneously from many different brain regions. These recordings provide the raw data for ISC analysis. We can then focus on one specific region of the brain and extract its activity time course from the recorded fMRI data from two individuals. To assess the similarity of these regional brain processes across subjects, we can use correlation analysis, which is what motivates the label ISC analysis. By repeating this procedure across all possible pairs of recipients, and for all subregions of the brain, we can create so-called ISC maps. These maps indicate where in the brain and how strongly a message commands similar brain responses across an audience.

That such similar, or shared, audience brain responses arise is now a well-established phenomenon. Dozens of studies have demonstrated its existence using various methods, such as functional magnetic resonance imaging (fMRI),

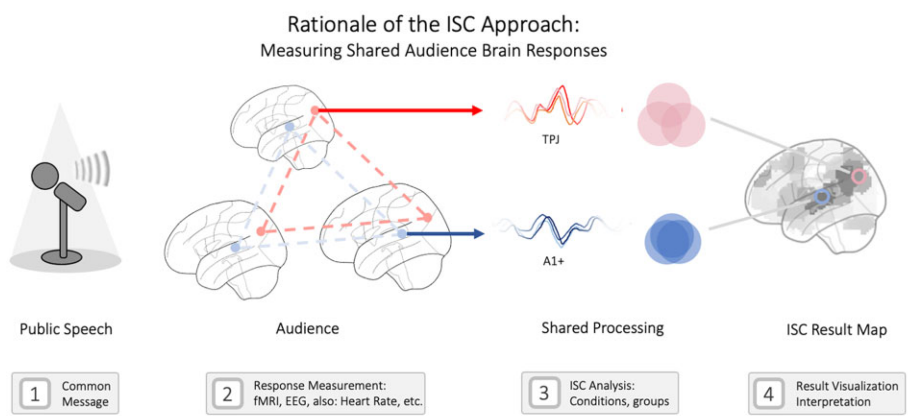


**Figure 1.** Principle of ISC analysis. During public speaking, the same message reaches audience members and evokes activity in brain regions involved in audition, comprehension, attention, and social cognition. ISC consists of cross-correlating the brain activity time courses from corresponding regions across audience members. The result reveals how similar the audience responds at the neural level to any given message—regardless of its complexity, modality, or media format. Of note, the example here uses fMRI to measure the message-evoked brain response. The same principles apply to EEG, fNIRS, heart rate, or other methods. Brain images adapted from (Abraham et al., 2014).

electroencephalography (EEG), heart rate, or other psychophysiological measures. Moreover, the ISC-technique has been used profitably to study shared responses across multiple contexts, such as public speaking, movie viewing, and even interpersonal communication[2] (Hasson, Malach, & Heeger, 2010; Nastase et al., 2019; Schmälzle & Grall, 2020a). This article describes these studies and proposes an integrative model for explaining why shared brain responses occur.

**Short History and Areas of Application**

The seminal study introducing the ISC-technique to measure shared audience responses examined brain responses to the Hollywood movie *The Good, the Bad, and the Ugly* (Hasson et al., 2004). The researchers carried out the procedure shown in Figure 1 (only for a movie instead of a speech), extracting and correlating the brain activity time-courses from individual brain regions, such as the visual cortex. Results demonstrated that while people viewed the same movie, their brains exhibited strong correlations of spatiotemporal activity patterns in about 30% of the cortex. The discovery of this new phenomenon was considered groundbreaking.

It is worth noting that at the time of publication, fMRI had only been around for a decade, and its use for studying cognitive processes was still challenged. Thus, while it may seem evident to communication researchers that media are a scientific wellspring (Okdie et al., 2014), this study was among the first to show that one could study brain activity during the type of semi-naturalistic stimulation provided by a movie. At that time, the neuroscience community had not yet accepted this and exhibited a preference for artificial and simple stimuli, such as individual images or simple sounds appearing in insolation (Hasson et al., 2010). By contrast, using a stimulus like a movie was considered as too uncontrolled. The main reason for this view was that existing methods for neuroimaging data analysis required a detailed annotation of the stimulus in order to map out which brain region's activity tracked with the presentation of each stimulus type, and this favored relatively simple paradigms.[3] With this in mind, it is understandable why the neuroimaging community was initially skeptical towards using movies or other real-world media as experimental stimuli. Critically, however, the ISC-approach circumvents the need for any stimulus annotation. Rather, it focuses on the similarity of the response to the same stimulus across recipients. Thus, an ISC analysis is applicable whenever participants are exposed to the same message, regardless of complexity, and this is what opened the door for using stories, movies, and other messages as experimental stimuli (Nummenmaa et al., 2014; Schmälzle et al., 2013; Zadbood et al., 2017).

