PERSONAL NARRATIVES AND
THE ALIGNMENT OF AUDIENCE BRAIN RESPONSES

By

Clare Grall

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Communication—Doctor of Philosophy

2020

ABSTRACT

PERSONAL NARRATIVES AND
THE ALIGNMENT OF AUDIENCE BRAIN RESPONSES

By

Clare Grall

Personal narratives are useful tools for engaging audiences and effectively communicating information to many people. However, the neurocognitive components underlying audience engagement remain unclear. To address this knowledge gap, this study takes a media neuroscience approach to examine the cognitive and affective processes associated with engagement in personal narratives. Using intersubject correlation analysis as a measure of audience brain engagement, a neuroimaging study using functional magnetic resonance imaging was conducted to determine whether personal stories engage audiences more than non-narrative messages and investigate the brain regions that facilitate this effect. Analyses showed that personal narratives elicited strong audience engagement as evidenced by robust correlations across the frontal and parietal lobes. Correlations were stronger across regions including the TPJ, pCC, aCC, dmPFC, and dlPFC when listening to narratives compared to a descriptive text. Additional analyses explored how narrative reception and engagement related to subsequent audience responses, although no reliable effects were observed. These findings contribute toward a biologically informed explanation for how narratives engage audiences to convey information.

ACKNOWLEDGEMENTS

I, Clare Grall, being of unsound mind, acting under duress and undue influence, and fully understanding my lack of property and of this disposition thereof, do hereby make, publish, and declare this Acknowledgement to be my Last Will and Testament.

I nominate and appoint Lindsay Hahn and Eric Novotny as executors of the 2016 ruleset for the Tamborini Research Team Drinking Game. In the unlikely event of an excess in funds associated with my degree, I direct that graduate director Brandon Van Der Heide allot the necessary amount to the purchase of a Crunchy's bucket for consumption by him alone, and all else to Daniel Totzkay for the purchase of cortados. I direct that my ghost haunt both room 470 and the hallway outside of room 552 of the Communication Arts and Sciences Building of Michigan State University so as to continue serving as "the bane of [Ron Tamborini's] existence." This ghost will respond only to Marge Barkman and Thomi Chrisinske, and it will continue to provide them with 1) properly completed paperwork and 2) seasonal arts and crafts.

I direct that all exorbitantly oversized PowerPoint files and Jupyter Notebooks containing data and figures be managed by Ralf Schmälzle, without whom I would not be academically fulfilled. To immediate family members Emma, Jacob, and especially my parents Jane and Steve, I bequeath the office chair previously stolen from them in the hopes that it supports them as much as they have supported me in the pursuit of my dreams. All the rest, residue, and remainder of my sanity I attribute to William Savino in acknowledgement of the daily socioemotional, culinary, and musical support provided by him.

TABLE OF CONTENTS

LIST OF FIGURES v

INTRODUCTION 1
A media neuroscience approach to studying audiences...1
Characterizing engagement as motivated attention 2
Personal narratives facilitate audience engagement 4
Hierarchical neurocognitive processing of narrative information 6
Measuring engagement in the brains of audiences 10
The current study 13

METHODS 16
Participants..16
Stimuli...16
Procedure 18
MRI acquisition and preprocessing 20
Analysis Plan: Hypotheses...21
Analysis Plan: Descriptive and exploratory analyses 22

RESULTS 26
Personal narratives evoke strong alignment of brain responses 26
Exploring brain engagement in response to personal narratives 29

DISCUSSION...33
Strengths, limitations, and directions for future research 36
Implications and broader theoretical impact...37
Conclusion 41

APPENDICES 42
APPENDIX A. Story moments at peaks of pattern alignment in TPJ...............................43
APPENDIX B. ISC differences between high- and low-rank groups for each narrative ..44
APPENDIX C. Distribution of correlations between listening and recall brain activity...45

REFERENCES 46

LIST OF FIGURES

Figure 1. Hierarchy of message content and brain processing..7

Figure 2. Auditory processing hierarchy in the brain 8

Figure 3. Collective alignment of audience brain responses 12

Figure 4. Methods and analysis..19

Figure 5. Personal narratives align the brain responses of audiences 27

Figure 6. Contrasting personal narratives with non-narrative messages.....................................28

Figure 7. Observed ISC strength along auditory processing hierarchy..29

Figure 8. Narratives align the brain responses of audiences..39

Figure 9. Story moments at peaks of pattern alignment in TPJ...43

Figure 10. ISC differences between high- and low-rank groups for each narrative.....................44

Figure 11. Distribution of correlations between listening and recall brain activity.....................45

INTRODUCTION

Personal narratives are highly effective vehicles for conveying important information to audiences in a way that is immediate and intuitive. Every day, thousands of physically and socially distant individuals tune in to consume the same personal stories shared on radio shows or podcasts like “This American Life,” or the “Made in America” or “Hometown Hero” segments of national nightly news broadcasts. Personal narratives have a range of positive impacts on audience thoughts and emotions (Green, Strange, & Brock, 2003) such as increasing feelings of well-being (Oliver et al., 2018), encouraging beneficial healthy intentions (Kim, Bigman, Leader, Lerman, & Cappella, 2012), and facilitating positive education outcomes (Slater & Rouner, 2002). Personal narratives represent a message format conducive for conveying information to an audience because they facilitate engagement across the minds of many individuals. However, knowledge on neurocognitive processes associated with how narratives engage the minds of many people is incomplete. To fill this knowledge gap, this study investigates whether personal narratives evoke more strongly shared brain responses, as an index of collective engagement, compared to non-narrative messages. In doing so, this study works toward an explanation for how narratives engage the minds of audiences to effectively convey information.

A media neuroscience approach to studying audiences

This study takes a media neuroscience approach to studying audience responses. This refers to the synergistic combination of research and methods from media psychology and human neuroimaging (Weber, Eden, Huskey, Mangus, & Falk, 2015). Media psychological researchers utilize a vast toolkit of multimodal and dynamic (i.e., time-varying) message stimuli to investigate message processing and effects as they naturally occur in everyday life. This contrasts with traditional neuroimaging paradigms that rely on static images or cognitive tasks that limit inferences about processes that occur over time like narrative consumption. However, human neuroscience methods like functional magnetic resonance imaging (fMRI) help capture uninterrupted brain responses as they unfold over time, which allows us to study the brain as a necessary component of any communication process. By using dynamic media stimuli and measuring responses using fMRI, scholars can observe how brains naturally respond over the course of a narrative.

A media neuroscience approach also has promise to contribute to mass communication research because it allows us to study audience responses from brain function to behavior. Mass communication research focuses on a one-to-many communication context wherein one message is received by many socially and physically distant people who, connected as an audience through their shared experience of the message, respond in patterned and predictable ways (McQuail, 1983). Neuroimaging represents another source of data to examine how a message exerts some common influence on individuals to bring about similar thoughts, emotions, and behaviors. Critically, by maintaining the audience as the unit of analysis and focusing on what is common among individuals, we can combine biological, psychological, and behavioral data to understand how messages create shared responses. This study works toward this goal by focusing on how narratives engage audiences at a biological level, which begins by characterizing the processes of engagement.

Characterizing engagement as motivated attention

Narratives are powerful tools with which to engage an audience. Previous use of the term *engagement* in relevant neuroscience literature loosely conceptualized it as a cognitive state of emotion-laden attention (Dmochowski, Sajda, Dias, & Parra, 2012; Imhof, Schmälzle, Renner, &

Schupp, 2020). Building on this conceptualization, this study refers to engagement as selective and sustained attention driven by motivationally-relevant information (Lang, Bradley, & Cuthbert, 1997). In other words, engagement is theoretically synonymous to motivated attention. Here, the term *attention* denotes a system of mechanisms that enhance or maintain the processing and representation of information in the brain (Chun, Golomb, & Turk-Browne, 2011). Motivationally-relevant information refers to cues that relate to an individual's physical and social needs, which the brain will prioritize when processing an external environment (Lang, Bradley, & Cuthbert, 1997; Schupp, Flaisch, Stockburger, & Junghöfer, 2006). Examples of these cues include sports, romantic couples, erotica, contamination, and human threat (Lang, Bradley, & Cuthbert, 2008), all of which represent information related to fundamental drives to preserve health and safety or form social connection. More complex content cues that satisfy human needs include representations of autonomy, competence, and relatedness (Tamborini, Bowman, Eden, Grizzard, & Organ, 2010) and displays of moral acts or altruism (Tamborini, 2013).

Research on information processing from both cognitive neuroscience and media psychology demonstrate that motivated attention influences how an audience receives information (Fisher, Keene, Huskey, & Weber, 2018; Hasson, Chen, & Honey, 2015; Lang, 2009). Specifically, when a message triggers the motivational systems that are common across humans, this can lead to enhanced information processing over time that effectively amplifies the signal a message attempts to send. This can make it easier to accurately detect message effects over possible sources of noise, especially given that individuals are limited in how much they can process from their external environment at a given time (Fisher et al., 2018; Lang, 2009; Oren et al., 2016), and individual differences can impact subsequent responses to a message

(Finn, Corlett, Chen, Bandettini, & Constable, 2018; Schmälzle, Häcker, Renner, Honey, & Schupp, 2013). Narrative media content is especially useful for triggering a host of interwoven cognitive and affective processes in audiences (Hasson et al., 2008; Pessoa, 2008; 2009). Furthermore, as shown in media research on limited capacity processing, motivated attention can improve an individual's ability to recognize and recall a message (Lang, 2010). Although the limited capacity model of motivated message processing has been valuable to communication research, it is important here to draw from an information processing framework designed to account for how the brain functions (i.e., a hierarchical process memory framework, discussed below). Moving forward, to maintain the distinction between the present and previous uses of the term motivation in message processing and for ease of communication, we use the term engagement as the colloquial referent of motivated attention. With this in mind, the current study examines how narratives engage the brains and minds of audiences, based on the rationale that personal narratives in particular represent an effective message format that captures and sustains attention of individual recipients and by extension across the audience as a whole.

Personal narratives facilitate audience engagement

A personal narrative is an account of someone's lived experience. Although the events of a personal narrative are representations of real life, this form of narrative is more akin to works of fiction than nonfiction. There are two key content features of personal narratives necessary to highlight. First, there is always a protagonist who serves as the focal point of the story. Second, the protagonist moves through a sequence of events. These two features are constant across uses of the term personal narrative or similar concepts, and they can provide important insight into how personal narratives operate differently than other message formats like argumentation or description.

The presence of a protagonist and event structure should facilitate engagement, and therefore message transmission, by presenting motivationally-relevant social information and doing so in a way that helps overcome processing capacity limitations. Many examples of motivationally-relevant information used in previous research include people or their interactions (for examples, see Lang, Bradley, & Cuthbert, 2008; Weber et al., 2018). Protagonists naturally pull audience attention as a source of potentially important social information (Birmingham, & Kingstone, 2009), and affective responses to stories are closely tied to characters and their actions (Mar & Oatley, 2008; Zillmann, 2000). The event structure acts as a guideline for focusing audience attention on particular characters, settings, and situations, which directs how audiences consume the story (Ames, Honey, Chow, Todorov, & Hasson, 2015; Mar & Oatley, 2008; Oatley, 2012). The audience does not have to sift through an expansive environment or competing cues for relevant information. Instead, like a movie montage, a personal narrative is often drastically condensed in time and space with only relevant details relayed (Dudai, 2012). This helps overcome any limitations on attention by highlighting information that is necessary to the story and minimizing information that is not.

When a personal narrative presents an event that each audience member can relate to in some fashion, this can activate the cascade of cognitive and affective processing underlying engagement that is then observable at the audience level. As a narrator depicts overcoming a challenge, the audience processes each sentence by accessing stores of knowledge represented by language and the relationship between words (Binder, Desai, Graves, & Conant, 2009). Each scene, or event, establishes the context of the narrative, which directly influences how the brain obtains knowledge to interpret the story (Hasson, Egidia, Marellic, & Willems, 2018). The shared context provided by the story and the rich social and emotional information common to personal narratives makes it easier for the audience to access their own similar thoughts, emotions, and previous experiences (Oatley, 2012). It has long been studied that when an audience perceives a story as personally relevant, due to perceived similarity with the speaker or because the content 'resonates' by aligning with someone's personal values, the more likely there will be an emotional or behavioral response (Greenwald & Leavitt, 1984; Schmitz & Johnson, 2007; Sherif, Kelly, Rodgers, Sarup, & Tittler, 1973; Vorderer & Halfmann, 2019). Because personal narratives are able to engage audiences in this way, they represent an ideal model for elucidating the role of the brain and associated brain function that supports narrative processing and engagement.

