Mediated Messages and Synchronized Brains

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Abstract (70-100 words)

When a mediated message is processed by different recipients, it prompts similar responses in separate brains. These hidden, but collectively shared brain responses can be exposed by computing cross-recipient correlations of brain activity time series, called inter-subject correlation (ISC) analysis. Here we provide an overview of this approach, review its findings to date, and discuss why it is highly relevant for communication science.

Keywords: inter-subject correlation, neuroimaging, media psychology, messages

"The fundamental problem of communication is that of reproducing at one point, either exactly or approximately, the message selected at another point."

C. Shannon, 1948

Introduction

Every morning thousands of commuters listen to the same radio program, and every evening millions watch the same news on TV. Large crowds gather to see the same movies, and readers flock around the same top-selling books. In each of these mass communication situations, the messages are the same for every recipient. Thus, the same stream of images, sounds, or letters will enter each recipients' eyes and ears, where it gets converted into neural impulses. On their pathways through the brain, these impulses produce activities at multiple levels of the neural hierarchy ranging from basic sensory-perceptual responses to higher-order computations involved in comprehension, attention, memory, and emotion (Gazzaniga, Ivry, & Mangun, 2013). In this chapter, we discuss how inter-subject correlation analysis (ISC) of neuroimaging data can be used to uncover cross-receiver similarities as well as individual differences in how audience members respond to mediated messages (Hasson et al., 2008; Hasson, Malach, & Heeger, 2010). Put simply, we can ask whether, where, and how strongly a message synchronizes[1] brain activity across receivers.

In a seminal study, Hasson et al. (2004) exposed a group of viewers to the movie *The Good, the Bad, and The Ugly* while recording their brain activity using functional magnetic

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[1] The term synchronization is often associated with coupled oscillators in physics (Nolte, 2014). However, the original word meaning derives from greek *'syn'* - *together*, *with*, and *'chronos'* - *time, temporal*, and may be translated as *concurrent* or *simultaneous*. Here we conceptualize message-evoked brain synchronization as the common effect of messaging on brain dynamics, which would not exhibit similarities if they were not exposed to the same message. However, the mechanism that elicits these similarities, or synchronicities, is not the same as in the physics of coupled oscillators, but rather works via commonalities in brain function and shared knowledge structures, which enable communication.

resonance imaging (fMRI; Hasson, Nir, Levy, Fuhrmann, & Malach, 2004). In their analysis, they extracted the response time-course in a given brain region from one viewer and compared it to the response time-course obtained in the corresponding brain region from another viewer (Figure 1). By computing this analysis for many brain regions and across all pairs of viewers, they identified brain regions that responded similarly to the movie.[2] Their results revealed highly similar responses in visual and auditory cortices, but also in frontal and parietal regions. This suggests that beyond collectively stimulating each receiver's sensory and perceptual brain apparatus, the movie also engaged systems involved in comprehension, following the narrative, and responding emotionally to its events in a similar way across individual recipients.

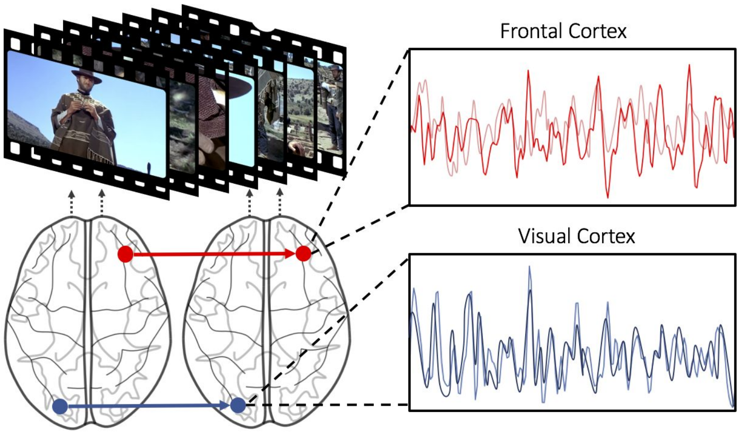

Figure 1. Principle of Inter-Subject Correlation Analysis. The time-course of brain activity in a given region of one recipient's brain is compared with the time-course from the corresponding region in another brain exposed to the same movie. The results reveal commonalities in how brains respond to mediated messages. Conceptually, this is like listening to the voice signal of individual brain regions and measuring how 'in unison' the same regions from different brains are responding to a particular message. Empirically, similar brain responses emerge for regions that subserve specific aspects of message processing: visual cortex for processing elemental