As of 2021, the ISC-approach for assessing shared brain responses is widely accepted and valued for its theoretical and methodological contributions (Yeshurun, Nguyen, & Hasson, 2021). For example, the ISC method has been used within cognitive neuroscience to examine time-scales of information integration (Lerner et al., 2011), a critical aspect of working memory that had been very difficult to study due to the experimental constraints of laboratory tasks and then-dominant analytical methods. This has led to improved theories of working memory that are more compatible with recent research in artificial intelligence (Hasson, Nastase, & Goldstein, 2020). Another example where the new approach led to advances was episodic memory research. For instance, when two people watch the same movie, similar responses during specific movie scenes are predictive of whether they will both recall the scene (Hasson et al., 2008). Additionally, it contributed to many broader topics, such as inter-species-correlations and evolution (Mantini et al., 2012), higher-level consciousness (Naci, Cusack, Anello, & Owen, 2014), and language and social understanding more broadly (Nummenmaa, Lahnakoski, & Glerean, 2018). For instance, it has been shown similar brain processes between a speaker and a listener predict story comprehension (Stephens, Silbert, & Hasson, 2010), and when people were unable to understand a story told in a foreign language, their brain activity did not correlate (Honey et al., 2012). As can be seen, the ISC-approach has already been used to shed light on many processes that are integral to communication, although these studies are often reported in neuroimaging journals and without mentioning the link to communication science, most likely because the concept of "audience" plays no theoretical role within neuroscience. We will return to these examples and discuss them more thoroughly below.

In brief, the ISC-technique is applicable to all situations where the same time-varying message is received and processed by multiple individuals comprising an audience: This includes people watching a movie, individuals reading the same narrative, audiences listening to a speech, and many more. In all these cases, the ISC-approach highlights shared brain responses between people who process the same message content (Hasson et al., 2010, 2012; Nummenmaa et al., 2018; Schmälzle & Grall, 2020a). The focus on shared responses, or commonalities in neural reception processes, makes it especially relevant to research that is concerned with audiences, such as public speaking, mass media messaging, and others.

However, although past reviews have mentioned ISC analysis among other methods (Huskey et al., 2020), there is a void for a dedicated review that articulates the theoretical and methodological contributions for revealing shared audience responses[4] (DeAndrea & Holbert, 2017). Such a review is needed because without it, studies exist in a theoretical vacuum and one can easily overlook the theoretical focus of this new approach (Greenwald, 2012). Moreover, examining shared responses runs somewhat orthogonal to existing methods in terms of goals and procedures, which creates a risk for confusion.[5] Specifically, the approach is unique in its focus on the brain-to-brain-similarity of message-evoked processes. This aspect barely plays a role in other methods. Thus, a dedicated review is warranted to describe the unique theoretical thrust and germane goals of this approach for communication science.

## Why Does Brain Activity Correlate? Neuroscientific Background for Understanding Shared Audience Responses

This section introduces a model of individual brain function, which is grounded in brain theory. Such a model is essential, although many empirical neuroimaging papers do not provide one, either because authors may take it for granted, or because they omit it due to space limitations. Given the relative novelty of neuroimaging in communication, it is important to provide such a model as a theoretical bridge. The following section will then discuss how this model can be applied to the case of multiple individuals comprising an audience, and how doing so can help us explain and predict the shared audience brain responses—the phenomenon that ISC-analysis reveals.

### Mesulam's Neurocognitive-Network-Model

The neurocognitive-network-model offers a conceptual framework for understanding sensation, perception, and cognition via large-scale, distributed, and hierarchical brain networks[6] (Mesulam, 1998). The model is well-known in cognitive neuroscience because it accompanied the evolution of brain mapping as a field. This provided a blueprint for linking neuroimaging data to large-scale brain networks. Specifically, the view articulated in Mesulam's now-classic article titled *From-Sensation-To-Cognition* (Mesulam, 1998) helped integrate neurophysiology with neuroimaging, and it has spearheaded the development of network-based methods within functional neuroimaging (Bassett & Sporns, 2017). This model might serve a similar purpose for communication science.

In brief, the model describes the distributed and hierarchical nature by which information processing in the brain happens along a gradient from sensation to cognition. As illustrated in Figure 2a, information arrives at local entry points, such as the cochlea for auditory input or the retina for visual input. Next, the information undergoes sensory analysis and gets passed on to perceptual processing modules, and further on to yet higher levels. These progressive transformations of information ultimately produce the phenomena we know as cognitive and emotional processes. As this happens, the information also becomes distributed across regions. Thus, the specific aspects of the stimulus representation depend on the analysis level, which the model categorizes into sensory, perceptual, or cognitive domains. One could, of course, write entire reviews about the implementation of single functions, such as attention, social cognition, or emotion. However, this article focuses on the more abstract notion of a gradient of information processing from sensation to cognition.

To make these abstract descriptions more concrete, consider what happens when the sound of a speaker's voice enters the ear. Physically, sound consists of vibrations, which one can characterize in terms of its frequency content. Sensory-perceptual brain systems are devoted to transducing the stimulus and analyzing such fundamental aspects of the stimulus.