Hierarchical neurocognitive processing of narrative information

To elucidate how narratives convey meaning to the minds of audiences, it is useful to consider the hierarchical nature of information processing in the brain (Mesulam, 1998). This begins by examining the structure of the input, i.e., the message. Narratives present hierarchically nested information that varies along a gradient of abstractness starting with more concrete sensory features (e.g., volume), to perceptual stimuli (e.g., words and sentences), all of which synthesize together and over time to express symbols that activate higher-order cognitive processes to convey meaning (e.g., plot; Figure 1). For example, consider listening to a radio broadcast. At the lowest level of abstraction there is the physical stimulus of sound waves hitting the ear and properties of the sound waves such as amplitude or frequency (decoded as volume and pitch). Audiences process these sound waves over time and they extract information that conveys the story. At the highest level of abstraction is the interpretation of the story and its delivery as a whole, such as how it made the audience think or feel (Kintsch & Mangalath, 2011).

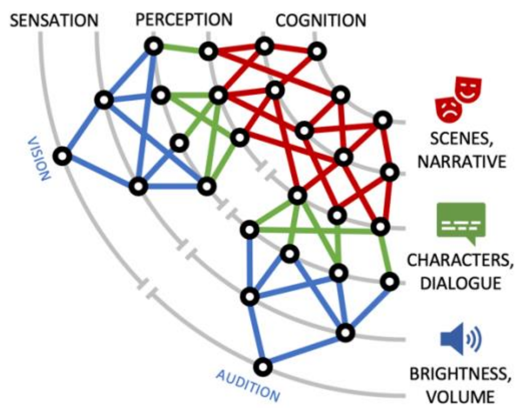

Figure 1. Hierarchy of message content and brain processing. To investigate the commonalities of message reception in the brain, we consider how the brain processes a message along a hierarchy from low-level sensory stimuli (blue) to perceptual cues (green) to higher-order cognitive and affective information (red) inferred from the iterative integration of sensory and perceptual streams.

The hierarchical process memory framework offers a theoretical account of how this extraction of meaning over progressively more abstract representations is implemented in the brain. According to the hierarchical process memory framework (Hasson et al., 2015), every brain region is viewed as part of a "working" memory/information integration system, but regions differ in a) the type of information they are sensitive to and b) in their ability to integrate such information over shorter or longer periods of time. For example, lower-level auditory regions are geared to perform specific transformations of the auditory input and do so instantaneously. As signals move up the neural hierarchy, the regions respond to more abstract input and set up a temporal context such that the region "holds" information related to the prior information (Figure 2). For instance, with regard to narratives, the stream of acoustic sounds to which the auditory cortex responds ('hearing') is subsequently relayed onto speech-related cortical regions to recognize language ('listening'). Sequences of parsed words are then passed on to regions that integrate the individual words into sentences, which are in turn integrated into meaningful paragraphs ('comprehension'). Notably, as information is passed higher up through the hierarchy, the more widely it is distributed across brain networks. From this perspective, story-level or narrative representations can be viewed as sitting at the apex of the hierarchy, or the highest level of abstraction where every story can be understood as a coherent informational unit comprised of sequential and carefully orchestrated individual elements (e.g., From top to bottom: story-level plot, subplot, chapters, paragraphs, sentences, words, syllables, and sounds).

Figure 2. Auditory processing hierarchy in the brain. Regions vary in the types of information they are sensitive to processing and the timescale over which they process information. The primary auditory cortex rapidly processes incoming sound information, the output of which is sent to adjacent regions that parse these signals as words, which are then passed to more distributed regions higher up the processing hierarchy for interpreting sequences of words as a meaningful sentence.

Personal narratives often include descriptions of experiences or challenges that the characters must overcome, delivered in some combination of nonverbal behavior and written or spoken language. This necessitates social-cognitive and semantic systems for receiving a narrative. Research on semantic systems in the brain focuses on the regions active when extracting meaning that is symbolically represented by language and the relationships between words (Binder, Desai, Graves, & Conant, 2009). This has long been associated with activity in the temporal lobes, and particularly the left posterior temporal region referred to as Wernicke's area (Binder et al., 1997). Building on this, recent evidence shows that extracting meaning from language and stories involves widely distributed brain activity that encompasses higher-order linguistic and extra-linguistic regions such as the anterior temporal lobe (aTL), the dorsomedial prefrontal cortex (dmPFC), and precuneus among others. These regions reportedly link basic word-meaning with brain systems involved in episodic construction, memory retrieval, affect, and working memory (Ferstl, Neumann, Bogler, & von Cramon, 2008; Huth, de Heer, Griffiths, Theunissen, & Gallant, 2016). As a story unfolds, it prompts the audience to consider their lived experiences and cues access to memories, thoughts, or emotions (Buckner & Carroll, 2007; Hassabis & Maguire, 2007; Oatley, 2012). This is akin to social cognitive processes such as autobiographical memory or theory of mind, which are associated with regional activity in the medial prefrontal cortex (mPFC), the bilateral temporoparietal junction (TPJ), and the posterior cingulate cortex (pCC; Mar, 2011; Schurz, Radua, Aichhorn, Richlan & Perner, 2014, Spreng, Mar, & Kim, 2008).

Previous research on motivated attention provides additional insight into the possible brain circuitry of an individual engaged with a personal narrative. Although a preponderance of neuroscientific research at the intersection of affect and motivation focuses on negatively-valenced emotions like fear, with some other work focusing on economic reward, the two regions that are consistently reported across domains, tasks, and stimuli include the anterior cingulate cortex (aCC) and mPFC (Etkin, Egner, & Kalisch, 2011; Roy, Shohamy, & Wager, 2012). Moreover, states of motivated attention are associated with amplified processing across the cortical hierarchy (Pessoa, 2018; Schupp et al., 2007). It is worthy to note that mediofrontal cortex, aCC, pCC, and precuneus have all been implicated in research on naturalistic narrative speech comprehension (Wilson, Molnar-Szakacs, & Iacoboni, 2008), and these findings are compatible with the hierarchical process memory perspective presented above and the role these association regions play in affective and motivational processes that emerge as stories unfold.

Although many literatures provide insight into the regional brain activity that should be associated with motivated narrative processing, prior research on these topics is still very limited. To more firmly grasp the neurocognitive components of engagement, audience brain responses must be measured while they consume personal narratives.

Measuring engagement in the brains of audiences

Intersubject correlation (ISC) analysis offers an effective method for audience response measurement in the brain by measuring the degree to which a message has recruited the regional brain activity of an audience as a whole (Hasson et al., 2004). When watching or listening to a narrative while undergoing fMRI, brain activity is recorded approximately every one to two seconds simultaneously from across regions of the brain. The time-varying brain activity measured from any individual brain region during message reception consists of three signals: 1) signal driven by the message that is consistent across viewers, 2) signal driven by the message that is unique to each individual, and 3) noise (Nastase, Gazzola, Hasson, & Keysers, 2019). Correlating the regional time courses across audience members isolates the signal representative of response similarities and thus captures the message-evoked brain responses while individuals are exposed to the same messages (Hasson et al., 2004). As such, ISC provides a tool to probe the ability of a given message to recruit neural processes that are collectively shared across multiple recipients (Schmälzle & Grall, in press; Schmälzle, Imhof, Grall, Flaisch, & Schupp, 2017).

Mounting evidence shows that ISC can serve as an index of the degree to which a message collectively engages an audience (Figure 3). Sensory regions such as the visual and auditory cortex show strong correlations when individuals view or hear the same movie or speech. If participants cannot comprehend a narrative, such as when it is in an unknown language or the sentence structure has been scrambled, ISC remains localized to those sensory regions. This aligns with the hierarchical process memory framework outlined above such that lower levels of the hierarchy are dedicated to the immediate processing of sensory cues but not integrating multiple cues to decode symbolic information. Therefore, regions like the primary auditory cortex will show strong alignment across audience brains fairly quickly after the onset of a story. However, when meaning can be inferred from a narrative, this recruits common brain activities in post-perceptual and associative regions (Honey, Thompson, Lerner, & Hasson, 2012). As audience members come to extract similar meaning, this will lead to a gradual alignment of brain responses in those regions involved in higher-order processing. Not only that, but ISC strengthens with dedication of attentional resources (Ki, Kelly, & Parra, 2016). For example, when participants are directed to pay attention to a visual stimulus while a separate audio stimulus is playing, this leads to amplified ISC that spreads beyond sensory and perceptual regions (Regev et al., 2019). Furthermore, when the narrative content is considered more powerful or more emotional, this also leads to stronger correlations across frontoparietal cortex (Hasson et al., 2008; Nummenmaa et al., 2014; Schmälzle, Häcker, Honey, & Hasson, 2015). Altogether, this suggests that the presence of ISC across the frontal and parietal lobes critically depends on some degree of dedicated attentional and affective processing, or engagement, with the message.

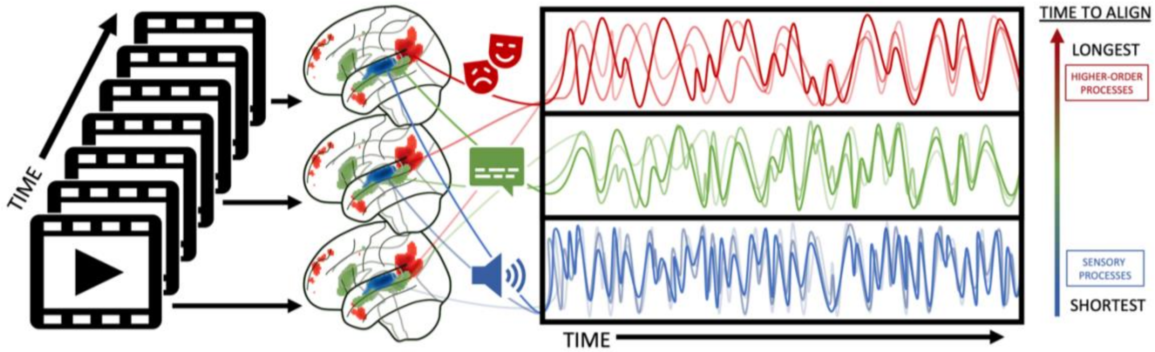

Figure 3. Collective alignment of audience brain responses. Listening to a narrative activates brain networks dedicated to sensory, perceptual, and higher-order processes synthesize the incoming information over time. When a narrative engages many individuals, this leads to aligned brain responses not only in sensory and perceptual networks but also networks associated with cognitive and affective processing. Because these networks are sensitive to different types of information and integrate information over different timescales, this leads to variation in how fast these regions show strong correlations. Sensory cortex will have the shortest time to align and will stay aligned due to instantaneous signal processing while higher-order regions will take longer to align and will fluctuate based on engagement due to accumulating more information over time.

Because a media neuroscience perspective is novel for the study of audience engagement with personal narratives, it is important to also consider how neuroimaging data and ISC can inform us about effects that are associated with engagement. Specifically, it is unclear how engagement relates to similarities in evaluative responses to a narrative and the degree to which engagement enhances subsequent recall. A growing body of work demonstrates that ISC across frontal and parietal cortex varies depending on interpretation and shared understanding. For example, changing select words to affect story interpretation while preserving grammatical structure leads to differences in ISC in the TPJ, mediofrontal cortex, and precuneus (all of which are associated with integrating information over longer time scales; Lerner, Honey, Silbert, & Hasson, 2011), but not sensory auditory cortex (Yeshurun, Nguyen, & Hasson, 2017). The more similar people's interpretation of a message, the stronger the ISC is across regions associated with higher levels of the cortical hierarchy (Lahnakoski et al., 2014; Yeshurun et al., 2017). Although this work reveals the sensitivity of ISC across the frontoparietal network to shared interpretation of the message, it remains unclear how ISC relates to subsequent evaluative responses such as whether the audience collectively deemed the narrative important or not. To speculate, if a personal narrative elicits ISC throughout the cortex, then ISC in frontoparietal regions should be particularly strong among individuals that share a similar evaluative response to the narrative. Additionally, previous research associated motivated attention with enhanced recall of a message (Lang, 2009). This study argues that personal narratives effectively convey information because they facilitate engagement, and this can be studied using neuroimaging data. If a narrative has effectively transmitted shared meaning to an audience that can be measured using the brain, then to some extent this meaning should be reinstated in the brain upon recall (Chen et al., 2017). Therefore, there should be some relationship between the brain activity while listening to a story and the brain activity while recalling the story, and this should be particularly strong for messages that effectively engage the audience. The body of work reviewed here sets the precedent for additional investigation into narrative processing in the brain and subsequent responses.

The current study

In summary, personal narratives have specific content features that facilitate engagement across the minds of an audience. However, it remains unclear what happens in the brains of audiences to create this effect. To study the neurocognitive components associated with engagement in personal narratives, ISC can be used to measure the degree to which a message has recruited regional brain activity over time and collectively across recipients exposed to the same message. The current study takes a media neuroscience approach by combining methods from media psychology and mass communication with cognitive neuroscience. Specifically, participants listened and responded to a series of six personal narratives, a non-narrative message, and an auditory control while undergoing fMRI to record their brain activity. If ISC is present throughout the frontal and parietal lobes of an audience, this indicates whether a personal narrative has effectively engaged an audience and what brain regions are associated with this process. To test this, the first hypothesis is posed:

> **H1:** Personal narratives promote stronger audience engagement, as indexed by higher positive ISCs across the frontal and parietal lobes, compared to a non-narrative message.