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[2] Of note, the viewers did not watch the movie simultaneously, but sequentially. The critical aspect is that the movie presentation was time-locked across viewers, which is the key prerequisite for running ISC analysis. Time-locked presentation guarantees that the message-evoked brain responses can be compared across the audience. Single-scanner environments are typically not equipped to study 'true' audience effects, which require simultaneous processing of messages. However, it is technically possible to measure the brains of 2 people in a scanner, or to perform so-called hyperscanning. Furthermore, techniques such as EEG, fNIRS, and psychophysiological measurement can also be used to study simultaneous audience responses.

visual features, face-sensitive cortex (e.g. FFA) for processing structural aspects of faces, or voice-sensitive cortex for processing vocal features in the case of spoken messages. More abstract psychological processes (e.g. related to comprehension) are rarely associated with single brain regions, but extensions of ISC analysis can also help to understand commonalities between spatially distributed processes. Figure adapted from Hasson et al., 2004.

Following this seminal study, the basic ISC logic has been applied to a broad variety of mediated messages, including popular movies (e.g., *Indiana Jones*, *Forrest Gump*, and Charlie Chaplin films), TV series (e.g., *Alfred Hitchcock Presents*, *Curb Your Enthusiasm*, *The Office*), written messages and narratives, speeches, documentaries and educational programs, health prevention messages and advertisements, podcasts, and music (Barnett & Cerf, 2017; Byrge, Dubois, Tyszka, Adolphs, & Kennedy, 2015; Cantlon & Li, 2013; Dmochowski et al., 2014; Dmochowski, Sajda, Dias, & Parra, 2012; Finn, Corlett, Chen, Bandettini, & Constable, 2017; Hanke et al., 2014; Hasson et al., 2008; Haxby et al., 2011; Imhof, Schmälzle, Renner, & Schupp, 2017; Jääskeläinen et al., 2008; Kauppi, Jääskeläinen, Sams, & Tohka, 2010; Nummenmaa et al., 2012; Richardson, Lisandrelli, Riobueno-Naylor, & Saxe, 2018; Schmälzle, Häcker, Honey, & Hasson, 2015; Schmälzle, Häcker, Renner, Honey, & Schupp, 2013; Wilson, Molnar-Szakacs, & Iacoboni, 2008).

An ISC approach is highly beneficial to the study of communication processes for several reasons. First, it yields an objective biological metric that is inherently social because it summarizes brain activity measured in an entire audience. Theoretically, this is highly relevant because it exposes brain-to-brain similarities that can be understood as commonalities between observers at the level of regional brain processes. In addition to the notion of ‘commonalities’ - obviously central to communication[3] - the word ‘processes’ is chosen deliberately here because

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[3] Latin *communis* - shared, common.

ISC analysis is computed on temporal data. Considering time is indispensable whenever the input signal is temporal in nature, which is clearly the case for speech, movies, and narratives. Further, ISC analysis can be applied to messages of any complexity, and this paves the way for experiments with mediated messages that contain a mixture of images, sounds, and language. In fact, although complex, these messages are in a way perfectly controlled because they are the same for all receivers. This makes it possible to assess functional similarities across brains during complex cognitive processing, even when the functions of individual regions and how exactly different stimulus properties drive regional activity are not yet fully understood. Lastly, the method is applicable to multiple measurement modalities, such as fMRI, EEG, fNIRS, psychophysiological data, eye-tracking data, and continuous response measures. In the following sections, we review how this approach can be used to gain new insights into how mediated messages i) collectively engage audiences, ii) transmit common meaning, and iii) underlie or produce socially shared processes.

Capturing Collective Engagement

ISC holds great promise to assess common effects of messages on multiple recipients, which are central to mass communication, media effects, and persuasion research. For example, one of communication science’s oldest effects is the phenomenon that the rhetorical quality of a speech strongly impacts the degree to which the audience is engaged (Aristotle, 1939). Powerful speeches “draw the audience in” and make everybody listen intently, whereas weaker speeches fail to captivate their listeners’ minds, letting them drift away. Schmälzle and colleagues (2015) examined this phenomenon by exposing a group of listeners to rhetorically strong and weak political speeches while recording fMRI data. As predicted, listening to any speech, powerful or weak, induced similar neural response time-courses in brain regions involved in spoken language processing, but this effect was stronger for rhetorically powerful speeches. In particular, auditory regions as well as the medial prefrontal cortex, a region associated with processing relevant stimuli and following the social content of a story, exhibited increased ISC.