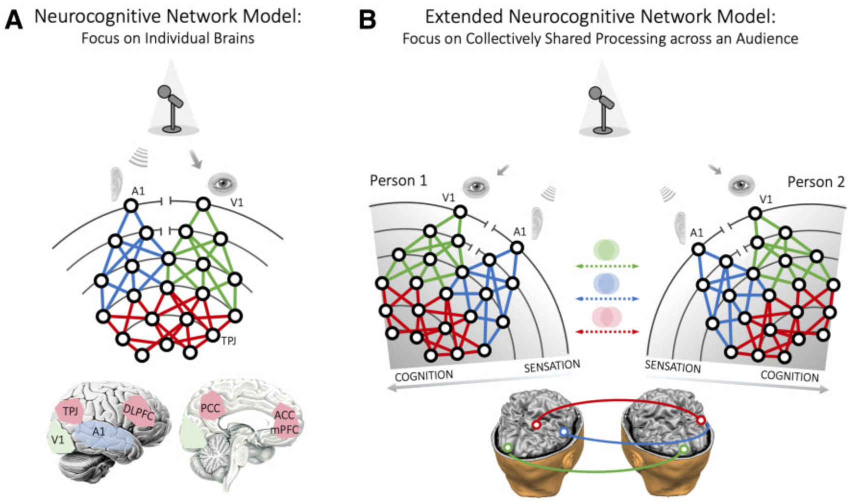


**Figure 2.** The neurocognitive-network-model. (a) Schematic representation of Mesulam's model of visual (green) and auditory (blue) streams along a sensation-to-cognition continuum. See text for further details. (b) Expanding the scope of the model to an audience consisting of two persons. Suppose the same message, such as the auditory and visual information comprising a public speech, enters the brains of these individuals. In that case, it will evoke similar responses at different levels of these neurocognitive networks to the extent that the network nodes are structurally and functionally corresponding. See text for further details.

It is clear, however, that understanding a speech requires additional computations beyond frequency analysis. These include parsing words, syntax, and semantics, to name but a few. Brain networks involved in lexical access, for instance, help us recognize individual words. Networks involved in syntactic processing assess the individual words in terms of their syntactical role (e.g., subject, verb, object). Analogously, single sentences are combined into paragraphs or entire stories (Grall et al., 2021), which are integrated into a conscious, global workspace (Dehaene et al., 2014).

While this example focuses on hearing, an analogous case can be made for vision, where the process would start with piecemeal information entering the retina. Again, progressive information transformations would analyze individual elements, such as "two eyes and a nose," until a coherent impression of the speaker's face emerges (Chalupa & Werner, 2003), which would in turn trigger further processes related to person recognition in memory, emotional expression analysis, and so forth.

Regarding where in the brain this all happens, we know that sensory sound analysis occurs within brain systems up to the auditory cortex. These mechanisms are also fairly localized (Fuster, 2003). The word-level analyses are more distributed, relying on broader association-networks (Fuster & Bressler, 2012). For instance, think about what happens if our hypothetical speaker utters the word "dog." Understanding this word involves multiple facets, like how a dog looks, how a dog barks, or how it may feel to pet a dog. Integrating these elements into the symbolic concept "dog" (or German – "Hund," French – "chien") relies on binding together visual, auditory, and tactile information (Pulvermüller, 2001).

These examples illustrate distributed and hierarchical processing at the level of sensation and perception. The same principles apply at higher analysis levels, which are more interesting for communication scientists. Indeed, although a single word like "dog" can convey symbolic meaning, communication tends to take more complex forms. However, when words occur in the context of sentences, they can convey more complex messages. Such information could range from a simple sentence, such as "A dog wiggles with the tail," to a complicated emotional story about our speaker's hairy childhood friend. Processing and integrating such a story would, according to the neurocognitive-network-model, involve yet higher levels of the cortical hierarchy, including networks related to attention, comprehension, and social cognition (Grall & Schmälzle, 2020a).

In favor of a conceptual view, we leave out anatomical details of this model, but the overarching idea should have become clear: The brain operates according to multiple, hierarchical, and blending gradients. These gradients range from basic audition to language, from basic vision to semantic scene understanding, and from unimodal hearing and seeing to an integrated perception of the entire public speech situation. Using neuroimaging, we can now observe how these processes unfold within the brains of message recipients.

One essential contribution of this model was that it resolves a vexing issue that plagues many who are new to cognitive neuroscience theory: Specifically, people often falsely presume a 1:1 mapping between psychological concepts, such as "attention," and a single brain region. Mesulam's model, like most network models, navigates these questions by articulating a brain-based theory that does not view "attention" (or any other process) as a merely hypothetical construct, nor equating it with the activity of a single brain region. Instead, it conceptualizes cognition as a brain-behavior mediational relationship that arises from these brain networks (Mesulam, 1998).