Whereas the first hypothesis assesses the overall level of ISC prompted by personal narratives, the second hypothesis focuses on the regional specificity of this effect as it varies along the processing hierarchy. The semantic and social content present in personal narratives directs our attention to the brain regions that should be associated with audience engagement. Listening to any common message leads to ISC in sensory regions associated with basic linguistic and auditory function including the superior and middle temporal gyri (Binder et al., 1997; Hickok & Poeppel, 2007). The motivated processing of relevant stimuli should be reflected in ISC in aCC and mPFC (Etkin, Egner, & Kalisch, 2011). Lastly, the semantic processing of the narrative and the presence of characters and their actions should evoke ISC in regions involved in social cognitive processing and extracting meaning over time including the aTL, TPJ, mPFC, pCC, and precuneus. With this in mind, the second hypothesis is posed:

> **H2:** Personal narratives promote stronger ISCs in regions of the brain associated with motivated, semantic, and social-cognitive processing compared to a non-narrative message.

There is minimal published work that describes the message content that is associated with high engagement as indexed by ISC, and there is an opportunity to further assess how neuroimaging data informs us about the content and effects that are associated with engaging narratives. Specifically, is it possible to detect differences in ISC based on the similarities in evaluative responses to a narrative or determine the degree to which engaging narratives enhance subsequent recall based on neuroimaging data alone? It is worth noting that to do this demands a shift from testing the main effects of narratives to exploring the natural variation of receiver responses. Although ISC is sensitive to shared interpretation of a message (Finn et al., 2018; Lahnakoski et al., 2014; Schmälzle et al., 2013; Yeshurun et al., 2017), it is unclear how ISC relates to shared evaluative responses to a narrative. Additionally, although it has been hypothesized that engagement with a message enhances recall, this has not been previously tested with neuroimaging data in the context of consuming personal narratives. Therefore, the following research question is posed:

RQ1: What is the association of ISC in response to a personal narrative and a) similarities in evaluative responses and b) recall?

METHODS

Participants

Thirty-three students (20 females, mean age 20.5 years) from the university participated for financial compensation. Experimental personnel recruited participants through advertisements across the university, and all participants were screened through survey and in-person meeting to ensure right-handedness, English as a first language, and general MRI eligibility. Imaging data from four participants were excluded due to technical issues (e.g., in-scanner headphone malfunction), and additional data were excluded if the participant fell asleep during a particular narrative. This resulted in a final data set of 23 participants who listened to all stories, with individual stories ranging from n = 24-26 ($n_{\text{obstacles}}$ = 24, $n_{\text{community}}$ = 24, $n_{\text{no-regrets}}$ =26 , $n_{\text{comfort-zone}}$ = 26, n_{vcr} = 25, n_{reverse}= 25). All participants provided written informed consent to participate in the study, and all procedures and materials were approved by the institutional ethics review board.

Stimuli

The experimental stimuli consisted of four personal narratives, one non-narrative control, and one audio control. Personal narratives were taken from *This I Believe*, a radio show turned podcast produced by a non-profit organization of the same name. A collection of these stories was chosen based on prior identification as prototypically impactful in nature (Allison & Gediman, 2006) and subsequently pretested in an online survey to identify the stories that fit the criteria for ongoing research on inspiration. Each of the four personal narratives include a protagonist and event structure, and each narrator describes one of their core beliefs and the life events that lead them to that belief. The first focuses on overcoming obstacles from an athlete with Parkinson's disease delivering the Olympic torch (Muhammad Ali's narrative as recorded by his wife[1]). The second emphasized the beauty of a community coming together from a young man recounting his younger, disabled brother's first home run in baseball. The third focused on living life with no regrets from a mother diagnosed with cancer. The fourth narrative emphasized stepping out of your comfort zone from a Hollywood producer who interviews diverse strangers. The stories are similar in that they are personal narratives about beliefs, but they represent a wide variety of life experiences from a local little-league baseball game to the Olympics.

For the comparison message, it was important to induce variation of motivated attention as it is driven by the content of messages. To achieve this, a three-minute recitation of a VCR manual was used as non-narrative control. This creates a perceptually similar input of continuous language, but the message is devoid of any social content or event structure and therefore less motivationally engaging. This VCR text is similar to comparison stimuli used in prior work (Hasson et al., 2008), and exemplifies a descriptive message. However, as described in the procedure below, all participants were told that they had to respond out loud in the scanner after listening to each story. Therefore, participants had an external goal to attend to the content of each message enough to respond, but the content itself was left to naturally facilitate engagement. An additional control message consisted of a unique *This I Believe* essay that was played in reverse to maintain structural auditory stimulus features without any semantic content. Although this type of control is not as theoretically useful for mass communication research, it is useful to ensure ISC findings are not due to low-level stimulus features and is included in similar paradigms (Schmälzle et al., 2015). The order of presentation was pseudo-randomized across participants to avoid confounds due to sequence effects.

1 Of all participants who listened to this narrative, only four recognized it as the story of Muhammad Ali.

Procedure

In a preliminary study using 10 unique participants and stories, the following survey and imaging procedure was refined to capture the naturalistic responses of participants consuming personal narratives, meaning there were no constraints other than to listen to each narrative (Figure 4). Participants were screened for fMRI eligibility through an online survey and an in-person preparation meeting with experiment personnel. The project was described as a neuroimaging study on how people tell personal stories. On the day of the scan, participants completed the consent forms and a short pre-scan self-report survey assessing mood and life satisfaction. In the scanner, participants first underwent an anatomical scan. For the functional scans, participants were instructed to keep their eyes closed and listen to the stories, all of which were preceded by a short neutral text to reduce transient effects.

For each of the six functional runs, participants first listened to the three-minute long message. The stories were presented using PsychoPy software and high-fidelity MR-compatible earphones (PSTNet Persaio). These headphones function optimally in the bore of the scanner and reduce acoustic scanner noise. Foam padding was used to stabilize participants' heads and to further attenuate external noise. During the auditory lead-in to every narrative, participants were directed to close their eyes. After each narrative, participants were directed to open their eyes and respond to a single item which asked, "This story told me something important" on a 5-point scale (1=not at all, 5=very much). Following the question, participants were cued to recall the narrative for 20 seconds, and then prompted to speak out loud into a microphone in the scanner for 30 seconds on how the narrative made them feel. Once the scan was finished, participants filled out a post-scan survey in which they completed a questionnaire about the stories. Participants were then debriefed, compensated, and thanked for their time. Two weeks after the scan, participants were emailed to complete a survey assessing their memory of the stories and additional questions regarding the potential influence of the stories. The pre- and post-survey and in-scanner talk-aloud data were recorded for use in another research project and therefore not featured in Figure 2A or the analysis plan.

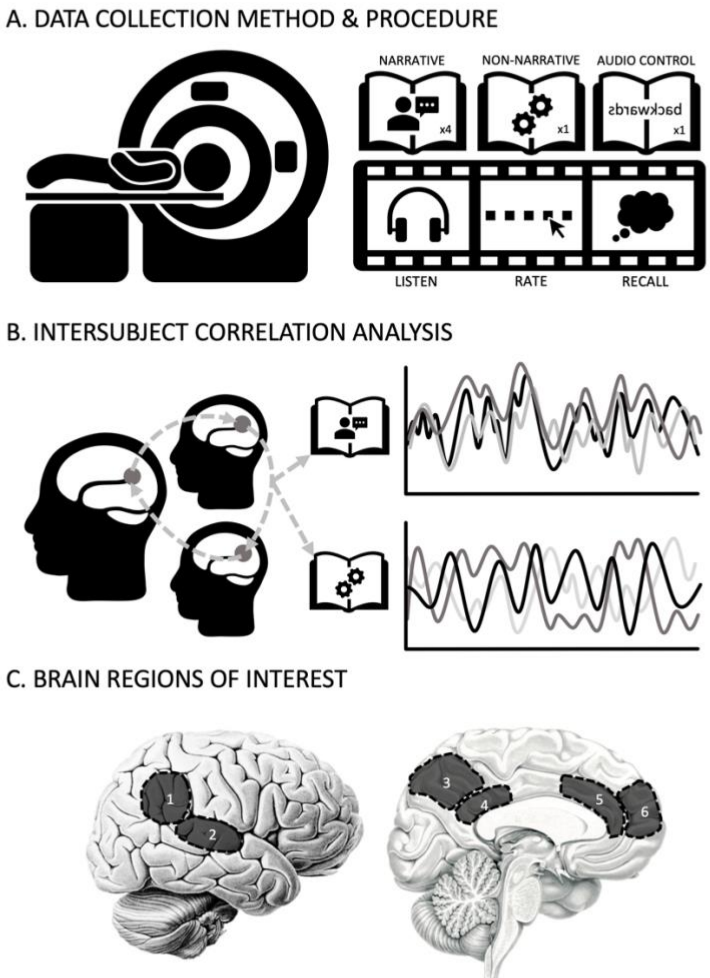

Figure 4. Methods and analysis. A) While scanning with fMRI, participants listened to four personal stories, one non-narrative message devoid of any social or emotional content (the recitation of a VCR manual), and one message played in reverse in pseudo-randomized order. For each narrative, participants first listened with their eyes closed for 3 minutes, submitted a single-item rating of the narrative's importance and then imagined the story for 20 seconds. B) Inter-subject (ISC) analysis was used to assess whether the personal stories lead to correlated regional brain responses of participants more than the non-narrative text or reversed speech. C) Broad representation of the regions of interest: 1 = temporoparietal junction, 2 = auditory cortex, 3 = precuneus, 4 = posterior cingulate cortex, 5 = anterior cingulate cortex, 6 = medial prefrontal cortex.

MRI acquisition and preprocessing

Imaging data were acquired using a 3T GE Signa HDx system. High resolution T1-weighted images were acquired using a MPRAGE sequence (184 slices, slice thickness = 1 mm, matrix = 256 × 256, FOV = 25 cm, flip angle = 8°). Functional images were recorded using an EPI sequence (TR = 2000 ms, TE = 25 ms, flip angle = 76°, matrix = 64 x 64, FOV = 22 cm, slice thickness = 3.0 mm, 36 slices). The protocol consisted of 6 functional runs of roughly 5 minutes each with 144 volumes collected for each run. Following conversion of DICOM images to NIFTI format and organization according to the brain imaging data structure (BIDS; (Gorgolewski et al., 2016), preprocessing was carried out using fMRIprep (Esteban et al., 2019). Functional data underwent slice-time correction, coregistration of functional and anatomical scans, and nonlinear normalization into a common MNI reference system.

After accounting for the auditory lead-in and the HRF lag, time series data corresponding to the listening portion of each run were extracted using NiftiMasker (Abraham et al., 2014; Pedregosa, 2011) with a functionally resampled voxelwise mask derived from the MNI152NLin2009cAsym anatomical image. During masking, the data was smoothed with an isotropic full-width half-maximum kernel of 4 mm and the following variables were included as regressors for each participant: six motion parameters, six principal components (aCompCor) estimated from combined subcortical, CSF, and WM masks calculated in T1w space, and three cosine regressors for high-pass filtering with 128s cut-off. Inspection of the masked brain activity data showed noticeable transients at the onset of each story in auditory and visual cortex. Because these transients can significantly influence correlation analyses, and to ensure analysis quality, the data corresponding to the last two minutes and twenty seconds of every story were kept. The final output of the preprocessing pipeline and data inspection was six functional runs corresponding to each narrative (70 TRs for each voxel).

Analysis Plan: Hypotheses

ISC analysis was used to assess whether personal narratives more strongly engage the brains of audiences compared to the control messages and where in the brain this effect occurs (H1 and H2). ISC analysis assesses the extent to which a time-varying stimulus, such as an audio narrative, aligns the regional brain responses across viewers. ISC is computed as the average correlation $R = \frac{1}{N} \sum_{j=1}^{N} r_j$, where r_j is the correlation between the voxel time course from one subject and the average time course from the corresponding voxel of all other subjects (Hasson et al., 2004; Honey et al., 2012; Nastase et al., 2019). This procedure was repeated for all voxels and resulted in a brain map representing the extent to which each brain region responded similarly as driven by the time-locked stimulus. ISC maps for each narrative were computed separately, and then for each message type including one for the personal narratives altogether, the VCR control message, and the reversed speech. To test whether the correlations were significantly different from zero for individual stories, ISCs were calculated using phase randomization with 1000 iterations per voxel. This procedure computes a null distribution using Fourier transformations to disrupt the temporal alignment of the signal while maintaining the same power spectrum. In an additional analysis step, we tested for differences in ISC between personal narratives and VCR text and the reversed speech. To do this, ISC maps were computed for each individual for each message type. An ‘all narratives’ ISC map was created for each participant by averaging the ISCs for each voxel across the four personal narratives. The computed differences between the ‘all narratives’ and non-narrative or reversed speech ISC maps for each participant were submitted to a nonparametric bootstrapping procedure with 1000 samples to test for significant differences (Chen et al., 2016).

