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Brain Network Reconfiguration for Narrative and Argumentative Thought

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1 **Abstract (max 150 words)**

2 Our brain constructs reality through narrative and argumentative thought. Some hypotheses argue that
3 these two modes of cognitive functioning are irreducible, reflecting distinct mental operations underlain
4 by separate neural bases; Others ascribe both to a unitary neural system dedicated to long-timescale
5 information. We addressed this question by employing inter-subject measures to investigate the stimulus-
6 induced neural responses when participants were listening to narrative and argumentative texts during
7 fMRI. We found that following both kinds of texts enhanced functional couplings within the frontoparietal
8 control system. However, while a narrative specifically implicated the default mode system, an argument
9 specifically induced synchronization between the intraparietal sulcus in the frontoparietal control system
10 and multiple perisylvian areas in the language system. Our findings reconcile the two hypotheses by
11 revealing commonalities and differences between the narrative and the argumentative brain networks,
12 showing how diverse mental activities arise from the segregation and integration of the existing brain
13 systems.

14

15 Keywords: narrative, argument, inter-subject correlation, inter-subject functional connectivity, brain
16 network

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17 **Introduction**

18 "To say that all human thinking is essentially of two kinds – reasoning on the one hand, and narrative,
19 descriptive, contemplative thinking on the other – is to say only what every readers' experience will
20 corroborate."

21 *William James*

22

23 Humans are thinking animals. Flows of concepts and ideas pass through our minds from time to time.
24 These concepts and ideas are seldom in isolation; they are often sequentially connected, composed into a
25 mental discourse, which has been called the "train of thought" (Hobbes, 1651). Psychologists argued for
26 decades that these complex thoughts are essentially of two natural kinds, each gluing its elements in a
27 different manner (Bruner, 1986; James, 1983): The narrative thought comprises a series of events, which
28 unfold through temporal causality and implied purpose (Beach and Bissel, 2016). The argumentative
29 thought consists of a chain of propositions, forming the interlinked premiss-illative-conclusion structure,
30 according to which a final conclusion is reached through progressive inferences (Hitchcock, 2007).

31 Despite the fact that both modes of thought are pervasive in our mental life, most neuroimaging
32 studies merely focused on the neural basis of narrative thought (Kemmerer, 2014; Mar, 2004). In these
33 studies, a narrative text is divided into its constituent sentences, and the order of these sentences is
34 randomized to form a sentence-scrambled version of the text. The conditions presenting the intact texts
35 are contrasted to conditions presenting the sentence-scrambled texts. As participants can only generate a
36 coherent narrative discourse in the intact-text condition, this contrast outstands the neural basis of narrative
37 thought from the one of linguistic processing regarding word meaning and syntax. A meta-analysis of 12
38 such neuroactivation studies indicates that narratives consistently induced greater activation than the
39 sentence-scrambled text in the anterior temporal lobe, temporoparietal junction, precuneus, and medial

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40 prefrontal cortex (Ferstl et al., 2008); a set of regions that coincides with the default mode network (DMN)
41 (Buckner et al., 2008). Instead of investigating the overall level of activation, recent studies demonstrate
42 that the DMN activity can also capture the dynamic progress in a narrative (Lerner et al., 2011; Simony
43 et al., 2016). As it is hard to obtain an explicit event-related response model that can describe a narrative
44 discourse, these studies used one individual's neural response to model another's by measuring the shared
45 neural responses across participants when they were listening to the same narrative (Nastase et al., 2019).
46 For instance, one study using the inter-subject correlation (ISC) method find that listening to the same
47 narrative synchronizes the blood-oxygen-level-dependent (BOLD) fluctuations in the same regions of the
48 DMN across subjects; listening to the same sentence-scrambled text does not (Lerner et al., 2011). Another
49 study further illustrates such higher synchronization in the DMN not only exist between the same regions
50 across subjects (i.e., ISC) but also between different regions across subjects (i.e., the inter-subject
51 functional connectivity, ISFC) (Simony et al., 2016). The later findings demonstrate that regions in the
52 DMN underlie narrative thought by coordinating with each other as a network.

53 What are the neural bases of argumentative thought? There are two hypotheses (Jacoby and
54 Fedorenko, 2018). The content-dependent hypothesis inherits the two modes of thought view, suggesting
55 the narrative and the argumentative thought are irreducible to one another (Bruner, 1986; James, 1983);
56 they reflect distinct mental operations, which should correspond to separate neural bases. Tracing a
57 narrative plot relies on constructing and updating the representation of a state of affairs, i.e., "situation
58 model" (Zwaan and Radvansky, 1998), to simulate the temporal causality and to infer the characters'
59 intentions. This set of cognitive functions is indeed attributed to the DMN, which plays a role in mental
60 simulation and theory of mind (Buckner et al., 2008). Following an argument, instead, relies on identifying
61 and evaluating the logical structure embedded in the use of natural language, i.e., "informal logic" (Blair,

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62 2015). This set of cognitive functions might warrant cooperation between the language and the reasoning
63 brain system.

64 On the contrary, the content-independent hypothesis suggests that the narrative and the
65 argumentative thought are fundamentally the same; they share the same neural mechanism. One
66 commonality of these two modes of thought is that the content at each time point relates to the context
67 established at previous time points. Iteratively accumulating information over time and holding the
68 information online over a long timescale seems equally crucial to framing a coherent narrative and a valid
69 argument. According to the hierarchical process memory framework, all the cortical circuits accumulate
70 information over time, but their processing timescale increases along the hierarchical topography, from
71 milliseconds in primary sensory regions to minutes in high-order regions (Hasson et al., 2015). This
72 framework suggests that the DMN, which is at the top of the topographical hierarchy (Margulies et al.,
73 2016; Sepulcre et al., 2012), supports narrative thought by virtue of its wide temporal receptive window
74 (TRW), integrating information over a long timescale, e.g., up to minutes (J. Chen et al., 2016). As a wide
75 TRW is also crucial to the progress of an argumentative thought, the DMN might potentially serve as
76 general machinery for long-timescale information integration, supporting both narrative and
77 argumentative thought.

78 Testing these two hypotheses requires to fill the vacancy of studies on argumentative thought. Here,
79 we investigated the neural correlates of both narrative and argumentative thought by contrasting the BOLD
80 signal elicited by two narrative texts and two argumentative texts to the signal elicited by their
81 corresponding sentence-scrambled version (Table 1). We also acquired the BOLD signal during the
82 resting state as a baseline. Specifically, we employed ISC and the ISFC as measures to respectively
83 investigate the stimulus-induced regional activity and interregional functional coupling during the
84 narrative and the argumentative thought. The content-independent hypothesis will predict a higher ISC or

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85 ISFC in the DMN in both the narrative and the argumentative conditions compared to their corresponding
86 sentence-scrambled conditions. The content-dependent hypothesis, instead, will predict a higher ISC or
87 ISFC in the DMN only when the narrative condition and its sentence-scrambled condition are compared;
88 alternative brain networks that relate to language and reasoning will engage in the discourse-level
89 comprehension of argumentative texts.