These patterns of correlated brain responses across listeners, which are amplified during high-quality speeches, bear resemblance to metaphors of resonance that are often brought up in the context of audience research. The emerging picture suggests that ISC can be used to measure the "strength of the grip" (Hasson et al., 2008) a given message has on an audience, revealing how people become involved with the message or how it "resonates" with them (Greenwald & Leavitt, 1984; Schmälzle et al., 2015; Sherif & Sargent, 1947). Similar findings have been obtained using a variety of messages, including emotional stories, movies, and effective health messages (Hermans et al., 2011; Imhof et al., 2017; Nummenmaa et al., 2012). From a neuroscientific perspective, such resonance-like effects can be linked to the literature on motivated or selective attention (Lang, Bradley, Cuthbert, & Others, 1997; Schupp, Flaisch, Stockburger, & Junghöfer, 2006). This clearly invites research on the neural mechanisms underlying entertaining or persuasive messages (Barnett & Cerf, 2017; Dmochowski et al., 2014; Dmochowski et al., 2012; Dudai, 2012; Hasson et al., 2008), topics that have occupied center stage in communication science since the field's earliest days (Lazarsfeld & Stanton, 1949).

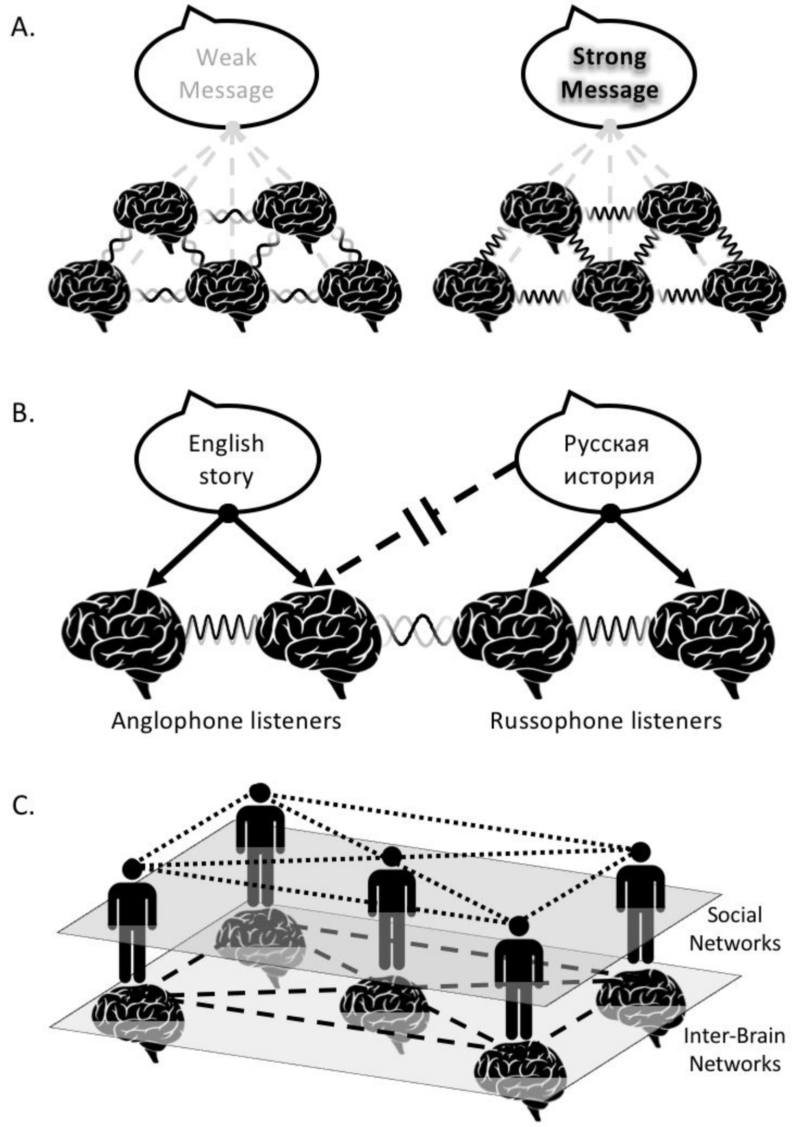

Figure 2. A) ISC can measure the degree to which a given message commands similar processes in different brains. The schematic graphic illustrates overall ISC (computed across the entire brain), but more refined metrics in individual brain regions or systems are possible. B) Anglophone listeners exposed to a story told in English exhibit ISC because they can successfully decode the message. Similarly, Russophone listeners understand the story when it is conveyed in Russian, but Anglophone listeners exposed to Russian stories are not able to do so. C) Measuring inter-brain similarities during exposure to message content opens up new possibilities for multilevel integrative studies of social phenomena and may explain social network phenomena.