One additional analysis step was taken to further access H2 and the regional variation in ISC along the auditory processing hierarchy. Data was masked and extracted from spheres centered on a set of coordinates derived using a combination of reviewed literature and Neurosynth.org (Lerner et al., 2011; Yarkoni, Poldrack, Nichols, Van Essen, & Wager, 2011). Specifically, data was extracted from the primary auditory cortex, superior temporal gyrus, TPJ, and precuneus. It is expected that ISC is strong in the primary auditory cortex no matter the message, and ISC in the superior temporal gyrus is stronger when listening to narratives and the descriptive VCR text compared to the reversed speech, which lacks any interpretable language. Lastly, ISC in the TPJ and precuneus should be strongest for the narratives relative to the descriptive message and reversed speech due to the ability of narrative content to similarly engage higher-order cognitive processes in audiences. All phased-randomized ISC maps and the bootstrapped differences maps were corrected for multiple comparisons using a voxelwise false discovery rate threshold of $q < .05$ (Benjamini & Hochberg, 1995).

Analysis Plan: Descriptive and exploratory analyses

A pattern-based variant of ISC analysis was used to describe the message content associated with moments of peak engagement. Instead of correlating the brain activity over time to derive a map with an ISC value for every region, a pattern-ISC analysis correlates activity across regions to derive a time course with an ISC value representing the similarity of spatial brain activity across participants for that moment in time. Based on the auditory processing hierarchy (Hasson et al., 2015), data for this analysis was selectively extracted from portions of the Stanford FIND Lab’s functional mask corresponding to regions of the language network that integrate information over longer timescales, namely bilateral TPJ (Shirer, Ryali, Rykhlevskaia, Menon, & Greicius, 2011). Focusing on the TPJ provides insight into the moments of the message associated with highest functional alignment across a region previously implicated in processing social information and narratives (Marr, 2011; Schurz et al., 2014). For each personal story, pattern-ISC in the TPJ was computed and the top five highest values were taken as peaks of engagement. In a procedure referred to as reverse correlation analysis (Ringach & Shapley, 2004), these peaks were then used to extract the content of the message that was playing during each peak (with 3 seconds before and after). Due to the limited length of each story, the limited number of stories, and the many choices available for selecting the window length for peak extraction, only descriptions of the message content will be reported.

To investigate the association of engagement with a personal narrative and subsequent evaluative responses (RQ1a), the in-scanner ratings of each narrative's importance were used as an index of evaluative response such that those who rated a narrative as a 1 are similar because they rated the story as personally unimportant while those who responded with a 5 rated it as personally important. For each participant, the relative rank for each story was used to sort participants into two groups such that those participants who ranked a story high (rating a 5 translating to a rank of 1) were grouped together while those participants who ranked the story low were grouped. Grouping by relative story ranking allowed for some preservation of power to run a between-subjects analysis for each story between high-ranking participants and low-ranking participants. It may be the case that those who rated a narrative as relatively unimportant did not become motivated to engage with the message, which would result in a noisy ISC map with no significant correlations outside of the sensory cortex. However, it may also be the case that attending to the narrative inspired this strong negative valuation of the message, which would result in ISCs across the cortex. At the very least, it is expected that among participants with higher ratings of importance there will be strong ISC across frontoparietal regions.

Regarding recall (RQ1b), the similarity of spatial brain activity was used to explore the relationship between the patterns of regional activation during narrative listening and activation patterns during narrative recall. For each participant, the average activation value for each voxel during narrative recall was computed to derive an average pattern of activation for each narrative (recall vector). The recall vector was then correlated with each TR of data from every story to obtain an array of 70 correlation values that were then averaged together to ascertain the degree to which listening and recall activity aligned (and doing so in a way that accounts for time). If it is the case that a narrative strongly engaged an audience to convey information, this should be associated with a unique pattern of activation across brain regions that may be reinstated when that narrative is being recalled. The average correlations were sorted into two groups: 1) matched listening and recall, where the values represent the average correlation between listening data and the recall vector in response to the same narrative (e.g., correlating the community-story recall vector with data from listening to the community story), and 2) mismatched listening and recall, representing the average correlation between one narrative's listening data and the recall vector from all other narratives (e.g., correlating the community-story recall vector with data from listening to the all other stories). This was repeated for all participants, for all narratives, and averaged correlations were sorted accordingly. If a narrative evoked a particular signature or memory trace that is reinstated during recall, then it should be the case that the average correlations between listening and recall are higher when the narrative played during exposure and the one recalled are the same. To assess this, the distribution of correlation values from each group, matched and mismatched, were plotted to assess differences.

All analyses were carried out using python 3.7 using a combination of modules from nilearn, brainIAK, and custom-written tools (Abraham et al., 2014). All data and analysis scripts are available upon request to uphold transparency, replicability, and reproducibility.

RESULTS

The in-scanner ratings indicated that all personal narratives were evaluated as higher in importance. Averages of the in-scanner ratings showed the narratives about living life with no regrets (m = 4.15) and community coming together (m = 4.10) were rated the highest, next the narrative about overcoming obstacles (m = 3.81), the narrative about challenging comfort zones (m = 3.38), and lastly the VCR text (m = 1.88) and reversed speech (m = 1.13). Within-subjects t-tests revealed that participants considered the personal narratives to be telling them more important information than the reversed speech (*t-values* = 10.7-16.7, p's < .001) and the VCR text (*t-values* = 4.4-7.9, p's < .001).

Personal narratives evoke strong alignment of brain responses

ISC across message types. To broadly assess whether personal narratives promoted strong audience engagement, a phase-randomized ISC analysis was conducted for each individual story. As expected, all narratives evoked some degree of similarity and thus collectively shared temporal activity patterns across the brains of their recipients. As shown in Figure 5, in line with the fact that the stimuli were narrated stories, the auditory cortex showed strong, widespread ISC values centered around primary auditory cortex no matter the message type (e.g., bilateral primary auditory cortex ISCs in response to the averaged personal narratives was r's = .25-.30, p's < .001). Notably, the ISC maps corresponding to the four personal narratives show widespread significant correlations throughout the parietal and frontal cortex, which is not the case for the maps corresponding to the reversed speech or VCR text. For the personal narratives, there are strong ISCs centered around the precuneus (r's = .12-.17, p's < .001), posterior cingulate (r = .16, p < .001), and bilateral temporoparietal junction (r's = .12-.16, p's < .001). Other notable regions include the anterior cingulate (r = .11, p < .001), the dorsal and ventral medial prefrontal cortex (*r* = .14 and .09, respectively, *p*'s < .001), and the bilateral dorsolateral prefrontal cortex (*r* = .13, *p*'s < .001; all reported values corrected for multiple comparisons using FDR threshold of *q* = .05).

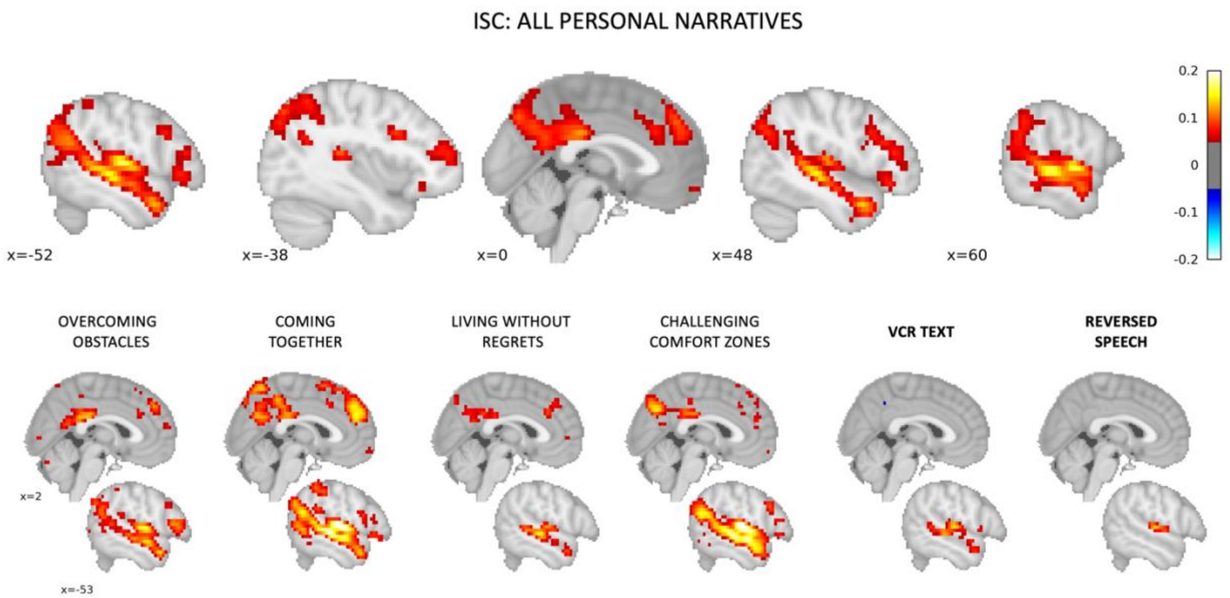

Figure 5. Personal narratives align the brain responses of audiences. The top row shows a brain map of the averaged Pearson's correlations for each voxel for all personal narratives averaged together, with brighter color signifying stronger correlations. The bottom row shows the ISC maps for individual messages, with the theme of each message written above. The reversed speech and VCR text control stories are written in bold. Occipital lobe ISCs are explained by a high amplitude signal change most likely driven by participants closing their eyes at the start of each message. Maps are smoothed for display (fwhm = 6) and additionally thresholded at *r* > .05 on top of previous FDR correction.

Comparing personal narratives versus non-narrative messages. To test the first hypothesis that personal narratives promote stronger engagement than non-narrative messages, the differences in ISCs were calculated for each individual for the averaged personal narrative data compared to the VCR text and the reversed speech, respectively. The maps of ISC differences were submitted to a nonparametric bootstrapping procedure to derive significance values, which were subsequently corrected for multiple comparisons (FDR corrected, *q* < .05). In contrasting personal narratives and the reversed speech, stronger ISCs appear along the temporal lobe outside of the primary auditory cortex, and around the posterior medial cortex, anterior cingulate, and dorsolateral prefrontal cortex. Moreover, as shown in Figure 6a, there are several regions throughout the frontal and parietal cortex in which ISCs were stronger for personal narratives compared to the VCR text. In line with the regions predicted in the second hypothesis, these include the precuneus, anterior cingulate, posterior cingulate, and temporoparietal junction.

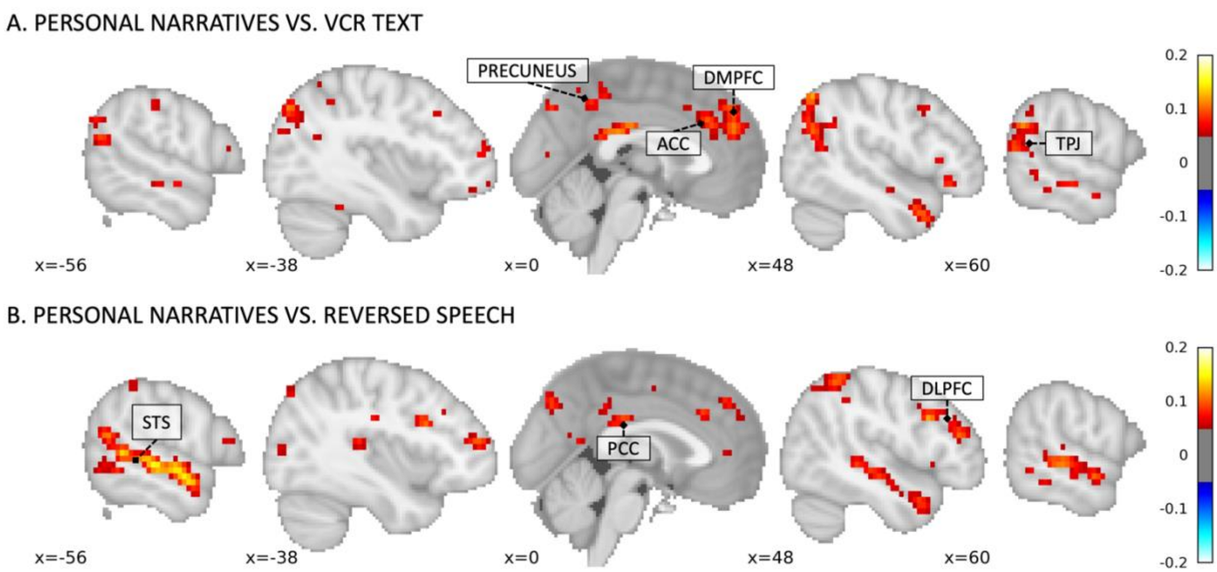

Figure 6. Contrasting personal narratives with non-narrative messages. The brain maps of t-values computed from within-subjects test for differences (FDR, *q* < .05; smoothed for visualization, fwhm = 6mm) between personal narratives compared A) the descriptive VCR text and B) the reversed speech audio control. aCC = anterior cingulate cortex, dmPFC = dorsomedial prefrontal cortex, TPJ = temporoparietal junction, STS = superior temporal sulcus, pCC = posterior cingulate cortex, dlPFC = dorsolateral prefrontal cortex.