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90 **Results**

91 *Behavior rating on stimuli*

92 Table 1 shows the information on the two selected narrative texts and the two selected argumentative texts
93 (see Methods for more detailed information). These texts were divided into segments consisting of
94 complete sentences, each one ending with a period, question mark, exclamation mark, colon, or semi-
95 colon. We sorted the segments according to random order and concatenated them together to generate a
96 sentence-scrambled version for each text. The number of words, duration, number of segments, number
97 of words of each segment, and the duration of each segment were matched between narrative texts and
98 argumentative texts. These measurements were also comparable to those in the previous studies using ISC
99 (Lerner et al., 2011) and ISFC (Simony et al., 2016) methods.

100 At the stimuli-selection stage, we rated narrative- and argument-relevant features of these texts on
101 a five-point Likert scale (Fig. 1). The questionnaire used to query these features can be found in the
102 supplementary materials. Each text was rated by 20 participants who did not participate in the MRI
103 experiment (see Methods for more detailed information). The results confirmed that the two narrative texts
104 had higher ratings than the two argumentative texts on narrative-related features such as narrativeness
105 (Welch's $t(77.81) = 20.11$; $P < 0.001$), concreteness (Welch's $t(69.93) = 3.39$; $P = 0.001$), scene
106 construction (Welch's $t(52.52) = 9.24$; $P < 0.001$), self-projection (Welch's $t(68.92) = 5.18$; $P < 0.001$),
107 and theory of mind (Welch's $t(77.97) = 3.99$; $P < 0.001$) (Figure 1a). The two argumentative texts received
108 higher ratings than the two narrative texts on argument-related features such as argumentativeness
109 (Welch's $t(78.00) = -10.36$, $P < 0.001$), abstractness (Welch's $t(78.00) = -11.51$, $P < 0.001$), and logical
110 thinking (Welch's $t(77.81) = -11.03$, $P < 0.001$) (Fig. 1b).

111 The 16 participants who took part in the fMRI experiment filled in the same rating questionnaire
112 after scanning. The results largely validated the above rating patterns (Supplementary Fig. 1). In the

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113 questionnaire, these participants also rated to which degree they understood the texts on a five-point Likert
114 scale. The results showed that they understood the intact texts better than the sentence-scrambled texts:
115 The comprehensibility rating on the intact narrative texts (mean \pm SD: 4.69 \pm 0.51) was significantly
116 higher than the scrambled narrative texts (mean \pm SD: 2.63 \pm 0.67) (pair $t(15) = 15.17$, $P < 0.001$), and
117 the comprehensibility rating on the argumentative texts (mean \pm SD: 4.41 \pm 0.74) was significantly higher
118 than the scrambled argumentative texts (mean \pm SD: 2.97 \pm 0.99) (pair $t(15) = 8.46$, $P < 0.001$).

119

120 *Narrative, not argumentative texts, evoked time-locked neural activity in the DMN*

121 We first investigated the time-locked regional activity evoked by narrative and argumentative thought by
122 comparing the ISC in the intact-text conditions when the participants could construct coherent thoughts
123 to the ISC in the scrambled-sentence conditions when participants could only process the literal meaning
124 of each sentence (Fig. 2). To recognize which brain systems are engaged in narrative and argumentative
125 thought, we calculated the percentage of significant brain areas (i.e., the number of vertexes) that fall into
126 each pre-identified brain system. The distribution of each brain system was identified based on a study
127 applying clustering analysis on the interregional connectivity pattern (Thomas Yeo et al., 2011)
128 (Supplementary Fig. 2; see Methods for details).

129 As a sanity check, we examined the contrast between the scrambled-sentence condition and the
130 resting-state condition. We predicted that sentence-scrambled texts should mainly synchronize the
131 auditory, language, and domain-general process across participants. The results confirmed this prediction
132 by showing that, independently of text type (narrative or argumentative), about 90% of significant vertexes
133 fell into the four brain systems relating to auditory, language, control, and attention ($P < 0.05$, FDR
134 corrected, area > 200 mm²; Fig. 2, first row; Supplementary Fig. 2b, first row).

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135 We moved on to investigate the neural correlates of narrative and argumentative thought by
136 detecting the regions that show additional or higher synchronization in the intact-text condition compared
137 to the scrambled-sentence condition ($P < 0.05$, FDR corrected, area $> 200 \text{ mm}^2$; Fig. 2, second and third
138 row; Supplementary Fig. 2b, second and third row). The results contrasting intact-narrative condition to
139 the resting-state condition showed a much wider distribution of brain areas than the results contrasting
140 scrambled-sentence condition to the resting-state condition. Note that, in the intact-narrative condition,
141 18% of significant regions fell into the DMN, whereas in the scrambled-narrative condition, this portion
142 was less than 1%. Directly contrasting the intact-narrative condition to the scrambled-narrative condition
143 revealed about 90% of significant regions fell in four brain systems: the default mode, language, control,
144 and attention, of which 37% were in the DMN. Specifically, the significant regions in the DMN included
145 the angular gyrus (AG), the area comprising the precuneus, the posterior cingulate cortex (PCC), and the
146 ventral retrosplenial complex (RSC), and the middle portion of the left peri-hippocampal area. Intriguingly,
147 contrasting intact-argumentative condition to the resting-state condition only showed brain areas confined
148 within the brain areas that emerge when contrasting the scrambled-sentence condition to the resting-state
149 condition. Directly contrasting the intact-argumentative condition to the scrambled-argumentative
150 condition did not reveal any additional brain areas, even at a lower threshold ($P < 0.001$, uncorrected).

151 We also contrasted the ISC result of narrative thought to the argumentative one, i.e., (Intact
152 Narrative - Scrambled Narrative) $>$ (Intact Argument - Scrambled Argument) ($P < 0.05$, FDR corrected,
153 area $> 200 \text{ mm}^2$; Supplementary Fig 3). The significant brain areas coincided with the results of the
154 narrative thought: Over 90% of the significant regions fell into the default mode, language, control, and
155 attention systems, of which 25% were in the DMN. The opposite contrast did not reveal any region more
156 involved in the argumentative thought than the narrative one, even at a lower threshold ($P < 0.001$,
157 uncorrected).

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158 To validate the above results and to evaluate the across-stimuli consistency, we repeated the
159 analysis on each of the two narrative texts (Supplementary Fig. 4) and the two argumentative texts
160 (Supplementary Fig. 5) ($P < 0.05$, FDR corrected, area $> 200 \text{ mm}^2$). The results showed an overall
161 consistency between the two texts of the same type despite the considerable difference in content and
162 writing style. For the two narrative texts, contrasting the intact-text condition to the scrambled-sentence
163 condition revealed significant brain areas that mostly overlapped in the DMN, i.e., the precuneus and the
164 posterior angular gyrus. For the two argumentative texts, the same contrast did not reveal any significant
165 brain areas.