The empirical discovery of large-scale networks has lent strong support to the general model (Mesulam, 2012). Numerous topics, such as attention, memory, and self-relevant processing, are now examined through this lens (Bassett & Sporns, 2017). Network-based approaches are also on the rise in communication, including topics like mentalization (Schmälzle et al., 2017), flow (Huskey, Wilcox, & Weber, 2018), social influence (Wasylyshyn et al., 2018), or narrative processing (Grall et al., 2021; Yeshurun et al., 2021). The recent explosion of research on artificial neural networks provided further support for the notion of hierarchical and distributed processing and linked abstracted models to mathematical theory (Marblestone, Wayne, & Kording, 2016).

To summarize, the model of brain function described above provides a conceptual blueprint for how the mind can be understood in terms of stimulus-brain-behavior relationships. Central notions are hierarchical and distributed processing that happens within brain networks. These concepts have always been difficult to grasp, but they are overwhelmingly supported by neuroanatomy, functional neuroimaging, and computational modeling. These developments are relevant for communication science because they open up new opportunities to increasingly ground hypothetical processes (e.g., "attention," "involvement," "elaboration") in observable brain responses. However, to reap these benefits, we need to find ways to bridge the gap between models of individual brain function and larger scales, such as mass audiences.

**Applying the Neurocognitive-Network-Model to Multiple Recipients**

The neurocognitive-network-model focuses on explaining neural responses within a single brain. This section will show how one can extend the scope of the model to multiple brains, and how doing so explains why shared processes emerge. The central idea that animates this section will be that of similarity of structure and function.

All humans have a lot in common, despite our many differences in overt appearance, language, and behaviors. As members of the species homo sapiens, we all share a common evolutionary ancestry. Likewise, our development also follows a similar trajectory, starting at conception until we can perceive, act, and communicate. Our bodies exhibit many commonalities as well: Our faces may differ in size and shape, but they are similar in that we all have two ears and two eyes. These eyes and ears connect to nerves, which transmit information into the brain. There, again, we find a conserved gross-anatomical architecture across people in terms of hemispheres, lobes, and gyri.

This notion of commonalities in structure and function can be applied to the neurocognitive-network-model. The rationale is that if we have a similar brain architecture, we should also exhibit commonalities in how our brains operate. Thus, we can expect that systems for audition should respond similarly when presented with the same sound. After all, the ear's auditory mechanics, the auditory pathways, and so forth are conserved across humans. Thus, when a public speech arrives at the ears of audience members, we can expect it to evoke similar reactions in separate brains.[7]

Figure 2b illustrates this idea by showing a second model image to represent the brain of a second person. As can be seen, the second model resembles the first one, highlighting the notion that peoples' brains operate according to similar neurocognitive principles (i.e., gross-anatomical similarities and a conserved architecture of basic sensory, perceptual, and cognitive brain networks). The prediction that follows from this reasoning is that if a speaker addresses an audience, the incoming stream of sounds will set forth similar processes within the brains of different people. By correlating the brain activity from corresponding brain regions (or homologous nodes in the model), as is done in ISC analysis, we can reveal these commonalities.

Equipped with this general model, we can now better understand the phenomenon of shared brain responses between people who are processing the same messages. Specifically, correlated brain responses emerge because a message engages neurocognitive functions across multiple audience members, or collectively. Thus, if people process the same sounds, auditory brain networks respond similarly because they face similar processing demands, have a similar functional architecture, and will thus show similar activities as the message unfolds. If these sounds comprise words and if people are in command of the language, then they will perceive speech and understand the words. This would cause language-related regions to come online, which would again happen in a similar fashion across all audience members who can hear and understand the words. Lastly, if people follow the same story, including its emotional and social content, then cognitive, social-cognitive, and affective functions will become similarly engaged across listeners.

Each of these processes would rely on a shared structural and functional neurocognitive architecture. In this sense, the model explains the emergence of shared brain responses due to shared sensory, perceptual and conceptual knowledge structures that become engaged while processing the incoming message, and similarly across many people. By carrying out ISC analysis, we can reveal the degree to which the same message evokes shared responses across multiple brains.[8] Importantly, this model opens the door for studies with complex messages because it requires no detailed stimulus annotation, focusing instead on similarities of message-evoked processes across recipients. Moreover, the model is relatively parsimonious as it makes no direct claims about hypothetical constructs. Rather, the demonstration that there are shared responses across the brains of audience members provides the theoretical basis for further identification of the mechanisms that underlie cognitive processes addressed by those messages (e.g., attention, comprehension, memory, etc.): In particular, after being able to reveal shared audience brain responses, we can manipulate message or audience variables and observe the effect on the strength and spatial distribution of shared responses.