ISC along auditory processing hierarchy compared across message types. To further assess regional variation in ISC across message conditions along the auditory processing hierarchy (Hasson et al., 2016), data was extracted from regions across the temporal lobe up to the medial parietal lobe and submitted to ISC analysis (Figure 7). As expected, observed ISC values in the primary auditory cortex are strong no matter the message condition (A1: $r_{stories}$ = .30, r_{vcr} = .28, $r_{reversed}$ = .22). Moving up the hierarchy to those regions implicated in processing information over longer timescales, the superior temporal gyrus shows stronger ISC for the message conditions that have interpretable language (STG: $r_{stories}$ = .18, r_{vcr} = .18) compared to the lack of alignment when listening to reversed speech (STG: $r_{reversed}$ = .06, *p's* < .001). Lastly, ISCs in regions associated with higher-order processing and integrating information on the order of seconds or minutes, namely the TPJ and precuneus, are significantly stronger in response to narratives (TPJ: $r_{stories}$ = .16, precuneus: $r_{stories}$ = .15) compared to the VCR text or reversed speech (TPJ: r_{vcr} = -.05, $r_{reversed}$ = .05; precuneus: r_{vcr} = -.04, $r_{reversed}$ = -.00; *p's* < .001; FDR corrected).

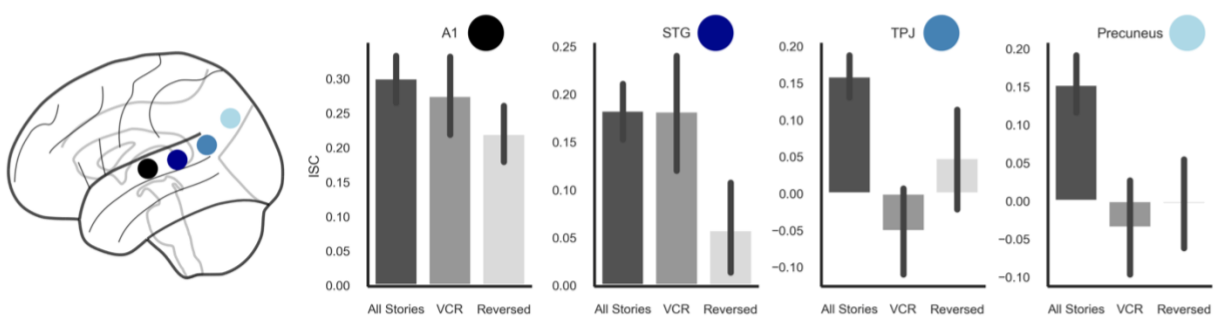

Figure 7. Observed ISC strength along auditory processing hierarchy. ISC values extracted from specific regions along showing strong differences between the personal narratives and VCR text (8mm spheres; A1 = primary auditory cortex, +/- 58, -16, 4; STG = superior temporal gyrus, +/- 62, -36, 10; TPJ = temporoparietal junction, +/- 54, -56, 20; precuneus, +/- 8, -72, 38). These plots show the bilateral ISC values averaged together. Error bars represent the 95% confidence intervals around the ISC values.

Exploring brain engagement in response to personal narratives

Reverse correlation: Associating message content and peak pattern-ISC in TPJ. A pattern-ISC analysis was conducted on data from 2,526 voxels associated with and surrounding the bilateral TPJ. For each narrative, a time course of correlations was derived representing audience alignment at that TR, and the top five peaks were reverse correlated back to the narratives to extract moments from the audio files corresponding to each peak. To be consistent with prior ISC analyses, only the last 140 seconds of each story were analyzed. The highest peaks of alignment were strongest in response to the “overcoming obstacles” (r = .20; “Nothing in life has defeated me. I am still ‘The Greatest.’ This I believe.”) and “community coming together” (r = .22; “Thoughts ran through my mind, such as: Would the kids make fun of him?”) narratives compared to the “living life with no regrets” (r = .15; “And I’ll say this to any who’ll listen; I believe you should live your life so at the end of it…”) and “challenging comfort zones” (r = .18; “...even if it was only that I’m not interesting to a physicist with no taste for our pop culture.”) narratives. The text associated with the top five peaks from the last 140 seconds of each narrative are provided in Appendix A.

Association of ISC and similarities in evaluative responses. To investigate whether ISC is stronger among participants who share a similar evaluative response to a personal narrative, each participant’s in-scanner story ratings were rank-ordered. Among all personal narratives, however, there was a lack of variance among ratings such that the narratives consistently received high scores and therefore high ranks. With this in mind, the ranks were used to group participants (high rank versus low rank) for a between-subjects comparison for the “overcoming obstacles” narrative ($n_{highrank}$ = 13, $n_{lowrank}$ = 12), the “community coming together” narrative ($n_{highrank}$ = 12, $n_{lowrank}$ = 10), and the “living with no regrets” narrative ($n_{highrank}$ = 16, $n_{lowrank}$ = 9). The “challenging comfort zones” narrative received a sufficient mix of scores to split data into relatively equal groups across high, middle, and low ranks, and to further accentuate group differences, only high and low rank groups were used ($n_{highrank}$ = 10, $n_{lowrank}$ = 7).

Carrying out the ISC analyses and applying a nonparametric permutation procedure with subject-wise resampling to test for differences between groups for each narrative revealed that no differences survived multiple comparisons correction. In light of this, the uncorrected ISC maps showed several notable differences across the narratives. For the "community coming together" narrative, there were a higher number of ISCs that were stronger for the high-rank group than the low-rank group, particularly around the temporal pole. In contrast, the "challenging comfort zones" narrative map of ISC differences shows that the low-rank group had a higher proportion of stronger ISCs, especially around the precuneus. Thresholded and smoothed ISC maps of group differences are provided in Appendix B for clarity. Again, none of these values withstood proper statistical thresholding.

Association of brain activity during listening and recall. For every participant, the averaged brain activity during recall was correlated across the listening brain activity for each story to obtain an average correlation representing the degree of alignment between narrative listening and narrative recall. It was expected that the average correlation between listening and recalling the same story ("matched") would be higher than listening and recalling different stories ("unmatched"). Inspection of the distributions when plotted show that this is not the case (Appendix C). Both distributions were centered on a mean of roughly .50. Specifically, the "matched" distribution showed a mean of .497, *std* = .045, *minimum* = .323, and *maximum* = .585. The "unmatched" distribution showed a mean of .495, *std* = .041, *minimum* = .36, and *maximum* = .596. As an additional exploratory step, this analysis was repeated with data masked only from the precuneus due to previous findings suggesting that the medial parietal lobe may be more sensitive to this effect. Again, no difference in distribution means was detected. The "precuneus-matched" distribution showed a mean of .508, *std* = .056, *minimum* = .38, and *maximum* = .649, and the "precuneus-unmatched" distribution had a mean of .503, *std* = .059, *minimum* = .301, and *maximum* = .664 (Appendix C).

DISCUSSION

This study investigated how personal narratives represent an effective message format for conveying information to large audiences, and it presented theory and methods that build knowledge regarding how messages transmit information to audiences and in such a way that the information is shared across individuals. Narratives are a powerful tool for positively influencing the well-being of individuals and fostering feelings of community (Green, Strange, & Brock, 2003). For example, the *This I Believe* program began in the 1950s and its immense popularity over decades underscores the potential of narratives to engage mass audiences in such a way that they continue to consume similar content in the future. Despite this utility, it remains unclear how the brain facilitates states of engagement and why particular types of messages may be more engaging than others. By leveraging a media neuroscience approach, this study emphasizes the importance of both message content and brain responses to explain how personal narratives engage audiences.

All personal narratives, regardless of topic or theme, elicited strong ISCs throughout the frontal and parietal lobes, particularly across regions along the auditory processing hierarchy from the primary auditory cortex extending into the distributed functional networks involved in linguistic and higher-order integrative processes. Listening to any message, no matter if it was a narrative, description, or reversed speech, resulted in robust ISCs in the auditory cortex. The descriptive VCR text, which had discernable language but offered no relatable social information or a structure that would facilitate audience comprehension, elicited ISCs that were also localized to the temporal lobe although they spread outside the auditory cortex along the middle temporal gyrus. In contrast, personal narratives showed the degree to which narratives, even short ones, can create widespread alignment across the brains of audiences.

Within the larger body of neuroimaging work using natural stimuli like videos, music, or audio stories, this study bolsters the idea that ISC indexes the extent to which a message has successfully engaged an audience. The long history of the *This I Believe* series attests to the ability of personal stories to continuously attract and engage mass audiences. Here, results show that this ability finds a correspondence at the neural level. Recent work demonstrates that ISC is enhanced when participants are instructed to pay attention (Ki, Kelly, & Parra, 2016), and ISCs extend beyond sensory cortices when the audience can derive meaning from the message they are consuming (Honey et al., 2012). Furthermore, when a message is designed to be more engaging, like emotional videos, powerful speeches, or effective health messages, this leads to ISCs throughout anterior or posterior medial cortex that are reminiscent of the effects observed in this study (Imhof, Schmälzle, Renner, & Schupp, 2017; Nummenmaa et al., 2014; Schmalzle et al., 2015). If personal narratives were not able to engage the brain networks involved in generating meaning or emotion to some degree, there would be no ISCs across frontal or parietal cortex. Thus, the fact that personal narratives prompted enhanced brain alignment most likely is a result of selective sustained attention due to specific content features of the stories.

Formal comparison of personal narrative and VCR text ISCs show significantly stronger correlations across a network of regions including the more posterior areas such as the TPJ and pCC as well as frontal regions including the aCC, dmPFC, and dlPFC. Taken together, these regional findings align with the growing body of naturalistic neuroimaging research suggesting that brain networks, originally being identified as highly connected *within* individuals, operate in a similar fashion *across* individuals (Simony et al., 2016). In the context of this study, narrative reception demanded linguistic processing, social information processing, emotional information processing, and continuous integration of information over time. The dlPFC is often implicated in language comprehension and memory (Binder et al., 2009; Ferstl et al., 2008), the aCC is associated with processing salient emotional cues (Schmälzle et al., 2013), and the TPJ, pCC, and mPFC correspond to nodes of the default-mode network, implicated in the integration of abstract information over longer timescales (Lerner et al., 2011; Marr, 2011; Spreng et al., 2007). Many published works focus on one brain network, such as the salience or default-mode network, which is useful to better grasp the complexity of brain function. Although this can give the impression of mutual exclusivity between networks, the robust ISCs elicited by personal narratives show the many nodes of major networks that are similarly activated across audience members. The strong regional differences in ISCs between narratives and the descriptive text demonstrate the utility of using naturalistic stimuli to study dynamic brain connectivity and function.

This study is one of the first to investigate audience brain engagement in response to positively-valenced message content. Thus far, a dominant proportion of ISC-based research has focused on suspenseful narratives (Hasson et al., 2008; Schmälzle & Grall, 2020), or messages designed to prompt risk perceptions (Schmälzle et al., 2013) or paranoia (Finn et al., 2018). In contrast, the stimuli used here had themes of community, hope, and kindness. Together with previous ISC work on positive states such as moral elevation and admiration (Englander, Haidt, & Morris, 2012), these results strongly suggest that positively-valenced content is effective at motivating attention like negatively-valenced content under naturalistic conditions. This paves the way for further work on the brain-based differences in engagement when induced by content that varies in valence (Nummenmaa et al., 2014).

Beyond these main analyses, several exploratory analyses were carried out that demonstrate the flexibility of the ISC family of analyses to address a variety of research questions. It is important to emphasize that this study was designed to investigate audience brain responses to personal narratives compared to other types of messages, and the additional analyses applied here were limited by the small number of stories used and their relatively short length, which would lead to very unreliable effects had any been observed. Despite this, the described procedures show that researchers can study message content based on ISC analyses of a particular region, the neural bases of affective responses to message content, and cognitive processes driven by narratives such as memory. Exploring these analyses here provides a glance at the flexibility and utility of a media neuroscience approach when designing studies specifically with these goals in mind.

Strengths, limitations, and directions for future research

The present study is among the first to examine neural processes associated with audience engagement under naturalistic conditions. It offers a high degree of external validity by using audio narratives that are popular and freely available, but it leaves out important issues of how engagement happens in the real world when individuals are inundated with a constant stream of messages. More work with larger and diverse stimulus sets is needed, and research will benefit from novel paradigms for testing attention and motivation under naturalistic conditions (Weber, Alicea, Huskey, & Mathiak, 2018). Related to this, there were no reliable findings to report when assessing the relationship between ISC and evaluative responses and activity during listening and recall. The procedures like those presented in the exploratory analyses necessitate "long" (many subjects) and/or "deep" (many time points) datasets. For example, previous work on naturalistic recall used a movie stimulus that was 48 minutes in length (Chen et al., 2017), and some procedures that enhance the reliability of detecting ISC effects require at least 20 minutes of data (Guntupalli et al., 2016). However, the robust ISC effects shown here demonstrate that there is still much to learn from datasets that may be considered limited. Furthermore, the increasing number of shared datasets due to open science initiatives make it easier than ever to address research questions at the intersection of media and the brain.