166 The above ISC analysis verifies the previous findings that the DMN engages in narrative thought
167 (Ferstl et al., 2008; Lerner et al., 2011), but fails to reveal the neural basis for the argumentative one. It
168 seems that the DMN does not serve as the general machinery for long-timescale information integration,
169 supporting both modes of thought.

170
171 *Network reconfiguration for narrative and argumentative thought*

172 It is worth noting that the ISC analysis investigates the stimulus-induced neural activity region by region
173 in isolation. Constructing a coherent thought throughout a relatively long text might rely on the
174 reconfiguration of brain networks already active during sentence-level processing, without necessarily
175 recruiting additional brain regions. As the ISFC measures the purely stimulus-induced functional coupling
176 between discrete regions (Simony et al., 2016), it can reflect the brain network reconfigurations across
177 different task states. The current analysis aimed to investigate the network reconfiguration for narrative
178 and argumentative thought by comparing the ISFC in the intact-text conditions to those in the scrambled-
179 sentence conditions (Fig. 3 and Fig. 4).

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180 We implemented the ISFC analysis based on a whole-brain parcellation atlas comprising 200 brain
181 regions (Schaefer et al., 2018). The atlas also provides information about which brain system each of the
182 200 brain areas belong to. Fig. 3 and Fig. 4 illustrate the network reconfiguration in the narrative
183 conditions and the argumentative conditions, respectively. The left panel in both figures shows the
184 network layout of all the significant ISFC differences between conditions ($P < 0.05$, FWE corrected) using
185 the force-directed graph drawing algorithm (Fruchterman and Reingold, 1991), where strongly connected
186 nodes cluster together, and weakly connected nodes are pushed apart. The nodes represent brain areas of
187 each brain system, where the size of nodes denotes the node degree, i.e., the sum of edges that connect to
188 the nodes. The edges represent the significant interregional ISFC difference, where the width of edges
189 denotes the standardized effect size of the contrast (SES). The right panel in both figures summarizes the
190 edge distribution within and between brain systems. Each cell denotes the mean SES, i.e., the ratio
191 between the sum of all the significant edges and the number of all the possible edges in the fully connected
192 situation.

193 For narrative conditions, the ISFC results were mostly in line with the ISC results. Scrambled-
194 narrative texts, in contrast to the resting state, synchronized the neural activity mainly in the brain systems
195 relating to auditory, language, control, and ventral attention (Fig. 3, the first row). Intact-narrative texts,
196 in contrast to the resting state, extended the synchronization to the DMN (Fig. 3, the second row). A direct
197 comparison between the intact-narrative condition and the scrambled-narrative condition was
198 implemented by detecting the edges that simultaneously met the criteria (1) Intact Narrative > Scrambled
199 Narrative ($P < 0.05$, FWE corrected) and (2) Intact Narrative > Resting State ($P < 0.05$, FWE corrected).
200 The significant edges mainly fell into the brain systems relating to the default mode, language, control,
201 and dorsal attention. (Fig. 3, the third row). Supplementary Fig. 6a illustrates the top 20 edges with the
202 biggest SES within the DMN. These critical functional couplings covered all the core regions in the DMN,

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203 i.e., the AG (Brodmann area 39), the dorsal lateral prefrontal cortex (8Ad area) (Petrides, 1999), the
204 anterior medial prefrontal cortex, the PCC, the ventral RSC, and the parahippocampal area. The result
205 confirmed previous findings that areas in the DMN are synchronized as a network to support the narrative
206 thought (Simony et al., 2016).

207 For argumentative conditions, scrambled-argumentative texts, in contrast to the resting state, also
208 synchronized the neural activity mainly in the brain systems relating to auditory, language, control, and
209 ventral attention (Fig. 4, the first row). Intact-argumentative texts seemed not to involve additional brain
210 systems. Most of the significant edges were within the language system (Fig. 4, the second row). A direct
211 comparison between the intact-argumentative condition and the scrambled-argumentative condition was
212 conducted by detecting the edges that simultaneously met the criteria (1) Intact Argument > Scrambled
213 Argument ($P < 0.05$, FWE corrected) and (2) Intact Argument > Resting State ($P < 0.05$, FWE corrected).
214 The significant edges were mostly within the control system or connected the control and the language
215 systems. Not even a single significant edge fell into the DMN. Supplementary Fig. 6b illustrates the top
216 20 edges with the biggest SES in all the brain systems. All these critical functional couplings were between
217 the control system and the language systems. More specifically, they were the one-to-many connections
218 from the bilateral anterior bank of the intraparietal sulcus (IPS) in the control system to multiple
219 perisylvian areas in the language system including the orbital frontal cortex (Brodmann area 47), the dorsal
220 lateral part of the temporal pole, the whole length of superior temporal gyrus/sulcus (STG/STS, Brodmann
221 area 22), and the temporoparietal junction (TPJ).

222 We also validated the above results and evaluated the inter-stimuli consistency within the same
223 text type by repeating the analysis on each of the two narrative texts (Supplementary Fig. 7) and each of
224 the two argumentative texts (Supplementary Fig. 8). The results indicated a substantial level of
225 consistency between the different texts of the same type.

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226

227 *Commonalities and differences between narrative and argumentative networks*

228 Next, we disentangled the brain network shared by both narrative and argumentative thought from the
229 brain network specific to narrative or argumentative thought. The shared brain network for both narrative
230 and argumentative thought was defined as the functional couplings which met the following criteria
231 simultaneously: (1) Intact Narrative > Resting State ($P < 0.05$, FWE corrected); (2) Intact Narrative >
232 Scrambled Narrative ($P < 0.05$, FWE corrected); (3) Intact Argument > Resting State ($P < 0.05$, FWE
233 corrected); (4) Intact Argument > Scrambled Argument ($P < 0.05$, FWE corrected). We found 88 edges
234 that meet these criteria (Figure 5a). Most of the functional couplings were in the control system; the others
235 were mainly within the language system or between the language and control system (Figure 5b). Figure
236 5c illustrates the SES of the 88 edges of the contrast between each condition and the resting state. The
237 SES in the intact condition was greater than the one in the scrambled condition for all the four texts
238 regardless they were narrative or argumentative. Figure 5d illustrates the top 20 edges with the largest
239 averaged SES in the contrasts between intact-narrative condition and scrambled-narrative condition and
240 between intact-argumentative condition and scrambled-argumentative condition. Most edges linked areas
241 within the control system. They connected the anterior bank of the IPS to multiple lateral prefrontal
242 regions and the temporooccipital area at the temporal entrance.