Several neuroimaging studies have already begun to examine these issues and their results are compatible with the model presented here. We will discuss specific findings below, but a general abstraction is that when audiences process the same speech stream, we find strongly correlated responses in early auditory regions involved in sound analysis, perisylvian areas involved in language processing (Lerner et al., 2011), and extralinguistic regions involved in executive attention, saliency, emotion, and social information processing (Honey et al., 2012; Regev et al., 2019; Schmälzle et al., 2015; Schmälzle & Grall, 2020b; Yeshurun, Nguyen, & Hasson, 2017). These levels correspond roughly to the sensory, perceptual, and cognitive layers in Figure 2.

Overall, this approach can contribute to communication science in many ways: Communication is fundamentally about how information is exchanged between sender(s) and receiver(s) (Shannon, 1949). However, there has always been a significant theoretical gap between the message as a physical stimulus and its effects on the mind—be it within single individuals or in audiences at large. Although we do not claim that this gap can be completely closed at this point, it is clear that neuroimaging can shed light on the mechanisms by which messages affect audiences. As such, the approach of studying shared audience responses during message reception creates a bridge between the transmission model of Shannon and Weaver and the domain of cognitive neuroscience.[9] This bridge is theoretically relevant for all areas of communication that make claims about reception processes, but have henceforth not provided any grounded explanation for how the message as a physical stimulus (i.e., the sound wave) is transformed into what we know as message or media effects. Neuroimaging helps us close this explanatory gap by revealing the hidden brain responses to the message. Moreover, by showing that a message evokes a common "signal" across the brains of recipients, we can conclude that the message has arrived in the brains of audience members, suggesting that communication has been successful or at least a precursor of communication success. Said differently, brains start to correlate because the message evokes similar neurocognitive responses at specific levels of the neurocognitive hierarchy and ISC analysis can reveal whether and how this happens. Conversely, if the message did not act as an audience-aligner (Imhof et al., 2020), then brain activity would not correlate across people (Hasson et al., 2004). Several studies, discussed below, have demonstrated that these neural-level commonalities explain and predict theoretical phenomena related to language understanding, memory, attention and social cognitive processes, which are all critical mediators between message content and message effects on individuals and audiences at large.

## Using the Model as a Lens to Review Recent ISC-Based Studies and Make Predictions for Future Research

The previous sections described the rationale of the approach to measure shared brain responses and introduced a domain-general model of brain function. We then expanded the scope of the model to the case where different people process the same message. Using this model as a scaffold, we can now review and reinterpret various results from studies that were conducted without this model in mind. Thus, the goal is to use the model as a lens to demonstrate the value added for understanding the shared audience response phenomenon in the context of various potential research paradigms and to highlight connections to existing communication theories.

Since the first ISC study, which used a Hollywood movie as a stimulus to study vision (Hasson et al., 2004), many other studies examined brain responses to movies. How can we look at this study against the scaffold of the neurocognitive-


**Figure 3.** Demonstrating the versatility of the model for paradigms. (a) Applying the model to various simple situations makes predictions for where in the brain coupled audience responses should emerge as a function of processing demands. (b) More interesting paradigms in which message properties or message-receiver fit can be manipulated.

network-model? First, a movie with its moving images provides the same time-varying sensory input. This predicts similar responses across the visual-sensory brain (see Figure 3a). This was confirmed. Second, the movie also contained sound, predicting similar responses in auditory-sensory regions. This was also confirmed. Third, because the film also had a strong narrative, one would expect additional brain regions to come online. This was also confirmed, although little was known about these functions and their functional anatomy at the time of the study.

Further studies zoomed in on individual modalities, for instance, by presenting silent films (images, but no sounds) or spoken language (sound, but no images) (Hasson et al., 2008; Lerner et al., 2011). As expected, these types of content prompted ISC effects in visual or auditory regions, respectively (see Figure 3a). These results are hardly surprising and perhaps not immediately relevant for communication theory, but they helped establish the general approach and demonstrated the possibility of using complex stimuli like movies or stories as experimental stimuli in neuroimaging studies.

A powerful demonstration of what this approach offers for communication comes from a study by Honey et al. (2012). In brief, the authors presented the same story in different languages (English and Russian) and to listeners who were either able to understand the language or not (Figure 3b). Again, considering this study through the lens of the multi-brain extension of the neurocognitive-network-model (Figure 2b) makes them easier to understand. First, presenting the same auditory stimulus should engage listeners' auditory-sensory brain regions in similar ways—irrespective of language knowledge. This was confirmed. However, as we move higher-up in the neural hierarchy, it will matter whether the recipient possesses language knowledge. Thus, if a story told in Russian is processed by a person in command of the Russian language, this person will have the linguistic keys to follow the story. Therefore, brain regions subserving language comprehension and social cognition should become engaged in this person. Suppose we correlated the brain activity during story listening to another person who is also in command of the Russian language. In that case, we should see correlations between their brains in higher-order regions (as well as in auditory-sensory areas). However, if we correlated the brain activity with that of a person who does not speak Russian, that person will not be able to follow the story. Thus, their brain activity will not correlate beyond the residual correlations that are simply due to processing the auditory gibberish that a foreign language provides. These predictions were all confirmed. Taken together, what this study showed was that ISC is sensitive to higher-level processes beyond basic audition or speech processing. This finding is very relevant for communication science, especially in light of renewed interest in topics related to multilingual understanding and understanding in general (Gasiorek & Aune, 2020), which clearly touches on foundational questions of the discipline.