A further limitation relates to the conceptualization of engagement and other media-related phenomena that involve mixed cognitive-emotional processes that are, at least in part, difficult to describe and thus pose unique challenges for theoretical explication. In the past, the concept of "engagement" and related phenomena have been only loosely defined and existing definitions rely heavily on metaphors. As a result, there are many phenomena that, on their face, are very similar to engagement as we have described it here, but vary across research communities, across languages, and to some degree over time. Although this limits the resolution of what neuroimaging can reveal in terms of a mechanistic explanation for how narratives elicit engagement, studying the phenomenon with a biological approach allows us to capture and reveal the commonalities of the human cognitive and affective response systems that are evoked by narratives. As this body of work grows, we can begin to tease apart the similarities and differences of particular concepts that have henceforth been based on natural language, which will be especially beneficial for emotional phenomena and other mechanisms that are clearly addressed by media.

Implications and broader theoretical impact

Decades of communication research show the power of narratives to impact audiences, and the present study demonstrates this impact at the level of the brain. Compared to the reversed speech and the VCR text, narratives were able to elicit robust ISCs across all levels of the hierarchical process memory framework and especially the distributed regions representing the apex of the hierarchy, which are associated with synthesizing semantic content and integrating information with prior knowledge structures (Figure 8; Hasson et al., 2015). As argued here, the personal narratives' ability to elicit alignment across such regions including the TPJ, precuneus, and mPFC suggest that they were more successful at engaging the audience. This conclusion could not be drawn if there were no ISCs outside of the auditory cortex or if no differences in ISCs were present between message types.

The implications of this are two-fold. First, future research can build on this foundation to study the specific features that facilitate a narrative's ability to engage audiences. For example, one variable of interest is personal involvement. Strong emotional and behavioral responses are more likely when a message has inspired some degree of personal involvement and "strikes a chord" within an individual (Greenwald & Leavitt, 1984; Schmitz & Johnson, 2007; Sherif et al., 1973). Because such regions like the TPJ, pCC, precuneus, and aCC showed stronger ISC when listening to the personal narratives compared to the VCR text, these regions may be part of a commonly-shared, core network activated when a narrative elicits personal involvement. Neuroimaging evidence that supports this reasoning, although obtained in a different context, comes from a study examining the reception of information about the H1N1 swine flu pandemic. Specifically, recipients for whom the pandemic seemed personally relevant exhibited higher ISC in response to the information than those who were less involved with the issue (Schmaelzle et al., 2013). Although speculative, there was some additional evidence supporting this idea in the current study. The story that elicited the most widespread ISC was the one about a youth baseball team helping a disabled boy hit his first home run (which received high in-scanner ratings). The other stories mentioned the Olympics, interviewing famous professionals, and developing cancer as an adult. On its face, the baseball story was the most relatable to this study's participants because it was about an everyday event that could have been experienced by an early adult, and the narrator's voice may have sounded more similar in age to the participants than any other narrator. Given that many of the regions mentioned here have been implicated in integrating social and self-related information over time (Raichle, 2015; Simony et al., 2016; Spreng et al., 2008; Uddin, Iacoboni, Lange, & Keenan, 2007), future research might try to further manipulate the content variables to test whether these regions covary with the degree of personal involvement.

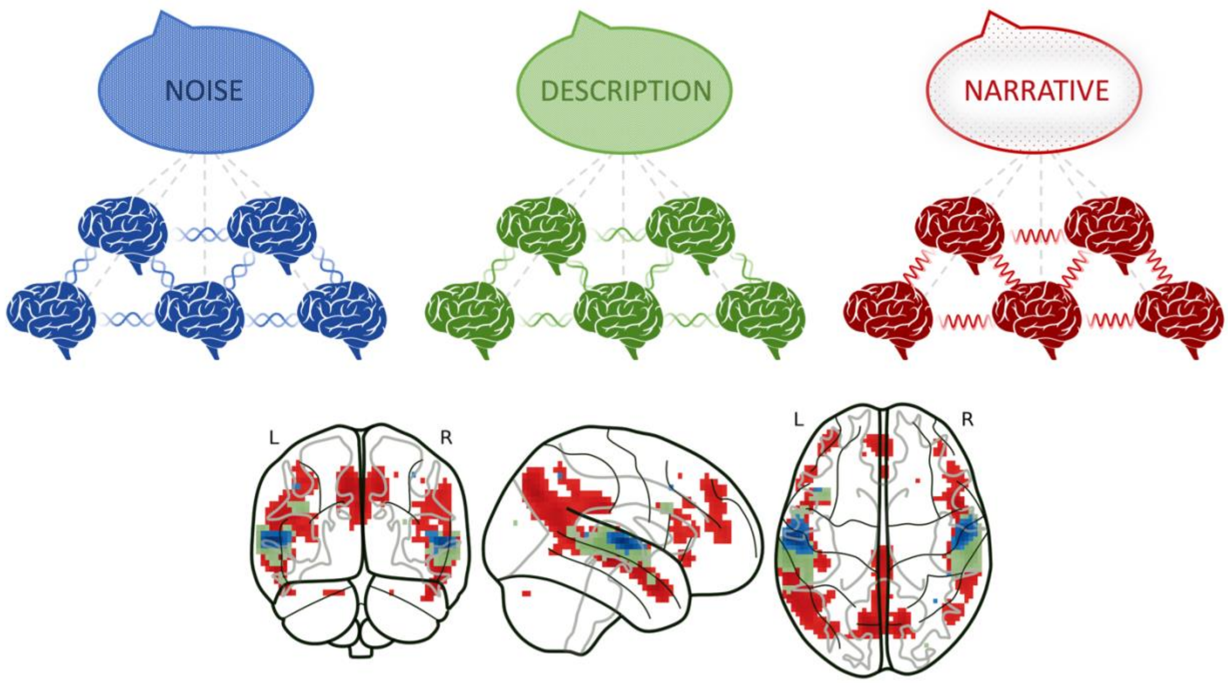

Figure 8. Narratives align the brain responses of audiences. When an audience listens to reversed speech, effectively a form of incomprehensible noise, this common stimulus can align audience brain responses in the auditory cortex. A descriptive message, one that is comprehensible in terms of language but is not structured in a way that facilitates ongoing processing, can elicit more widespread correlated responses across the temporal lobe. A personal narrative, however, which includes social information structured by events to facilitate processing, elicits widespread alignment across the temporal, parietal, and frontal lobes. The glass brain figures consist of ISC maps in response to the reversed speech (blue), the VCR text (green), and the personal narratives (red).

A second implication is that this study adds further evidence suggesting that narrative stimuli are well-suited to studying how meaning is created in the minds of audiences. Naturalistic neuroimaging studies that use media stimuli are increasingly popular, and characterizing patterns of brain responses is necessary. However, as shown here, not all naturalistic messages elicit widespread ISC. It is imperative that the specific content being used in these studies is given weight because the messages—their content, construction, and context—matter (Foudil, Kwok, & Macaluso, 2020; Schmälzle & Grall, 2020). One promising avenue for research at the intersection of message content and brain function is the reverse correlation analysis procedure demonstrated above (Ringach & Shapley, 2004). For example, peaks in ISC across particular brain regions can be used to extract the moments in a narrative that drove high alignment, and the extracted text or video can subsequently be content analyzed. This represents a novel, biologically-informed approach to content analysis.

Critically, ISC presents a theoretical and methodological key to fulfilling one of the underlying goals of mass communication research: explaining how one message exerts a common influence on many people. No explanation of a mass communication phenomenon can be complete without including all parts of the process that must logically start with the message, which is then received by many individual brains, and subsequently leads to observable effects on audience cognition, emotion, and behavior. ISC provides an objective measure of message reception over time and unlocks the brain as the critical mediating variable between a message and its effects. As argued here, narratives are particularly adept at capturing attention, facilitating comprehension, and eliciting a host of cognitive and emotional responses that are shared across an audience. ISC captures the collective engagement of these processes, which can then be linked to particular message features and subsequent behavior. In this way, ISC serves as the throughline for explaining mass communication as a process of alignment from shared brain responses to shared behavior.

Conclusion

To conclude, this study investigated the neural underpinnings of engagement with personal narratives. Analyses showed that personal narratives elicit robust ISCs across the brain compared to a descriptive message and reversed speech. Specifically, ISCs were stronger in several regions of the frontal and parietal lobes including the TPJ, pCC, aCC, dmPFC, and dlPFC. Several additional analyses explored the nature of brain engagement in response to personal narratives, and although no reliable effects were observed, the procedures demonstrate the utility of a media neuroscience approach to studying communication phenomenon. Altogether, this study contributes toward an explanation for the role of the brain in audience engagement with personal narratives.

APPENDICES

APPENDIX A

Story moments at peaks of pattern alignment in TPJ

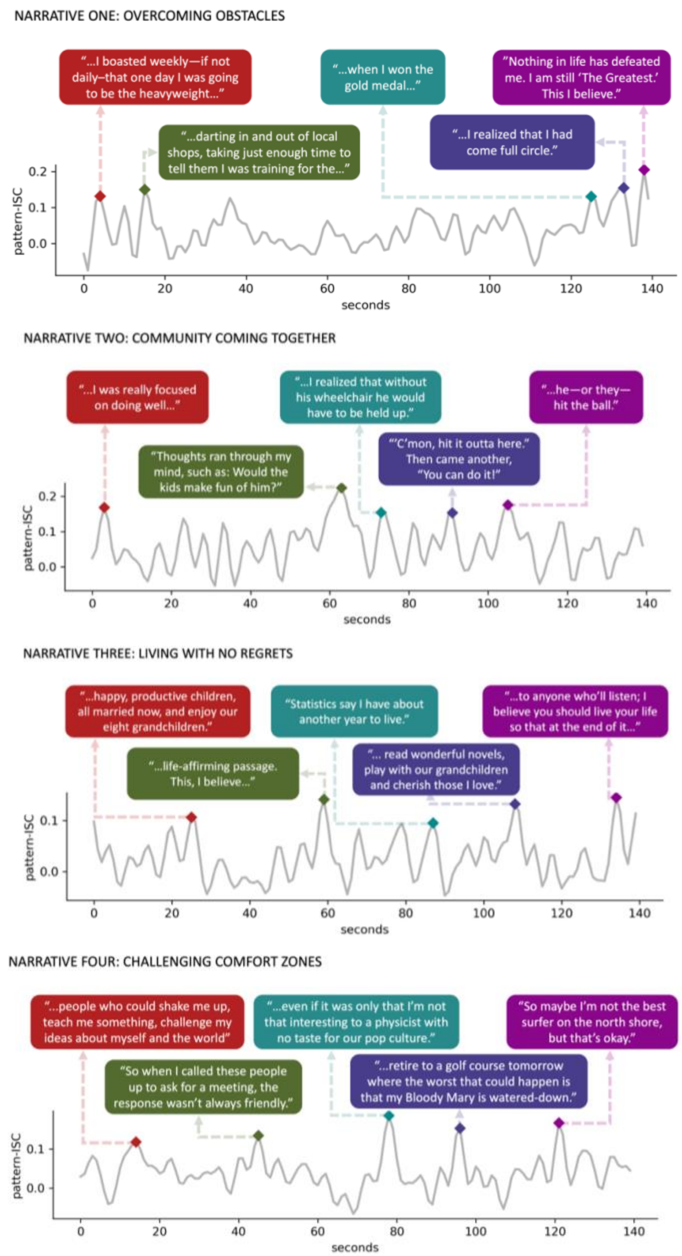

Figure 9. Story moments at peaks of pattern alignment in TPJ. For each story, a pattern-ISC analysis was conducted to derive a time series representing the spatial alignment of the TPJ for each TR. The top five peaks of each time series were used to extract specific story moments associated with the highest spatial alignment in the TPJ, a region commonly implicated in social information processing.