243 The brain network more sensitive to narrative thought was defined as the functional coupling
244 which met the following criteria: (1) (Intact Narrative – Scrambled Narrative) > (Intact Argument –
245 Scrambled Argument) ($P < 0.05$, FWE correction); (2) Intact Narrative > Scrambled Narrative ($P < 0.05$,
246 FWE correction); (3) Intact Narrative > Resting State ($P < 0.05$, FWE correction). We found 2348 edges
247 that met these criteria (Figure 6a). These edges mainly related to the language, default mode, control, and
248 dorsal attention systems (Figure 6b). There were 96 edges in the DMN. Figure 6c illustrates the SES of

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249 these 96 edges of the contrast between each condition and the resting state. The SES in the intact-narrative
250 conditions was greater than the one in the scrambled-narrative conditions. However, the SES in the intact-
251 argumentative conditions was not greater than the one in the scrambled-argumentative conditions. Figure
252 6d illustrates the top 20 edges in the DMN with the largest SES in the "(Intact Narrative – Scrambled
253 Narrative) > (Intact Argument – Scrambled Argument)" contrast. These edges covered all the core regions
254 in the DMN, including the AG (Brodmann area 39), the dorsal lateral prefrontal cortex (8Ad area)
255 (Petrides, 1999), the anterior medial prefrontal cortex, the PCC, the ventral RSC, and the parahippocampal
256 area.

257 The brain network specific to argumentative thought was defined as the functional coupling which
258 met the following criteria: (1) (Intact Argument - Scrambled Argument) > (Intact Narrative – Scrambled
259 Narrative) ($P < 0.05$, FWE correction); (2) Intact Argument > Scrambled Argument ($P < 0.05$, FWE
260 correction); (3) Intact Argument > Resting State ($P < 0.05$, FWE correction). We found 64 edges that met
261 these criteria (Figure 7a). These edges mainly connected the control and the language systems (Figure 7b).
262 Figure 7c illustrates the SES of these 64 edges of the contrast between each condition and the resting state.
263 The SES in the intact-argumentative conditions was greater than the one in the scrambled-argumentative
264 conditions. However, the SES in the intact-narrative conditions was not greater than the one in the
265 scrambled-narrative conditions. Figure 7d illustrates the top 20 edges in the whole brain with the largest
266 SES in the "(Intact Argument – Scrambled Argument) > (Intact Narrative – Scrambled Narrative)" contrast.
267 Most of the edges connected the control system and the language systems, more specifically, the one-to-
268 many connections between the bilateral anterior bank of the IPS in the control system and multiple
269 perisylvian areas in the language system, including the orbital frontal cortex (Brodmann area 47), the
270 dorsal lateral part of the temporal pole, the whole length of STG/STS (Brodmann area 22), and the TPJ.
271

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272 **Discussion**

273 To investigate the neural basis of the narrative and argumentative thought, we compared the stimuli-
274 evoked regional neural activity and functional coupling when participants were listening to narrative and
275 argumentative texts to those when participants were listening to sentence-scrambled text. We found that
276 the sentence-scrambled texts, whether they were narrative or argumentative, induced regional neural
277 activity and functional coupling mainly in the brain systems relating to auditory, language, attention, and
278 control (first row in Fig. 2, Fig. 3, and Fig. 4). While the intact-narrative condition additionally involved
279 the DMN, the intact-argumentative condition did not extend to other brain systems (second row in Fig. 2,
280 Fig. 3, and Fig. 4). Directly contrasted to the scrambled-sentence conditions, both intact-narrative
281 condition and intact-argumentative condition enhanced functional coupling mainly in the frontoparietal
282 control system (Fig. 5). The intact-narrative condition in contrast to the scrambled-narrative condition also
283 induced widely distributed neural activity and functional coupling that implicated the core regions in the
284 DMN (third row in Fig. 2 and Fig. 3; Fig. 6). However, we failed to find any neural activity or functional
285 coupling in the DMN when contrasting the intact-argumentative condition to the scrambled-argumentative
286 condition (third row in Fig. 2 and Fig. 4; Fig. 6c). Instead, we found functional couplings between the
287 anterior bank of the IPS in the control system and multiple perisylvian areas in the language system (Fig.
288 7). These one-to-many connections were not significant in the contrast between the intact-narrative
289 condition and the scrambled-narrative condition (Fig. 7c). We also validated our results by implementing
290 the same analyses on each of the two selected texts of the same types. The pattern of the result was
291 consistent with the one pooling two texts together (Supplementary Fig. 4, Fig. 5, Fig. 7, Fig. 8).

292 The results revealed the commonalities and differences between neural bases underlying narrative
293 and argumentative thought, which seems to support both content-independent and content-dependent
294 hypotheses (Jacoby and Fedorenko, 2018). The content-independent hypothesis predicts that the narrative

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295 and the argumentative thoughts should share the same neural basis because the coherence of both modes
296 of thought relies on iteratively accumulating and updating information over a long timescale. Instead of
297 the DMN, we found the shared neural basis for both narrative and argumentative thought in the
298 frontoparietal control system. The frontoparietal control system, together with the attention-relevant
299 regions in cingulo-opercular areas, is usually referred to as the "multiple demand system" (Duncan, 2010),
300 which is named after its broad engagement in a wide variety of demanding tasks (Fedorenko et al., 2013).
301 However, unlike the sustained activity in the attention-relevant brain area, the frontoparietal control
302 system rapidly adjusts its activity profile (MacDonald et al., 2000) and global functional connectivity
303 pattern (Cole et al., 2013) to adapt to the task context. Our results suggest that both modes of thought may
304 rely on the frontoparietal control system as a general working memory system to iteratively accumulating
305 and updating information over long temporal windows.

306 The content-dependent hypothesis predicts that the neural bases underlying narrative and
307 argumentative thought are irreducible to each other as these two modes of thought differ in their core
308 cognitive components. As mentioned in the Introduction, the narrative thought relies on constructing and
309 updating a "situation model" about the state of affairs to understand the temporal causality of the events
310 and the intention of the characters (Zwaan and Radvansky, 1998). The argumentative thought, instead,
311 relies on "informal logic" processing, which includes identification and evaluation of the logic structures
312 that are embedded in the natural language discourse (Blair, 2015). The findings that the DMN was specific
313 for narrative thought, and the cooperation between the control and the language systems via the IPS was
314 specific for argumentative thought, may support this hypothesis. The functionality of situation model
315 construction coincides with the role of the DMN in scene construction (Hassabis and Maguire, 2007;
316 Spreng et al., 2009), self-projection (Buckner and Carroll, 2007; Spreng et al., 2009), prospection
317 (Schacter et al., 2007; Spreng et al., 2009), and theory of mind (Lin et al., 2018; Spreng et al., 2009). The

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318 IPS, together with other brain areas in the frontoparietal control systems, is considered as the neural basis
319 of fluid intelligence (Bishop et al., 2008). Thus, the coordination and cooperation between the
320 frontoparietal control system and the language system, which is mediated by the IPS, might be critical to
321 identify and evaluate the informal logic in the natural language discourse.