Examining How Messages Convey Meaning

Beyond examining engagement with a stimulus, which can be encouraged through editing various substantive and stylistic features, a large body of evidence shows that brain activity correlations (ISC) are sensitive to the transmission of meaning. Upon first view, one may be tempted to attribute brain similarities in response to the same messages to purely sensory-driven processes that are not psychologically relevant. Indeed, it is hardly surprising that a message prompts similar responses across recipients if the identical physical properties command similar auditory and visual processes. However, an elegant study of narratives demonstrated that this view is too simplistic (Honey, Thompson, Lerner, & Hasson, 2012). In brief, the authors compared the fMRI response time-courses of anglophone and russophone listeners who heard a Russian narrative and its English translation. The same content was delivered to the listeners brains via different input, namely sequences of English or Russian words. When analyzing the brain activity between groups of anglophone listeners exposed to the English story or russophone listeners exposed to the Russian story, the early auditory regions, linguistic regions, as well as higher-order regions involved in story processing exhibited reliable ISC, suggesting that responses in these regions were similar across viewers from each language group. However, when anglophone listeners were exposed to the Russian story, it was unintelligible to them and ISC across their brains was confined to early auditory regions. This demonstrates that ISC in post-sensory regions, rather than being purely sensory-driven, depends on learned knowledge structures (i.e., knowledge of the Russian language), and similar brain responses across listeners can only emerge if they share common knowledge as a group. Notably, the authors also compared the brain responses of Anglophone listeners exposed to English to responses from Russophone listeners exposed to Russian. Results showed that despite dissimilarities in auditory regions, similarities emerged in higher-order regions, which were engaged by the same story being conveyed in different languages. This suggests that conceptual aspects of the story were represented in a similar fashion across all listeners, regardless of the language in which the story was initially delivered. Understanding how this similarity at the conceptual rather than the perceptual level relates to situation models, working memory, and comprehension (Kintsch, 1988; Zwaan, 1999) is currently a vibrant area of research (Hasson, Chen, & Honey, 2015; Lerner, Honey, Silbert, & Hasson, 2011).

Several other studies have shown the great potential of using complex stories to understand higher linguistic and communicative functions related to narrative processing, event segmentation, and natural discourse (Baldassano et al., 2017; J. Chen et al., 2016; Dikker, Silbert, Hasson, & Zevin, 2014; Farbood, Heeger, Marcus, Hasson, & Lerner, 2015; Stephens, Silbert, & Hasson, 2010; Wilson et al., 2008; Zadbood, Chen, Leong, Norman, & Hasson, 2017). For example, manipulating receiver expectations or interpretations for the same message leads to similar brain response patterns between those with similar interpretations, and different responses between those with different interpretations (Lahnakoski et al., 2014; Yeshurun, Nguyen, & Hasson, 2017; Yeshurun, Swanson, et al., 2017). These studies complement the findings from the Russian-English study by demonstrating that not only can different messages produce similar brain responses, but that the same message can also produce divergent responses depending on short-term (using framing to manipulate expectations) or long-term (language ability) contextual factors.

Altogether, cross-receiver similarities during message processing extend from sensory-driven auditory and visual responses to similarities associated with comprehension and mutual understanding. In this regard, ISC can be used to measure how messages “stimulate meaning” in the minds of others, which is one way that communication has been defined (McCroskey, 2015). This is perhaps best illustrated by a study of brain-injured patients (Naci, Cusack, Anello, & Owen, 2014). One patient, although being behaviorally completely unresponsive, exhibited a brain response that tracked with a movie’s narrative in a similar way as the brains of healthy viewers. This provides strong evidence for conscious experience of the brain-injured patient, who was unable to communicate but showed signs of functional executive processing.