APPENDIX B

ISC differences between high- and low-rank groups for each narrative

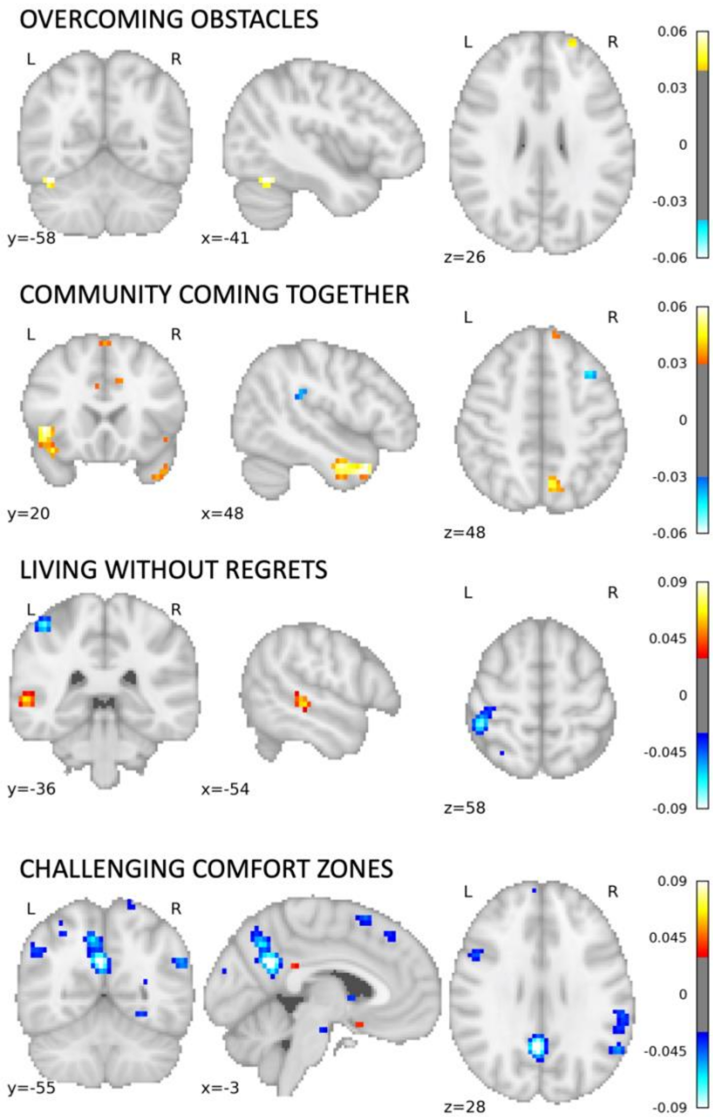

Figure 10. ISC differences between high- and low-rank groups for each narrative. No significant differences survived multiple comparisons correction using nonparametric between-groups permutation tests. The ISC difference values with p < .05 before correction are plotted here, thresholded at .04 and spatially smoothed for visualization (fwhm = 8).

APPENDIX C

Distribution of correlations between listening and recall brain activity

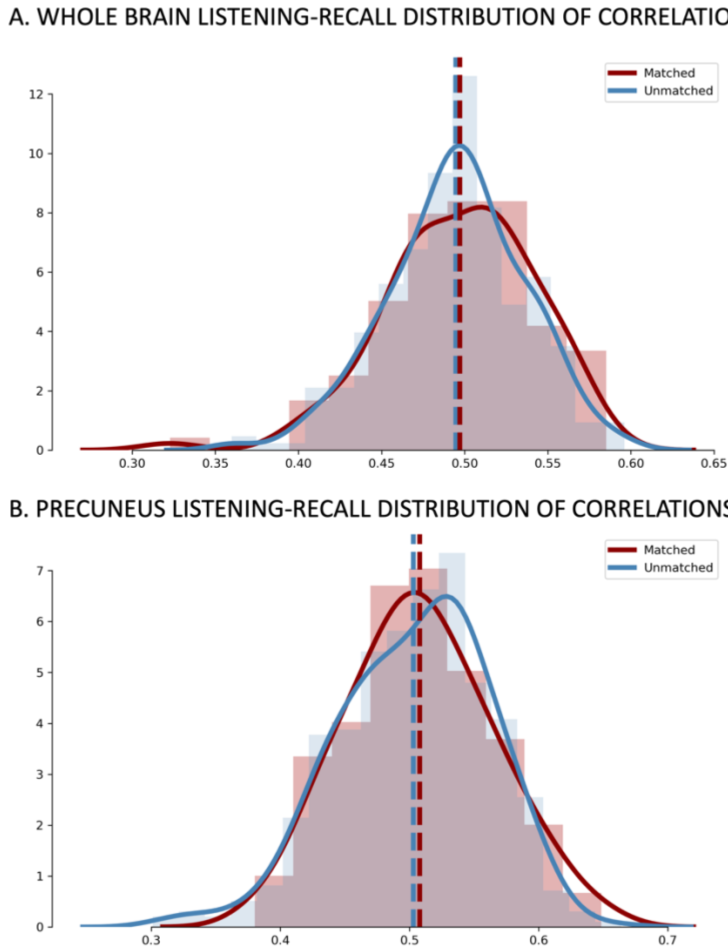

Figure 11. Distribution of correlations between listening and recall brain activity. For each participant and each story, brain activity was averaged during recall. This recall vector was correlated with brain activity at each time point during story listening and correlations were averaged to derive a single correlation representing how well recall brain activity aligned with listening brain activity. This procedure was repeated to compare all averaged recall vectors with all stories within participants and subsequently sorted into "matched" (the story being recalled matched the story heard) and "unmatched" (the recalled story and listened-to story were different) arrays. It was expected that the "matched" distribution would be higher than the "unmatched" distribution such that the relationship was stronger on average when comparing listening and recollection of the same story, which was not the case. This procedure was conducted for A) all brain voxels and B) voxels masked from the precuneus.

REFERENCES

REFERENCES

Abraham, A., Pedregosa, F., Eickenberg, M., Gervais, P., Mueller, A., Kossaifi, J., … Varoquaux, G. (2014). Machine learning for neuroimaging with scikit-learn. *Frontiers in Neuroinformatics*, *8*, 14. https://doi.org/10.3389/fninf.2014.00014

Allison, J. & Gediman, D. (Eds.). (2006). *This I Believe: The personal philosophies of remarkable men and women.* New York, NY: Henry Holt and Company.

Ames, D. L., Honey, C. J., Chow, M. A., Todorov, A., & Hasson, U. (2015). Contextual alignment of cognitive and neural dynamics. *Journal of Cognitive Neuroscience, 27*(4), 655–664. doi:10.1162/jocn_a_00728

Benjamini, Y., & Hochberg, Y. (1995). controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society. Series B, 57*(1), 289–300. https://doi.org/10.1111/j.2517-6161.1995.tb02031.x

Binder, J. R., Desai, R. H., Graves, W. W., & Conant, L. L. (2009). Where is the semantic system? A critical review and meta-analysis of 120 functional neuroimaging studies. *Cerebral Cortex, 19*(12), 2767–2796. doi:10.1093/cercor/bhp055

Binder, J. R., Frost, J. A., Hammeke, T. A., Cox, R. W., Rao, S. M., & Prieto, T. (1997). Human brain language areas identified by functional magnetic resonance imaging. *Journal of Neuroscience, 17*(1), 353–362. doi:10.1523/jneurosci.17-01-00353.1997

Birmingham, E., & Kingstone, A. (2009). Human social attention. *Attention, 176*, 309–320. doi:10.1016/s0079-6123(09)17618-5

Bradley, M. M., Codispoti, M., Cuthbert, B. N., & Lang, P. J. (2001). Emotion and motivation I: Defensive and appetitive reactions in picture processing. *Emotion, 1*(3), 276–298. doi:10.1037/1528-3542.1.3.276

Buckner, R. L., & Carroll, D. C. (2007). Self-projection and the brain. *Trends in Cognitive Sciences, 11*(2), 49–57. doi:10.1016/j.tics.2006.11.004

Cacioppo, J. T., Gardner, W. L., & Berntson, G. G. (1999). The affect system has parallel and integrative processing components: Form follows function. *Journal of Personality and Social Psychology, 76*, 839–855. doi:10.7551/mitpress/3077.003.0036

Chen, J., Leong, Y. C., Honey, C. J., Yong, C. H., Norman, K. A., & Hasson, U. (2017). Shared memories reveal shared structure in neural activity across individuals. *Nature Neuroscience, 20*, 115–125. doi:10.1038/nn.4450

Chen, G., Shin, Y.-W., Taylor, P. A., Glen, D. R., Reynolds, R. C., Israel, R. B., & Cox, R. W. (2016). Untangling the relatedness among correlations, part I: Nonparametric approaches to inter-subject correlation analysis at the group level. *NeuroImage*, *142*, 248–259. doi:10.1016/j.neuroimage.2016.05.023

Chun, M. M., Golomb, J. D., & Turk-Browne, N. B. (2011). A taxonomy of external and internal attention. *Annual Review of Psychology*, *62*, 73–101. doi:10.1146/annurev.psych.093008.100427

Crinion, J. T., Lambon-Ralph, M. A., Warburton, E. A., Howard, D., & Wise, R. J. S. (2003). Temporal lobe regions engaged during normal speech comprehension. *Brain: A Journal of Neurology*, *126*, 1193–1201. doi:10.1093/brain/awg104

Dmochowski, J. P., Sajda, P., Dias, J., & Parra, L. C. (2012). Correlated components of ongoing EEG point to emotionally laden attention–a possible marker of engagement? *Frontiers in Human Neuroscience*, *6*. doi:10.3389/fnhum.2012.00112

Dudai, Y. (2012). The cinema-cognition dialogue: A match made in the brain. *Frontiers in Human Neuroscience*, *6*, 248. doi:10.3389/fnhum.2012.00248

Englander, Z. A., Haidt, J., & Morris, J. P. (2012). Neural basis of moral elevation demonstrated through inter-subject synchronization of cortical activity during free-viewing. *PLoS ONE*, *7*, e39384. doi:10.1371/journal.pone.0039384

Etkin, A., Egner, T., & Kalisch, R. (2011). Emotional processing in anterior cingulate and medial prefrontal cortex. *Trends in Cognitive Sciences*, *15*, 85–93. doi:10.1016/j.tics.2010.11.004

Ferstl, E. C., Neumann, J., Bogler, C., & von Cramon, D. Y. (2008). The extended language network: A meta-analysis of neuroimaging studies on text comprehension. *Human Brain Mapping*, *29*(5), 581–593. doi:10.1002/hbm.20422

Finn, E. S., Corlett, P. R., Chen, G., Bandettini, P. A., & Constable, R. T. (2018). Trait paranoia shapes inter-subject synchrony in brain activity during an ambiguous social narrative. *Nature Communications*, *9*(1). doi:10.1038/s41467-018-04387-2

Fisher, J. T., Keene, J. R., Huskey, R., & Weber, R. (2018). The limited capacity model of motivated mediated message processing: Taking stock of the past. *Annals of the International Communication Association*, *42*, 270–290. doi:10.1080/23808985.2018.1534552

Foudil, S.-A., Chai Kwok, S., & Macaluso, E. (2020). Context-dependent coding of temporal distance between cinematic events in the human precuneus. *The Journal of Neuroscience*, 2296–19. doi:10.1523/jneurosci.2296-19.2020

Gorgolewski, K. J., Alfaro-Almagro, F., Auer, T., Bellec, P., Capotă, M., Chakravarty, M. M., … Poldrack, R. A. (2016). BIDS Apps: Improving ease of use, accessibility, and reproducibility of neuroimaging data analysis methods. *PLoS Computational Biology*, *13*(3), e1005209. doi:10.1101/079145

Green, M. C., Strange, J. J., & Brock, T. C. (2003). *Narrative impact: Social and cognitive foundations*. New York, NY: Psychology Press. https://doi.org/10.4324/9781410606648

Greenwald, A. G., & Leavitt, C. (1984). Audience involvement in advertising: Four levels. *The Journal of Consumer Research, 11,* 581–592. doi:10.1086/208994

Guntupalli, J. S., Hanke, M., Halchenko, Y. O., Connolly, A. C., Ramadge, P. J., & Haxby, J. V. (2016). A model of representational spaces in human cortex. *Cerebral Cortex, 26*(6), 2919–2934. doi:10.1093/cercor/bhw068

Hassabis, D., & Maguire, E. A. (2007). Deconstructing episodic memory with construction. *Trends in Cognitive Sciences, 11*(7), 299–306. doi:10.1016/j.tics.2007.05.001

Hasson, U., Chen, J., & Honey, C. J. (2015). Hierarchical process memory: memory as an integral component of information processing. *Trends in Cognitive Sciences, 19*(6), 304–313. doi:10.1016/j.tics.2015.04.006

Hasson, U., Egidi, G., Marelli, M., & Willems, R. M. (2018). Grounding the neurobiology of language in first principles: The necessity of non-language-centric explanations for language comprehension. *Cognition, 180,* 135–157. doi:10.1016/j.cognition.2018.06.018

Hasson, U., Landesman, O., Knappmeyer, B., Vallines, I., Rubin, N., & Heeger, D. J. (2008). Neurocinematics: The neuroscience of film. *Projections, 2,* 1–26. doi:10.3167/proj.2008.020102

Hasson, U., Nir, Y., Levy, I., Fuhrmann, G., & Malach, R. (2004). Intersubject synchronization of cortical activity during natural vision. *Science*, *303*, 1634–1640. doi:10.1126/science.1089506

Haxby, J. V., Gobbini, M. I., Furey, M. L., Ishai, A., Schouten, J. L., & Pietrini, P. (2001). Distributed and overlapping representations of faces and objects in ventral temporal cortex. *Science, 293*(5539), 2425-2430. doi:10.1126/science.1063736

Hickok, G., & Poeppel, D. (2007). The cortical organization of speech processing. *Nature Reviews Neuroscience, 8*(5), 393–402. doi:10.1038/nrn2113

Honey, C. J., Thompson, C. R., Lerner, Y., & Hasson, U. (2012). Not lost in translation: neural responses shared across languages. *Journal of Neuroscience*, *32*, 15277–15283. doi:10.1523/jneurosci.1800-12.2012