322 How to reconcile these two seemingly opposing hypotheses? A likely possibility is that the brain
323 function is simultaneously featured by two factors: the temporal receptive window (TRW) for information
324 processing and the information types. Take the frontoparietal control system and the default mode system
325 as an example. On the one hand, according to the hierarchical process memory framework (Hasson et al.,
326 2015), the TRW of a brain system is defined by its position in the cortical hierarchy. In terms of
327 connectivity pattern, the frontoparietal control system and the default mode system are at the medial and
328 top level of the cortical hierarchy, respectively (Margulies et al., 2016; Sepulcre et al., 2012). They thus
329 can process longer-timescale information (e.g., the “train of thought”) than the sensorimotor cortices at
330 the low level of the cortical hierarchy. On the other hand, the information type processed by a brain system
331 is defined by its wiring patterns to the other functionally specialized brain modules. The frontoparietal
332 control system, which has widely distributed connections to the other brain systems (Power et al., 2011),
333 can serve as the general machinery to integrate long-timescale information of all kinds. The default mode
334 system, which has strong connections mainly to the medial temporal lobe, is more likely an extension to
335 the episodic memory system (Buckner et al., 2008), which is sensitive to the narrative information. Given
336 the default mode system is at an even higher level of in the cortical hierarchy than the frontoparietal control
337 system (Margulies et al., 2016; Sepulcre et al., 2012), the default mode system could have the capacity to
338 process longer narrative information than the domain-general information which is processed by the
339 frontoparietal control system. If this is true, it might be the reason to explain why narratives tend to be
340 more accessible and memorable than the other genres (Graesser et al., 1980; Zabrocky and Moore, 1999).

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341 Our study also indicates the importance of treating the brain as a network and illustrates how
342 diverse mental activities arise from network reconfiguration. There are two general mechanisms at play
343 (Park and Friston, 2013). One mechanism is through local integration. The brain was organized into
344 functionally specialized modular structures, where the areas within the module are densely connected
345 (Thomas Yeo et al., 2011). Each module can be selectively recruited as a functional unit according to
346 task requirements by enhancing its within-module functional couplings. For example, compared to the
347 scrambled-text condition, the intact-narrative condition selectively involved the default mode system
348 (Figure 3) by inducing the functional couplings among all the core regions with the DMN (Supplementary
349 Fig 6a; Fig. 6). Another mechanism is through global integration, which means these recruited modules
350 are coordinated by inter-module connections, aiming to achieve more complicated tasks. Unlike the dense
351 intra-module connections, these inter-module connections are looser, and are usually mediated by a small
352 number of brain areas, termed "connectors." A prominent example is the neural basis of argumentative
353 thought. In the scrambled-argumentative condition, the language and control systems were already
354 involved but segregated (Figure 4). The intact-argumentative condition did not recruit additional brain
355 systems. Instead, it promoted the cooperation between the control and language systems, and this
356 cooperation is achieved strictly through the IPS, as the connector (Supplementary Fig 6b; Fig 7). The
357 global integration of the local integration strategy guarantees the efficiency and flexibility of brain
358 function, where the functionally specialized brain modules can be combined and coordinated to adapt
359 diverse task context.

360 To conclude, our study revealed the commonalities and differences in brain network
361 reconfiguration for the narrative and the argumentative thought. While both modes of thought rely on the
362 frontoparietal control system, the narrative thought specifically implicates the DMN, and the
363 argumentative thought specifically requires the cooperation between the control and the language systems,

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364 mediated by the IPS. These results provide insights into how the brain generates diverse mental activity
365 through global and local brain network integration.

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366 **Methods**

367 *Participants*

368 Twenty native Italian speakers who had no history of neurological or psychiatric disorders participated in
369 the fMRI experiment. They were paid as compensation for their time. Following the experimental protocol
370 approved by the local ethical committee at the University of Trento, all participants provided informed
371 written consent before the start of the experiment. Data from four participants were discarded: One
372 participant performed badly in the post-scanning questionnaire concerning the content of the narrative and
373 argumentative texts used in the experiment (his/her accuracy was outside 1.5 times the interquartile range
374 below the lower quartile across participants (Supplementary Fig. 9)). Three participants were excluded
375 due to excessive head motion; In two cases, the mean frame displacement index (Power et al., 2014) of
376 functional images was outside 1.5 times the interquartile range above the upper quartile across participants
377 (Supplementary Fig. 8), and one's structure image was so blurry that failed to be segmented. The remaining
378 16 participants (9 females; age range: 21 to 31, mean age: 24) were all educated (university students or
379 above) and right-handed (laterality quotient range: +40 to +100; mean: +90) (Oldfield, 1971). This sample
380 size was in line with the studies employing ISC (Lerner et al., 2011) and ISFC (Simony et al., 2016)
381 methods (11 and 18 participants, respectively).

382

383 *Stimuli*

384 This study employed a two (narrative vs. argumentative text) by two (intact vs. sentence-scrambled
385 version) design. We generated two stimuli for each of these four conditions following the procedure below.
386 First, we searched for narrative and argumentative texts that met the following criteria: (1) Written in
387 modern Italian. (2) Easy to understand. All the texts come from best-sellers for non-expert readers. (3)
388 Typical. The narrative text includes a story with the typical elements of the story grammar (Rumelhart,

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389 1975): settings, characters, the initialing event, conflicts/goals, actions, and resolutions. The
390 argumentative text includes the interlinked premiss-illative-conclusion argumentative structure
391 (Hitchcock, 2007), with an overall conclusion at the beginning or end of the text. (4) Self-content. The
392 narrative text should be a complete and independent story; the argumentative text should support a
393 conclusion based on the points independent from the previous chapters. (5) Text length between 1000 to
394 1300 words. We posited that a comfortable speed range for an Italian audiobook is between 165 and 170
395 words per minute, which is slightly slower than the average speed of the *Radiotelevisione Italiana* (192.46
396 words per minute) (Rodero, 2012). This criterion ensures the duration of the selected texts is relatively the
397 same, which is about 6 to 8 minutes, comparable to the 7-minute one used in the studies employing ISC
398 (Lerner et al., 2011) and ISFC (Simony et al., 2016) methods. In the end, we preselected seven such texts
399 - three narrative and four argumentative.