Shared Processing Among Social Groups

A classic adage from psychology holds that at some level every person is *like all others, like some others, like no other person* (Kluckhohn & Murray, 1948). This continuum from universality, to group-specificity, to individuality provides a useful framework for thinking about why shared and nonshared brain responses emerge, how they can be manipulated, and what we can learn by studying them. Although important individual differences and culture-specific influences exist, there are well-researched universalities in genetics, brain architecture, and function, as well as many shared ontogenetic factors that provide everyone with a vast amount of similarly structured sensory, perceptual, and conceptual ‘training data.’ Examples of this include seeing faces, using language to communicate, as well as emotional and socio-moral experiences (Brothers, 1990; Haidt, 2001; Panksepp, 2004). The sum of these commonalities, when addressed through message content, gives rise to similar brain responses. For example, every person’s visual system will respond roughly similarly to changes in brightness and contrast (Purves et al., 2008; Tootell et al., 1998), and all humans have a biological disposition to like sweet and dislike bitter tastes (Berridge & Kringelbach, 2013). In fact, a recent study demonstrated substantial inter-species brain correlations between monkey and human brains while watching the same movie (Mantini et al., 2012). This points to commonalities at least at the level of visual sensory and perceptual processes, if not beyond (Sliwa & Freiwald, 2017). From a communication perspective, similar brain responses to the same messages represent message main effects, or the effects that messages evoke uniformly in all receivers (Littlejohn & Foss, 2010). Such shared functions arguably provide the common protocol that enables communication between human brains (Hasson, Ghazanfar, Galantucci, Garrod, & Keysers, 2012; Weber, Sherry, & Mathiak, 2008; Zadbood et al., 2017). Similar ideas come from different disciplines, such as denotational meaning in linguistics, the field of semiotics (Chandler, 2007; Galantucci & Garrod, 2012), and philosophy of mind more broadly (Wittgenstein, 2013).

Receiver-sided factors can interact with message content beyond its main effects. The examples mentioned above, where the same story was interpreted differently and thus produced different brain responses, point to such message-receiver interactions (Lahnakoski et al., 2014; Schmälzle et al., 2013; Yeshurun, Nguyen, et al., 2017; Yeshurun, Swanson, et al., 2017). These phenomena are well-studied at the behavioral level and associated with a plethora of theories, such as motivated reasoning, attribution, and others (Donsbach, 2008; Heider & Simmel, 1944; Kunda, 1990). For instance, in their classic study of selective perception titled “They saw a game,” Hastorf and Cantril (1954) examined how spectators of a contested football match interpreted identical events in strikingly different ways based on team affiliation (Hastorf & Cantril, 1954). A clear next step would be to use ISC-based approaches to pinpoint neural correlates of such group differences in interpretation of the same physical input. In this sense, ISC can serve as a tool to study message processing in dyads, small teams, groups, or cultures. For instance, one can look at commonalities and differences during political messages (where recipients can be categorized into pro- and anti- groups, e.g. Turner et al. 2017) or any situation where recipients diverge on internal attitudinal or other knowledge structures. For example, during the outbreak of the H1N1 pandemic, Schmaelzle et al. (2013) exposed recipients who were selected to be extreme in terms of risk perceptions (i.e. either considered H1N1 to be a major concern or no concern at all) to an authentic half-hour TV documentary about H1N1. ISC analysis of fMRI data showed that both groups, regardless of risk perception level, responded similarly in visual and auditory cortices. The high risk perception group, however, showed more strongly aligned responses in the anterior cingulate cortex, a region associated with processing salient information and anticipatory anxiety. This indicates a message-receiver interaction in how the affective significance of a message is modulated based on internal factors, in this case pre-existing risk perception. Of note, the previously mentioned study of Russian and English listeners is another example of this type of design by using a quasi-experimental manipulation of the cognitive variable language knowledge. The same logic has been applied to examine processing differences associated with clinical diagnoses (e.g. autism and depression; Byrge et al., 2015; Hasson et al., 2009; Salmi et al., 2013; Wang et al., 2017) and can be used to examine whether any type of social group membership, stable or experimentally induced, affects how people respond to the same content.