Huth, A. G., de Heer, W. A., Griffiths, T. L., Theunissen, F. E., & Gallant, J. L. (2016). Natural speech reveals the semantic maps that tile human cerebral cortex. *Nature*, *532*, 453-458. doi:10.1038/nature17637

Imhof, M. A., Schmälzle, R., Renner, B., & Schupp, H. T. (2020). Strong health messages increase audience brain coupling. *NeuroImage*, 116527. doi:10.1016/j.neuroimage.2020.116527

Ki, J. J., Kelly, S. P., & Parra, L. C. (2016). Attention strongly modulates reliability of neural responses to naturalistic narrative stimuli. *Journal of Neuroscience, 36*, 3092–3101. doi:10.1523/jneurosci.2942-15.2016

Kim, H. S., Bigman, C. A., Leader, A. E., Lerman, C., & Cappella, J. N. (2012). Narrative health communication and behavior change: The influence of exemplars in the news on intention to quit smoking. *Journal of Communication, 62*(3), 473–492. doi:10.1111/j.1460-2466.2012.01644.x

Kintsch, W., & Mangalath, P. (2011). The construction of meaning. *Topics in Cognitive Science, 3,* 346–370. doi:10.1111/j.1756-8765.2010.01107.x

Lahnakoski, J. M., Glerean, E., Jääskeläinen, I. P., Hyönä, J., Hari, R., Sams, M., & Nummenmaa, L. (2014). Synchronous brain activity across individuals underlies shared psychological perspectives. *NeuroImage*, *100*, 316–324. doi:10.1016/j.neuroimage.2014.06.022

Lang, A. (2009). The limited capacity model of motivated mediated message processing. In R. L. Nabi & M. B. Oliver (Eds.), *The Sage handbook of media processes and effects* (pp. 99–112). Los Angeles, CA: Sage. doi:10.5860/choice.47-2995

Lang, P. J. (2010). Emotion and motivation: Toward consensus definitions and a common research purpose. *Emotion Review, 2,* 229-233. doi:10.1177/1754073910361984

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). Motivated attention: Affect, activation, and action. In P. J. Lang, R. F. Simons, & M. Balaban (Eds.), *Attention and orienting; Sensory and motivational processes*, (pp. 97-135). New York, NY: Routledge. doi:.4324/9780203726457

Lang, P.J., Bradley, M.M., & Cuthbert, B.N. (2008). *International affective picture system (IAPS): Affective ratings of pictures and instruction manual* (Technical Report A-8). University of Florida, Gainesville, FL.

Lerner, Y., Honey, C. J., Silbert, L. J., & Hasson, U. (2011). Topographic mapping of a hierarchy of temporal receptive windows using a narrated story. *Journal of Neuroscience, 31,* 2906-2915. doi:10.1523/jneurosci.3684-10.2011

Mar, R. A. (2011). The Neural bases of social cognition and story comprehension. *Annual Review of Psychology, 62*(1), 103–134. doi:10.1146/annurev-psych-120709-145406

Mar, R. A., & Oatley, K. (2008). The function of fiction is the abstraction and simulation of social experience. *Perspectives on Psychological Science, 3*, 173–192. doi:10.1111/j.1745-6924.2008.00073.x

McQuail, D. (1983). *Mass communication theory: An introduction*. Beverly Hills, CA: SAGE Publications.

Mesulam, M. M. (1998). From sensation to cognition. *Brain, 121*, 1013–1052. doi:10.1093/brain/121.6.1013

Nastase, S. A., Gazzola, V., Hasson, U., & Keysers, C. (2019). Measuring shared responses across subjects using intersubject correlation. *Social Cognitive and Affective Neuroscience*, nsz037, doi:10.1093/scan/nsz037

Nguyen, M., Vanderwal, T., & Hasson, U. (2019). Shared understanding of narratives is correlated with shared neural responses. *NeuroImage, 184*, 161–170. doi:10.1016/j.neuroimage.2018.09.010

Nummenmaa, L., Saarimäki, H., Glerean, E., Gotsopoulos, A., Jääskeläinen, I. P., Hari, R., & Sams, M. (2014). Emotional speech synchronizes brains across listeners and engages large-scale dynamic brain networks. *NeuroImage*, *102*, 498–509. doi:10.1016/j.neuroimage.2014.07.063

Oatley, K. (2012). The cognitive science of fiction. *Cognitive Science, 3*(4), 425–430. doi:10.1002/wcs.1185

Oliver, M. B., Raney, A. A., Slater, M. D., Appel, M., Hartmann, T., Bartsch, A., … Das, E. (2018). Self-transcendent media experiences: Taking meaningful media to a higher level. *Journal of Communication, 68*(2), 380–389. doi:10.1093/joc/jqx020

Oren, N., Shapira-Lichter, I., Lerner, Y., Tarrasch, R., Hendler, T., Giladi, N., & Ash, E. L. (2016). How attention modulates encoding of dynamic stimuli. *Frontiers in Human Neuroscience*, *10*, 507. doi:10.3389/fnhum.2016.00507

Pedregosa, F. (2011). Scikit-learn: Machine Learning in Python. *Journal of Machine Learning Research, 12*, 2825–2830.

Pessoa, L. (2008). On the relationship between emotion and cognition. *Nature Reviews. Neuroscience*, *9*(2), 148–158. doi:10.1038/nrn2317

Pessoa, L. (2009). How do emotion and motivation direct executive control? *Trends in Cognitive Sciences, 13*, 160–166. doi:10.1016/j.tics.2009.01.006

Pessoa, L. (2013). *The cognitive–emotional brain: From interactions to integration*. Cambridge, MA: MIT Press. doi:10.7551/mitpress/9780262019569.001.0001

Pessoa, L. (2018). Understanding emotion with brain networks. *Current Opinion in Behavioral Sciences*, *19*, 19–25. doi:10.1016/j.cobeha.2017.09.005

Regev, M., Simony, E., Lee, K., Tan, K. M., Chen, J., & Hasson, U. (2018). Propagation of information along the cortical hierarchy as a function of attention while reading and listening to stories. *Cerebral Cortex, 29*(10), 4017–4034. doi:10.1093/cercor/bhy282

Ringach, D., & Shapley, R. (2004). Reverse correlation in neurophysiology. *Cognitive Science, 28*, 147–166. doi:10.1207/s15516709cog2802_2

Roy, M., Shohamy, D., & Wager, T. D. (2012). Ventromedial prefrontal-subcortical systems and the generation of affective meaning. *Trends in Cognitive Sciences, 16*, 147–156. doi:10.1016/j.tics.2012.01.005

Schmälzle, R. & Grall, C. (2020). The coupled brains of captivated audiences: How suspense in a movie modulates collective brain dynamics. *Journal of Media Psychology*. doi.org/10.1027/1864-1105/a000271

Schmälzle, R. & Grall, C. (in press). Mediated messages and synchronized brains. In R. Weber & K. Floyd (Eds.), *Handbook of Communication Science and Biology*. New York, NY: Routledge.

Schmälzle, R., Häcker, F., Honey, C.J., & Hasson, U. (2015). Engaged listeners: Shared neural processing of powerful political speeches. *Social, Cognitive, and Affective Neurosciences*, *1*, 168-169. doi:10.1093/scan/nsu168

Schmälzle, R., Häcker, F., Renner, B., Honey, C. J., & Schupp, H. T. (2013). Neural correlates of risk perception during real-life risk communication. *Journal of Neuroscience*, *33*, 10340–10347. doi:10.1523/jneurosci.5323-12.2013

Schmälzle, R., Imhof, M. A., Grall, C., Flaisch, T., & Schupp, H. T. (2017, July 3). *Reliability of fMRI time series: Similarity of neural processing during movie viewing*. *bioRxiv*. doi:10.1101/158188

Schmitz, T. W., & Johnson, S. C. (2007). Relevance to self: A brief review and framework of neural systems underlying appraisal. *Neuroscience and Biobehavioral Reviews, 31*, 585–596. https://doi.org/10.1016/j.neubiorev.2006.12.003

Schupp, H. T., Flaisch, T., Stockburger, J., & Junghöfer, M. (2006). Emotion and attention: event-related brain potential studies. *Progress in Brain Research, 156*, 31–51. doi:10.1016/s0079-6123(06)56002-9

Schupp, H. T., Stockburger, J., Codispoti, M., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2007). Selective visual attention to emotion. *The Journal of Neuroscience*, *27*, 1082–1089. doi:10.1523/jneurosci.3223-06.2007

Schurz, M., Radua, J., Aichhorn, M., Richlan, F., & Perner, J. (2014). Fractionating theory of mind: A meta-analysis of functional brain imaging studies. *Neuroscience and Biobehavioral Reviews*, *42*, 9–34. doi:10.1016/j.neubiorev.2014.01.009

Shannon, C. E. (1948). A mathematical theory of communication. *Bell System Technical Journal*, *27*(3), 379–423. doi:10.1002/j.1538-7305.1948.tb01338.x

Sherif, C. W., Kelly, M., Rodgers, H. L., Jr., Sarup, G., & Tittler, B. I. (1973). Personal involvement, social judgment, and action. *Journal of Personality and Social Psychology*, *27*(3), 311-328. doi:10.1037/h0034948

Shirer, W. R., Ryali, S., Rykhlevskaia, E., Menon, V., & Greicius, M. D. (2011). Decoding subject-driven cognitive states with whole-brain connectivity patterns. *Cerebral Cortex, 22*, 158–165. doi:10.1093/cercor/bhr099

Simony, E., Honey, C. J., Chen, J., Lositsky, O., Yeshurun, Y., Wiesel, A., & Hasson, U. (2016). Dynamic reconfiguration of the default mode network during narrative comprehension. *Nature Communications, 7*, 12141. doi:10.1038/ncomms12141

Slater, M. D., & Rouner, D. (2002). Entertainment-education and elaboration likelihood: Understanding the processing of narrative persuasion. *Communication Theory, 12*(2), 173–191. doi:10.1111/j.1468-2885.2002.tb00265.x

Spreng, N. R., Mar, R. A., & Kim, A. S. N. (2007). The common neural basis of autobiographical memory, prospection, navigation, theory of mind, and the default mode: A quantitative meta-analysis. *Journal of Cognitive Neuroscience*, 21, 489–510. doi:10.1162/jocn.2008.21029

Tamborini, R. (2013). Model of intuitive morality and exemplars. In R. Tamborini (Ed.), *Media and the moral mind* (pp. 43-74). London, UK: Routledge.

Tamborini, R., Bowman, N. D., Eden, A., Grizzard, M., & Organ, A. (2010). Defining media enjoyment as the satisfaction of intrinsic needs. *The Journal of Communication*, *60*, 758–777. doi:10.1111/j.1460-2466.2010.01513.x

Vorderer, P., & Halfmann, A. (2019). Why do we entertain ourselves with media narratives? A theory of resonance perspective on entertainment experiences. *Annals of the International Communication Association, 43*, 79–96. doi:10.1080/23808985.2019.1599298

Weber, R., Alicea, B., Huskey, R., & Mathiak. K. (2018). Network dynamics of attention during a naturalistic behavioral paradigm. *Frontiers in Human Neuroscience*, *12*(182), 1-14. doi: 10.3389/fnhum.2018.00182

Weber, R., Eden, A., Huskey, R., Mangus, M., & Falk, E. (2015). Bridging media psychology and cognitive neuroscience. *Journal of Media Psychology*, *27*, 146–156. doi:10.1027/1864-1105/a000163

Weber, R., Mangus, J. M., Huskey, R., Amir, O., Swanson, R., Gordon, A., Khooshabeh, P., Hahn, L., & Tamborini, R. (2018). Extracting moral foundations from text narratives: Relevance, challenges, and solutions. *Communication Methods and Measures, 12*, 119-139. doi:10.1080/19312458.2018.1447656

Wilson, S. M., Molnar-Szakacs, I., & Iacoboni, M. (2008). Beyond superior temporal cortex: intersubject correlations in narrative speech comprehension. *Cerebral Cortex , 18*, 230–242. doi:10.1093/cercor/bhm049

Yarkoni, T., Poldrack, R. A., Nichols, T. E., Van Essen, D. C., & Wager, T. D. (2011). Large-scale automated synthesis of human functional neuroimaging data. *Nature Methods, 8*, 665–670. doi:10.1038/nmeth.1635

Yeshurun, Y., Nguyen, M., & Hasson, U. (2017). Amplification of local changes along the timescale processing hierarchy. *Proceedings of the National Academy of Sciences, 114*(35), 9475–9480. doi:10.1073/pnas.1701652114

Yeshurun, Y., Swanson, S., Simony, E., Chen, J., Lazaridi, C., Honey, C. J., & Hasson, U. (2017). Same story, different story: The neural representation of interpretive frameworks. *Psychological science, 28*, 307-319. doi:10.1177/0956797616682029

Zillmann, D. (2000). Basal morality in drama appreciation. In I. Bondebjerg (Ed.), *Moving images, culture, and the mind* (pp. 53-63). Luton, UK: University of Luton Press.