400 Then, we recruited 35 native Italian speakers (who did not participate in the fMRI experiment; 11
401 females; age range: 23 to 67, mean age: 32) to rate nine features of these seven texts on a five-point Likert
402 scale. Each participant rated four texts; hence each text was rated by 20 participants. The nine features
403 were difficulty, narrativeness, concreteness, scene construction, Self-projection, theory of mind,
404 argumentativeness, abstractness, and logical thinking (see the questionnaire in the supplementary
405 material). For each text, we also designed two questions on its content before the rating questions to
406 indicate whether the participants had read and comprehended the texts (accuracy rate: 5/8 to 8/8, mean
407 accuracy: 7/8). As all participants provided at least one correct response for each text, we did not exclude
408 any data points. We discarded the texts with high ratings on difficulty (mean rating > 3) and chose two
409 narrative texts and two argumentative texts as our stimuli by maximizing the difference between the
410 ratings of these two text types: the narrative texts had higher ratings on narrative, concreteness, scene
411 construction, and theory of mind; the argumentative texts had higher ratings on argumentativeness,

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412 abstractness, and logical thinking (Fig. 1). The two selected narrative texts came from: *The wasp*
413 *treatment* in the book *Marcovaldo* by Italo Calvino, who tells a story in which the protagonist asks his
414 children to catch wasps and uses them to cure his neighbors' rheumatism (Narrative 1); *Kulala's four*
415 *veils* in the book *The bar beneath the sea* by Stefano Benni, who tells a typical fairy tale (Narrative 2).
416 The two selected argumentative texts were truncated from: *Counting happiness* in the book *Sapiens: a*
417 *brief history of humankind* by Yuval Noah Harari, who discusses which are the most crucial factors
418 leading to happiness (Argument 1); *An instinct to acquire an art* in the book *The language instinct: how*
419 *the mind creates language* by Steven Pinker, who argues the nature of language is an instinct faculty, not
420 a cultural product (Argument 2).

421 Next, we divided the selected four texts into segments. Each segment included one or more
422 complete sentences, which ended with a period, question mark, exclamation mark, colon, or semi-colon,
423 i.e., we did not divide the sentences into clauses. We matched the extent of fragmentation (i.e., the number
424 of segments and the length of segments) between these two text types (Table 1). In the argumentative text,
425 each segment consisted of only one complete sentence. As the sentences in narrative texts (mean \pm SD:
426 15 ± 8 words) were on average shorter than those in the argumentative texts (mean \pm SD: 23 ± 11 words),
427 in the narrative text, each segment might consist of more than one sentence.

428 After that, the same professional voice actor recorded all the four texts with relatively the same
429 volume, speed, voice, and tone. We cut the audio clips according to the segments that we had divided.
430 The duration of each segment was comparable to the duration of the sentence-scrambled version ($7.7 \pm$
431 3.5 s) used in the studies employing the ISC/ISFC method (Lerner et al., 2011; Simony et al., 2016) and
432 matched between the two text types (Table 1). We sorted these segments according to a random order and
433 concatenated them together to generate a sentence-scrambled version for each text.

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434 Finally, we added the same 10s neutral music before both intact and scrambled versions of the
435 stimuli following previous studies employing ISC (Lerner et al., 2011). The volume of the music tapered
436 to zero before the audio texts started. As an abrupt beginning of the sound may elicit a global arousal
437 response in the brain, a piece of opening music here helped to capture the participants' attention and to
438 protect the start of the texts from being affected by such an arousal shift. We excluded the neural signal
439 in this music period from the analysis (see fMRI preprocessing).

440

441 *Procedures*

442 Participants were told that they would be listening to the intact and the scrambled version of four texts
443 during fMRI scanning. They were instructed to follow and comprehend the texts attentively and were
444 informed that they would be asked to fill in a post-scanning questionnaire on the content of what they
445 have heard. To avoid visual intrusion, we blindfolded the participants and turned off the light in the
446 scanning room.

447 We presented the audio stimuli using Psychtoolbox-3 (<http://psychtoolbox.org/>). The sound was
448 delivered through an in-ear headphone. Before the formal scanning, participants were instructed to check
449 the sound in the headphone under the scanning noise. We adjusted the volume for each participant to
450 ensure they could hear the pronunciation clearly but meanwhile did not feel too loud.

451 The functional scanning included nine runs, one for the eight-minute resting state, four for the
452 sentence-scrambled version of the texts, and four for intact version of the texts. Each task runs presented
453 one single text. To make sure the participants were unable to replay the stimuli in the resting state, we put
454 the resting-state run before all the task runs. To make sure the participants were unable to construct
455 coherent thought in the sentence-scrambled runs based on the intact texts they had already heard, we put
456 the four sentence-scrambled runs before the runs for the intact texts. The order of the four sentence-

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457 scrambled runs was randomized across participants. For the same participant, the intact-text runs followed
458 the same order of their corresponding sentence-scrambled runs.

459 After the scanning, all participants completed a questionnaire on the content of the texts that they
460 had heard during the scanning. We designed two questions for each of the four texts. In the same
461 questionnaire, we also asked the participants to do the ratings that were used in the stimulus-selection
462 stage. They were also asked to rate to which degree they could understand each text on a five-point Likert
463 scale.

464

465 *MRI acquisition*

466 MRI data were acquired using a MAGNETOM Prisma 3T MR scanner (Siemens) with a 64-channel head–
467 neck coil at the Centre for Mind/Brain Sciences, University of Trento. Functional images were acquired
468 using the simultaneous multislices echoplanar imaging sequence, the scanning plane was parallel to the
469 bicommissural plane, the phase encoding direction was from anterior to posterior, repetition time (TR) =
470 1000 ms, echo time (TE) = 28 ms, flip angle (FA) = 59°, field of view (FOV) = 200 mm × 200 mm, matrix
471 size = 100 × 100, 65 axial slices, slices thickness (ST) = 2 mm, gap = 0.2 mm, voxel size = 2 × 2 × (2 +
472 0.2) mm, multiband factor = 5. Three-dimensional T1-weighted images were acquired using the
473 magnetization-prepared rapid gradient-echo sequence, sagittal plane, TR = 2140 ms, TE = 2.9 ms,
474 inversion time = 950 ms, FA = 12°, FOV = 288 mm × 288 mm, matrix size = 288 × 288, 208 continuous
475 sagittal slices, ST = 1 mm, voxel size = 1 × 1 × 1 mm.

476

477 *MRI preprocessing*

478 We performed fMRI preprocessing using *fMRIPrep 1.5.0* (Esteban et al., 2019), which is based on *Nipype*
479 *1.2.2* (Gorgolewski et al., 2011). Please see the section *MRI preprocessing using fMRIPrep 1.5.0* in the

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480 supplementary material, where a boilerplate text directly generated by the *fMRIPrep* describes the
481 preprocessing steps used in the current study. The first 10s, which was the music period in the task runs,
482 was labeled as the dummy scans; thus, they were excluded from the analysis. As surface-based analysis
483 can significantly improve the spatial localization compared to the traditional volume-based analysis
484 (Coalson et al., 2018), we used the images in the *fsaverage5* surface space generated by *fMRIPrep*.