The studies presented so far show that the ISC-approach can resolve the common processes induced by visual and auditory messages and that it is sensitive to shared language knowledge between recipients. An important next step was to examine whether it also provides a way to tap into attentional phenomena, specifically whether ISC-based neuroimaging is capable to reveal whether a message can capture and sustain the attention of multiple message recipients.[10] An ability to study differential attentional allocation to messages while the message unfolds, but also with the audience-based perspective that the ISC approach entails, would clearly be relevant for many theories of communication. For instance, there have been longstanding debates about audience involvement (Greenwald & Leavitt, 1984) and its internal degree of activity (Biocca, 1988), but relevant concepts have been notoriously difficult to pin down. Although we do not claim here that they can be simply reduced to selective attention, it seems clear that these concepts touch centrally on how much a message engages the audience attentionally. Similarly, the Extended-Elaboration-Likelihood-Model (eELM), a theory explaining the influence of persuasive communication embedded in entertainment programs (Slater & Rouner, 2002), centers around the notion of attentional absorption, and various related constructs have been proposed in research on narratives, entertainment, and message processing more broadly (e.g., Donohew, Palmgreen, & Duncan, 1980; Lang, 2000). In sum, hidden attentional processes are central and foundational within many communication theories. An improved ability to reveal effects related to attention during message reception could help test and advance these theories.

To address the question whether ISC-based measures are sensitive to basic manipulations of attention, a study by Ki, Kelly, and Parra (2016) instructed participants to selectively attend to stimuli. This instruction strongly affected the strength of shared processes, i.e., ISCs of individuals' brain activity, suggesting that ISC analysis is a useful method in this context. However, while manipulating attention via instruction provides a very good experimental demonstration, naturalistic attention is often not deployed in an instructed manner, but rather based on self-defined relevance.[11] The question then becomes whether the strength (or regional distribution) of shared brain processes (identified via ISC) would be affected by such modulations of a message's relevance: For instance, would hungry audiences show higher ISC while watching cooking shows, or would audiences show higher ISC during highly suspenseful scenes of a movie? Or, focusing again on speeches, would rhetorically powerful speeches prompt more similar responses than weak exemplars? The evidence to date suggests that this is the case (Goldberg, Preminger, & Malach, 2014; Grall et al., 2021; Nummenmaa et al., 2014; Schmälzle et al., 2015), thereby suggesting the ISC-based paradigm as a versatile approach to study how audiences attend differentially to messages.

Again, looking at these studies through the lens of the neurocognitive-network-model (Figure 2), the model explains why these phenomena arise: Specifically, we know that attention—in the individual brain—increases the neural response to the attended stimulus content and its selectivity to specific types of content (Chun, Golomb, & Turk-Browne, 2011). To the extent that individual attention amplifies the same content, we can again expect that ISC would increase if multiple people focus on the same content aspects. In fact, given that attention is challenging to measure without interrupting the phenomenon, measuring shared audience responses via neuroimaging provides a promising method to track the degree of attention an audience allots to a message (Dmochowski et al., 2014). Going forward, we foresee that ISC-based neuroimaging studies could thus be connected to the communication theories highlighted above (ELM, eELM, narrative theories) and some relevant studies have already appeared (Schmälzle et al., 2015; Imhof et al., 2020; Grall et al., 2021).