The previous examples conceived of the social group as the independent variable and compared the degree of similarity of neural processing (dependent variable) between groups to test if group status makes a difference. In a recent study, Parkinson and colleagues (Parkinson, Kleinbaum, & Wheatley, 2018) turned this logic on its head, asking if the degree of brain similarity between individuals could predict a social outcome. The researchers had a large cohort view videos and recorded their brain activity. Additionally, they obtained information about the participant's social networks, which allowed them to compute the degree of separation between each pair of participants. They then tested if the similarity of neural processing would be associated with social network proximity. The results showed that as neural similarity decreased, real-world social network distance increased. In other words, these findings provide initial evidence of homophily at the neural level. Clearly, there is much more to explore in how *social brain networks* are linked to classical social networks at the interpersonal level (Falk & Bassett, 2017; Schmälzle et al., 2017). One intriguing question, for example, is whether messages preferably propagate along diffusion paths that are 'carved' by similarities of brain responding.

In sum, group- or individual-difference based ISC approaches provide a versatile tool to identify responses to messages that are shared among some but not all recipients, and thus can either define group membership (e.g., in the case of diagnostic applications or audience segmentation) or provide a manifestation of its effects (e.g., in the case of motivated political reasoning). Given that only a handful of studies exist to date, there are still many important questions that have yet to be asked. This research direction holds great potential for message-tailoring and targeting, conflict and risk communication, audience segmentation, or for identifying the influence of factors such as age, ability, or interest on message processing.

Future research on mediated messages and synchronized brains

The field of media neuroscience (Hasson et al., 2008; Weber et al., 2008) has rapidly expanded and is currently one of the major growth areas of neuroimaging, including population initiatives (Campbell et al., 2015; Chen et al., 2016; Cohen et al., 2017; Dubois & Adolphs, 2016). In parallel with topical expansion, several methodological developments have taken place. New methods have been introduced to improve the alignment of different brains (Chen et al., 2016; Conroy, Singer, Guntupalli, Ramadge, & Haxby, 2013; Haxby et al., 2011) and statistical inference on ISC matrices (Chen et al., 2016). As discussed above, the basic ISC framework assumes a one-to-one mapping between responses, but although human brains are quite similar at a coarse spatial scale, they differ in their meso- and micro-structure just like the shapes of our ears and faces. Newer methods hold promise to be more sensitive to fine-grained differences that wash out during conventional spatial alignment procedures. Another area is the integration of ISC analysis with network neuroscience approaches (Bassett & Sporns, 2017). In brief, these approaches typically focus on response similarities within brains, or '*intra-brain* connectivity', whereas inter-subject correlation methods assess '*between-brain* connectivity'. A recently proposed variant of ISC analysis, called inter-subject functional connectivity (ISFC; Simony et al., 2016), blends these approaches. Last, but not least, a very important push comes from studies that apply ISC-based analyses to other methods than fMRI, particularly EEG, fNIRS, and psychophysiological measures (Bridwell, Roth, Gupta, & Calhoun, 2015; Cohen et al., 2018; Dikker et al., 2017; Dmochowski et al., 2014; Haufe et al., 2017).

These methodological developments are certainly important, but ultimately it will be the scientific productivity of the approach that will determine its adoption in communication science. In that regard, beyond the three main topics outlined above (engagement, message meaning, social influences) we see the following avenues as most promising: First, the majority of studies has treated message-evoked brain synchrony (ISC) as the dependent variable. Relatively few studies have used a brain-as-predictor approach (Berkman & Falk, 2013), in which the brain serves as the IV. However, given that ISC offers a group-based metric for audience engagement, it seems ideal to link this measure to outcomes at larger scale (Barnett & Cerf, 2017; Dmochowski et al., 2014; Parkinson et al., 2018). Second, hardly any work examines how collective brain engagement waxes and wanes over the course of a message, such as during engaging moments of a speech, interesting parts of a lecture, or suspenseful scenes of a movie. These questions can be addressed with dynamic, time-resolved ISC analyses (Dmochowski et al., 2012; Grall & Schmälzle, 2018; Naci et al., 2014), essentially providing a brain-based version of Lazarsfeld and Stanton's famous Program Analyzer (Levy, 1982) for measuring how audiences respond to messages.

Summary

Mass-mediated messages carry content from a sender via a medium to the receiver. When a given message is processed by many receivers, a natural question to ask is how similarly their brains will respond to the same content. ISC analysis provides the answer to this question. In this sense, the ISC approach provides a good example that "there is nothing so theoretical as a good method" (Greenwald, 2012; Weber, Fisher, Hopp, & Lonergan, 2018) because the correlated brain responses indicate that communication has been successful, namely that a message has been transmitted and evokes shared informational states across multiple recipients.

Author Bios (75 words max per bio)

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