485 We excluded the non-neuronal signal sources through two steps (Pruim et al., 2015). First, we
486 removed the motion-relevant noise using an Independent Component Analysis based strategy for
487 Automatic Removal of Motion Artifacts (ICA-AROMA) (Pruim et al., 2015). The identified motion-
488 relevant components and the signal components were fit into the same general linear model (GLM) to
489 predict the BOLD signal in each vertex on the brain surface. We estimated the beta coefficients using
490 the *fitglm* function in Matlab 2019a and subtracted the motion-relevant terms from the BOLD signal. In
491 this way, the motion-relevant components were removed "non-aggressively" by preserving the shared
492 variance between the motion-relevant components and the signal components. Then, we further removed
493 the other nuisance variables like the mean timecourses in a conservative mask of the white matter (WM)
494 and the cerebrospinal fluid (CSF), which were extracted by *fMRIPrep*. As a recent study demonstrate that
495 the low-frequency component (0 - 0.01 Hz) makes a significant contribution to the ISC (Kauppi et al.,
496 2010), we did not implement high-pass temporal filtering. Instead, we fitted the quadratic polynomial time
497 trend together with the WM and the CSF timecourse into the same GLM to predict the timecourse resulting
498 from the first step, aiming to remove the signal drift. In the same way, we estimated the beta coefficients
499 and subtracted the WM, the CSF, and the quadratic polynomial terms from the signal.

500 We implemented the surface smoothing on the resulting images with a full width at half maximum
501 of 8 mm using the *mri_surf2surf* command in FreeSurfer (<http://surfer.nmr.mgh.harvard.edu/>). The
502 timecourse in each vertex was then z-normalized across time points to enter the following analyses.

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503

504 *Brain network identification*

505 We identified the brain systems based on a pre-labeled atlas (Thomas Yeo et al., 2011). The brain systems
506 in this atlas are identified by applying the clustering analysis on the pattern of 1000 young healthy
507 participant's resting-state functional connectivity (RSFC). The atlas has two versions: one coarse version
508 with seven networks and one fine-resolution version with 17 networks. We chose the fine-resolution
509 version as the start for two reasons. First, the fine-resolution version separates the dorsal somatosensory
510 and motor cortex corresponding to the body parts mainly below the neck from the ventral networks
511 consisting of the auditory cortex and the somatosensory and motor cortex corresponding to the body parts
512 mainly up the neck. This division helps us to differentiate the auditory cortex from most of the
513 somatosensory and motor areas. Second, the fine-resolution version also separates the language network
514 (Fedorenko et al., 2011) and the DMN (Buckner et al., 2008). Previous studies suggest these two networks
515 are dissociated in respective of both activation profile and functional connectivity pattern (Mineroff et al.,
516 2018; Xu et al., 2017, 2016). We merged the Network 14 and Network 17 as the language network, which
517 mainly includes the perisylvian cortex and the 55b area (Fedorenko et al., 2011; Glasser et al., 2016). We
518 merged Network 15 and Network 16 as the DMN, as these two networks largely correspond to the two
519 identified sub-networks of the DMN (Braga and Buckner, 2017). We preserved the labels used in the
520 coarse version of the atlas for the other brain networks. These networks are visual; ventral
521 attention (Corbetta and Shulman, 2002; Fox et al., 2006), which may implicate multiple networks variably
522 referred to as the salience (Seeley et al., 2007) and the cingulo-opercular (Dosenbach et al., 2008); dorsal
523 attention (Corbetta and Shulman, 2002; Fox et al., 2006); frontoparietal control (Dosenbach et al., 2008;
524 Vincent et al., 2008); and limbic. In the end, we obtained an atlas, including nine brain systems
525 (Supplementary Fig. 2a).

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526

527 *ISC analysis*

528 The ISC was defined as the Pearson's correlation between the timecourse in the same area of different
529 participants. We calculated the ISC for each vertex each run using a leave-one-participant-out approach.
530 For each participant, we first averaged the timecourses of all the other participants and then correlated this
531 mean timecourse with this participant's timecourse. The resulting Pearson's correlation coefficients (one
532 per participant) were Fisher-z transformed using the inverse hyperbolic tangent function before they were
533 averaged as one ISC index. In this way, we obtained one ISC surface map for each of the nine runs.

534 We contrasted the ISC surface maps between different conditions to obtain a veritable ISC contrast
535 value for each vertex for each contrast. The major contrasts were: (1) Scrambled Narrative Contrast:
536 (Scrambled Narrative 1 + Scrambled Narrative 2) - 2 × Rest; (2) Intact Narrative Contrast: (Intact
537 Narrative 1 + Intact Narrative 2) - 2 × Rest; (3) Narrative Contrast: (Intact Narrative 1 - Scrambled
538 Narrative 1) + (Intact Narrative 2 - Scrambled Narrative 2); (4) Scrambled Argumentative Contrast:
539 (Scrambled Argument 1 + Scrambled Argument 2) - 2 × Rest; (5) Intact Argumentative Contrast: (Intact
540 Argument 1 + Intact Argument 2) - 2 × Rest; (6) Argumentative Contrast: (Intact Argument 1 - Scrambled
541 Argument 1) + (Intact Argument 2 - Scrambled Argument 2); (7) Narrative Specific Contrast: [(Intact
542 Narrative 1 - Scrambled Narrative 1) + (Intact Narrative 2 - Scrambled Narrative 2)] - [(Intact Argument
543 1 - Scrambled Argument 1) + (Intact Argument 2 - Scrambled Argument 2)]; (8) Argumentative Specific
544 Contrast: [(Intact Argument 1 - Scrambled Argument 1) + (Intact Argument 2 - Scrambled Argument 2)]
545 - [(Intact Narrative 1 - Scrambled Narrative 1) + (Intact Narrative 2 - Scrambled Narrative 2)]. We also
546 implemented similar contrasts using individual narrative texts and individual argumentative texts to
547 validate our results and to evaluate the inter-stimulus consistency. The following ISFC analysis used the
548 same contrasts here.

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549 The statistical likelihood of each contrast was assessed using the subject-wise bootstrapping
550 method, where the exchangeability and independence assumptions are satisfied (G. Chen et al., 2016). In
551 each bootstrapping iteration, the same number of participants were randomly resampled with replacement.
552 The ISC was calculated between the timecourse of one participant and the mean timecourse of the other
553 participants. Here, "the other participants" were those excluding him/herself and the repeated ones of
554 him/herself due to resampling with replacement (Nili et al., 2014). The obtained Pearson's correlation
555 coefficients (one per participant) were Fisher-Z transformed and averaged. We then contrasted these maps
556 between conditions in the same way as before. This procedure was repeated 5000 times to form a sampling
557 distribution for each contrast. The null distribution of each contrast was generated by subtracting the
558 veritable contrast value from the sampling distribution, and the veritable contrast value was then ranked
559 against the null distribution (Hall and Wilson, 1991). As the null distribution of each contrast of each
560 vertex was symmetrical (the skewness is within ± 1), to provide a quantitative measure of the magnitude
561 across contrasts and vertexes, we calculated the standardized effect size (SES) as $(x - \mu)/\sigma$, where x is
562 the veritable contrast value, μ is the mean of the null distribution, and σ is the standard deviation of the
563 null distribution (Botta-Dukát, 2018). To obtain a high-resolution P-value given the limited number of
564 resamples, we estimated the right-tail p-value of each contrast by approximating a generalized Pareto
565 distribution to the tail of the null distribution (Knijnenburg et al., 2009). We corrected for multiple
566 comparisons across the entire brain surface using the false-discovery rate (FDR) correction algorithm
567 without the need for the assumption of independence across vertices (Benjamini and Yekutieli, 2001) (P
568 < 0.05).