Next, the right panel in Figure 3b shows examples in which one could experiment with knowledge structures beyond language knowledge (see left panel in Figure 3b), tapping more into hot-cognition phenomena, such as attitudes. The example shows a hypothetical study in which people who are in favor vs. against gun-control are exposed to pro- vs. anti-gun-control arguments. Instead of focusing on gun control, however, we can refer to an issue that is also very polarizing these days: pandemic risk communication. For example, during the H1N1 pandemic of 2009/10, researchers in Germany used a survey to identify people with either high or low risk perception and exposed them to the same TV-documentary about H1N1 (Schmälzle et al., 2013). Thus, the incoming information was the same for everyone, but people differed based on their pre-existing level of risk perception. This study found that the brains of all audience members showed similar responses regardless of their pre-existing risk perception in visual and auditory regions. However, people who considered H1N1 as a high risk exhibited more strongly aligned brain responses while processing the H1N1-related TV report compared to those with low risk perception. This effect was strongest in the anterior cingulate cortex (ACC), a region often associated with salience processing and topics like anticipatory anxiety, and at lower thresholds also in regions of the so-called executive control and default-mode-network (DMN). This pattern of results can be understood by looking at the model in Figures 2b and 3b. Specifically, if the incoming visual information is received by person 1 and person 2, it will set forth similar processes in regions involved in visual processing in both brains—regardless of peoples' risk perception. The same applies for the TV documentary's soundtrack: the same stimulus commanded similar responses. However, in higher-order regions (such as the ACC, red colors in Figure 2b), the strength of shared responses between recipients depended on whether there was a match in terms of risk perception level. These results have implications for studies on message targeting (Kreuter & Wray, 2003) as well as broader attitudinal topics, although at this point this emerging neuroimaging work is not yet fully connected to the concepts from existing communication theories, like the "involvement" construct in the ELM or the "latitude of acceptance" and "latitude of rejection" in Social Judgment Theory (Sherif & Hovland, 1961). However, it seems clear that such an integration becomes increasingly possible and thus, like for the example on attentional mechanisms during message reception, we expect that more studies will use ISC-based methods to examine the processing and effects of pro-and counter-attitudinal messages from a neural perspective.

To summarize, the ISC-approach is useful to study effects of audience setup or message content manipulations. The six panels in Figure 3 demonstrate how the multi-brain extension of the neurocognitive-network-model can be used to understand results from prior studies, and how one can use this general model to make predictions about future studies. Given that many communication theories feature henceforth unobservable mental processes, the ability to interrogate multiple neurocognitive processes during message reception and with an eye towards shared audience responses is relevant for these theories and points to new ways to test or advance them.

Of course, these are only selected examples and measuring shared audience brain responses would be of interest for many other topics. Among the key processes of interest are many social-cognitive functions, which loom large in communication. As the methods and the field have matured, these topics are coming more and more to the front. For example, one large-scale brain network that is consistently involved in social-cognitive processes and sensitive to ISC effects is the so-called DMN (Yeshurun et al., 2021). This network includes nodes like the medial prefrontal cortex, the precuneus, and the temporoparietal junction. The DMN has received special attention in social neuroscience and there even exist anatomical studies that demonstrate that this network maps well onto the higher-level, reddish nodes (Figure 2) of the neurocognitive-network-model (Schurz et al., 2020). Several of the studies mentioned above, such as the English-Russian study or the study of engaging political speeches, have found ISC-effects in this network. However, given the limited number of ISC-based studies, more work is needed to follow up on these findings, especially from the perspective of communication science.

## General Discussion

The model presented here provides new insights by explaining how a given message engages the brains of audience members in similar ways and making predictions about when such effects will occur. The underlying neurocognitive processes span a broad range of scale—from shared sensory processing to perceptual and attentional responses, and up to a mutually shared understanding of what has been said and its social relevance. The approach to measure these shared processes as audiences consume content offers new vistas for communication scientists who strive to understand the links between media content, reception processes, and effects. The approach also applies to a wide range of messaging contexts, such as public speaking, radio, audiobooks and television, or digital and print media, and across neuroimaging methods.

As with all models and methods, however, limitations of scope and precision need to be acknowledged. For example, the ability of fMRI, EEG, or other psychophysiological methods to link shared biological processes to their specific causes in message input and to subtle behavioral responses will depend on the measurement's resolution in terms of space and time (Cacioppo et al, 2007; Potter & Bolls, 2012). fMRI, for instance, offers an excellent spatial but poor temporal resolution. A promising alternative is EEG. Although most of the studies mentioned above relied on fMRI methods, EEG-ISC studies exist and promise to tap into fast-paced changes (Imhof et al., 2020; Ki, Kelly, & Parra, 2016).

Also, the nature of the fMRI environment comes with a host of challenges regarding experimental realism: Although it is by now possible to show movies in a brain scanner, the situations are way less natural than a typical cinema-viewing experience. This invites new methods, such as EEG or fNIRS, which aspires to become a portable alternative to fMRI (Piazza et al., 2020). Furthermore, measures like heart rate, skin conductance, or others can also be used to study shared audience responses (Golland, Keissar, & Levit-Binnun, 2014).

Despite these challenges, the ISC-approach to measuring shared audience brain responses offers numerous benefits. The area that has attracted the most attention and was the focus of this article is that of audience response measurement. This pairs well with the theoretical goals of, e.g., the rhetorical tradition as a whole, mass communication, persuasion, and entertainment media research. Other contexts, such as health communication, computer-mediated, and political communication, have also already made fruitful use of this approach (Cui, Bryant, & Reiss, 2012; Imhof et al., 2017; Schmälzle et al., 2013). Areas for which it should also be highly promising are nonverbal communication, virtual reality, and gaming research, although currently no studies have examined these topics (but see Bente & Novotny, 2020). Although much work remains to be done to connect constructs from existing communication theories to the shared brain responses we are now able to observe, the model presented above can serve as an organizing framework in this endeavor.

## Summary

In sum, communication requires establishing common ground between minds that are physically separated. This is enabled by neurocognitive systems that are shared between humans. The model and method presented here allow researchers to examine how the same messages prompt similar responses in separate brains. This phenomenon—similar responses in individual brain regions across multiple recipients—can be linked to message characteristics and subsequent message effects in both individuals and large-scale audiences.

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## Notes

1 For instance, in statistics there are many procedures, such as ANOVA, regression, and so forth. Similarly, in neuroimaging, there are also many different methods, which can answer different questions. The ISC-technique is a method *sui generis*, which addresses a different question than other methods. In fact, whereas many approaches ask “which brain regions activate during a certain cognitive task?,” the ISC-approach asks “which brain regions exhibit similar responses across recipients while processing a complex message?”

2 This article focuses on audience responses to messages (one message, many recipients). The basic theoretical argument, however, also holds for interpersonal communication.

3 For example, a prominent topic in the early days of neuroimaging was the neural basis of face perception. Researchers would present participants with a series of images of faces and control objects (e.g., houses) while recording their brain activity. Next, they would extract the brain response to faces from the recordings and contrast it with the brain response to houses. This approach relies on the assumption that brain activity that is evoked during both tasks (viewing faces, viewing houses) can be "subtracted out" to reveal the difference. For instance, when subtracting the brain image corresponding to "viewing houses" from the brain image for "viewing houses," brain activity related to basic visual processing is likely present in both brain images, so that the contrast will reveal brain activity that is more specific to recognizing face compared to houses. Although this example focuses on basic visual processing, this subtractive approach can be expanded to more complex cognitive processes as well. For example, one could show participants images of faces and instruct them to attend to faces during certain time periods, but not during other time periods. In this case, one could then compare conditions of "attention to faces" vs. "no attention to faces." This subtractive method has been quite fruitful in cognitive neuroscience although not all cognitive processes add up so neatly that they can be isolated via subtraction. Critically, however, the kinds of experiments this approach favored are very different from the kinds of stimulation that natural media messages provide: Media messages provide a continuous stream of complex visual scenes and rich auditory information, but the traditional approach called for stimuli that are presented in isolation and manipulate a specific stimulus or task characteristic (e.g., whether a face is depicted or should be attended to).

4 I refer to shared responses across audience members as the theoretical phenomenon, whereas ISC analysis denotes the methodological technique to identify these responses.

5 For example, a widely used approach for neuroimaging data analysis relies on the General-Linear-Model (GLM). This method uses stimulus-model (information about when stimuli are presented) to "map out" brain regions that track with stimulus parameters via subtractive approaches (see note 3). The ISC-approach works differently as it does not use a similar stimulus-based model. Instead, the idea is to first identify response-commonalities across people exposed to the same stimulus, and then compare these results across conditions.

6 "Distributed" processing refers to processing that uses more than one processor. In this context, processors can be either individual neurons or groups of neurons that perform a certain task. "Hierarchical" generally refers to levels of abstraction or importance. Applied to the context of neural networks (biological or artificial), this means that there is an organization of neurons or neuronal assemblies that follows a hierarchical principle.

7 To be clear, similar does not mean identical. The argument is not at all that everyone's brain will respond in exactly the same way. Rather, there are many aspects of our bio-psycho-social existence that that are shaped by individual experiences or vary according to culture.

8 There are also many non-shared processes that affect the level of observed ISC. For instance, ongoing activity related to general system maintenance and homeostatic

functions is uncorrelated across brains (Hasson et al., 2004; Schmälzle et al., 2015). Likewise, much knowledge can be specific to individuals (e.g., autobiographical memories). If these are addressed by messages, then no shared responses would occur unless people possess similar knowledge.

9 In neurophysiology, the study of "signal correlations" and "noise correlations" is fairly common, but this has, to our knowledge, only been applied to sensory stimuli, but never to more complex messages such as the ones we find in communication.

10 There are multiple attentional phenomena, such as selective attention, spatial attention, and executive control, to name only a few. Regardless of these fractionations, attention is related to a re-weighing process in which certain aspects are enhanced. Attention clearly plays large role in communication and education. For instance, successful lecturing depends on whether students maintain selective sustained attention (Fisher, 2019), or whether they let their minds drift off and engage in daydreaming.

11 One example of this is "interest," a prominent construct in communication, cognitive science, and education (Hidi, 2006). Other fluctuations of relevance arise due to homeostatic motivations, such as hunger, thirst, and other bodily needs. The concept of "involvement" with subcomponents like issue-involvement or value-based involvement also relates to this. Issue involvement, for instance, has played a key role within the Elaboration-Likelihood-Model (Petty & Cacioppo, 1986), where it has been hypothesized to acts a bit like a switch between the central and peripheral route of argument processing.

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