569

570 *ISFC analysis*

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571 The ISFC was defined as the Pearson's correlation between the timecourse in two discrete brain areas from
572 different participants. We defined the brain areas based on the cortical parcellation derived by integrating
573 the local gradient approach, which detects the abrupt transitions in RSFC patterns, and the global similarity
574 approach, which clusters similar global ISFC patterns despite the spatial proximity (Schaefer et al., 2018).
575 Thus, the obtained parcels are locally homogenous and globally match to the brain networks shown above
576 (Thomas Yeo et al., 2011). We chose the template matched to the 17 brain networks and then relabeled
577 them as nine networks of interest. Considering the trade-off between the spatial resolution and the
578 computational load, we chose the cortical parcellation consisting of 200 parcels. The averaged the
579 timecourses across all vertexes in each parcel was used as the timecourse of that parcel.

580 We calculated the pair-wised, inter-regional ISFC among the 200 parcels for each run using a
581 leave-one-participant-out approach following the previous study (Simony et al., 2016). A 200 by 200 ISFC
582 matrix C was obtained for each of the nine runs, where each element in the matrix (e.g., C_{ij}) represents
583 the ISFC strength between each pair of regions (e.g., the i th and the j th brain areas). To calculate the value
584 of C_{ij} , we first averaged the timecourses of all the other participants in the j th area and then correlated this
585 mean timecourse with this participant's timecourse in the i th area. The resulting Pearson's correlation
586 coefficients (one per participant) were then Fisher-z transformed, averaged, and assigned to C_{ij} . Note that
587 the C_{ji} is not necessarily equal to C_{ij} . To make the ISFC measure unidirectional, we symmetrized the ISFC
588 matrix as $(C + C^T) / 2$, where C^T is the transpose of the matrix C . We contrasted the ISFC matrix
589 between different conditions using the same contrasts in the ISC analysis to obtain a veritable contrast
590 value for each pair of brain areas for each contrast.

591 The statistical likelihood of each contrast was assessed using a similar subject-wise bootstrapping
592 method shown in the ISC analysis. In each iteration of the bootstrapping, the same number of participants
593 were randomly resampled with replacement. A 200 by 200 ISFC matrix C was calculated using the data

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594 from this sample, where each element in the matrix (e.g., C_{ij}) represents the ISFC strength between each
595 pair of brain areas (e.g., the i th and the j th brain areas). C_{ij} was calculated as Pearson's correlation
596 coefficient between the timecourse in the i th brain area of one participant and the mean timecourse in the
597 j th brain area of the other participants. Here, "the other participants" were those excluding him/herself and
598 the repeated ones of him/herself due to resampling with replacement (Nili et al., 2014). The obtained
599 Pearson's correlation coefficients (one per participant) were Fisher-Z transformed, averaged, and assigned
600 to C_{ij} . We symmetrized the ISFC Matrix C in the same way as before. We contrasted these final ISFC
601 matrixes between conditions, ending this iteration. This procedure was repeated 5000 times to form a
602 sampling distribution of ISFC contrast value for each pair of brain areas for each contrast. The null
603 distribution of each contrast was generated by subtracting the veritable contrast value from the sampling
604 distribution (Hall and Wilson, 1991). As the null distribution of each contrast of each pair of brain regions
605 was symmetrical (the skewness is within ± 1), to provide a quantitative measure of the magnitude across
606 contrasts and pairs of brain regions, we calculated the SES as $(x - \mu)/\sigma$, where x is the veritable contrast
607 value, μ is the mean of the null distribution, and σ is the standard deviation of the null distribution (Botta-
608 Dukát, 2018). We controlled the family-wise error (FWE) rate by defining the threshold at the 5%
609 percentile of the null distribution of the maximum across all pairs of brain areas and thresholded the SES
610 matrix by assigning the insignificant brain pairs to zero.

611 The resulting thresholded SES adjacency matrix in each contrast was modeled as a weighted graph
612 comprising nodes and edges (Fornito et al., 2016); the nodes represent brain areas, and the edges represent
613 the SES of that contrast for the ISFC between each pair of the brain areas. We used the node degree to
614 measure the importance of one brain area in each contrast. The degree of node i was calculated as $\sum_{j=1}^{200} C_{ij}$,
615 where C was the thresholded SES adjacency matrix.

616

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617 *Visualization*

618 The ISC results were illustrated using the Connectome Workbench 1.3.2
619 (<https://www.humanconnectome.org/software/connectome-workbench>). For the visualization purpose,
620 we mapped the significant clusters from the fsaverage5 surface to the fsLR surface using the
621 ADAP_BARY_AREA method. We excluded the clusters that are smaller than 200 mm². The significant
622 clusters were illustrated on an inflate surface against the group-averaged sulcus image of 1096 young
623 adults from the dataset under the Human Connectome Project (<https://balsa.wustl.edu/reference/pkXDZ>).
624 For the ISFC results, the network layout was generated using the force-directed graph drawing algorithm
625 (Fruchterman and Reingold, 1991) with NodeXL (<https://www.smrfoundation.org/nodexl/>)(Smith et al.,
626 2010). The brain networks were visualized with the BrainNet Viewer (<https://www.nitrc.org/projects/bnv/>)
627 (Xia et al., 2013). To localize each node, we used the centroid of the Montreal Neurological Institute
628 coordinates of each brain parcel in the volume version of the same brain parcellation atlas.

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794

795 **Author contributions**

796 X.Y. and R.B. conceived the experiment. X.Y. and L.V. analyzed the data. X.Y. wrote the paper with

797 input from L.V., O.C., D.C., and R.B. All authors discussed the results and contributed to the paper.

798

799 **Competing interests**

800 The authors declare no competing interests.

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Table 1. Information on Selected Texts

		Narrative Texts		Argumentative Texts	
		Narrative 1	Narrative 2	Argument 1	Argument 2
Quoted from Book		Marcovaldo	The bar beneath the sea	Sapiens	The language instinct
Texts	N. Words	1335	1158	1283	1183
	Duration (s)	458	402	464	431
Segments ^a	N. Segments	58	50	54	52
	N. Words ^b	23 ± 12	23 ± 10	24 ± 12	23 ± 11
	Duration (s) ^b	7.9 ± 4.1	8.0 ± 3.4	8.6 ± 4.3	8.3 ± 4.1

^a Each segment included one or more complete sentences, which ended with a period, question mark, exclamation mark, colon, or semi-colon. In the argumentative texts, each segment included one sentence. As the sentences in the narrative texts (mean ± SD: 15 ± 8 words) were on average longer than those in the argumentative texts (mean ± SD: 23 ± 11 words), in the narrative texts, each segment might include one more sentence.

^b mean ± standard deviation

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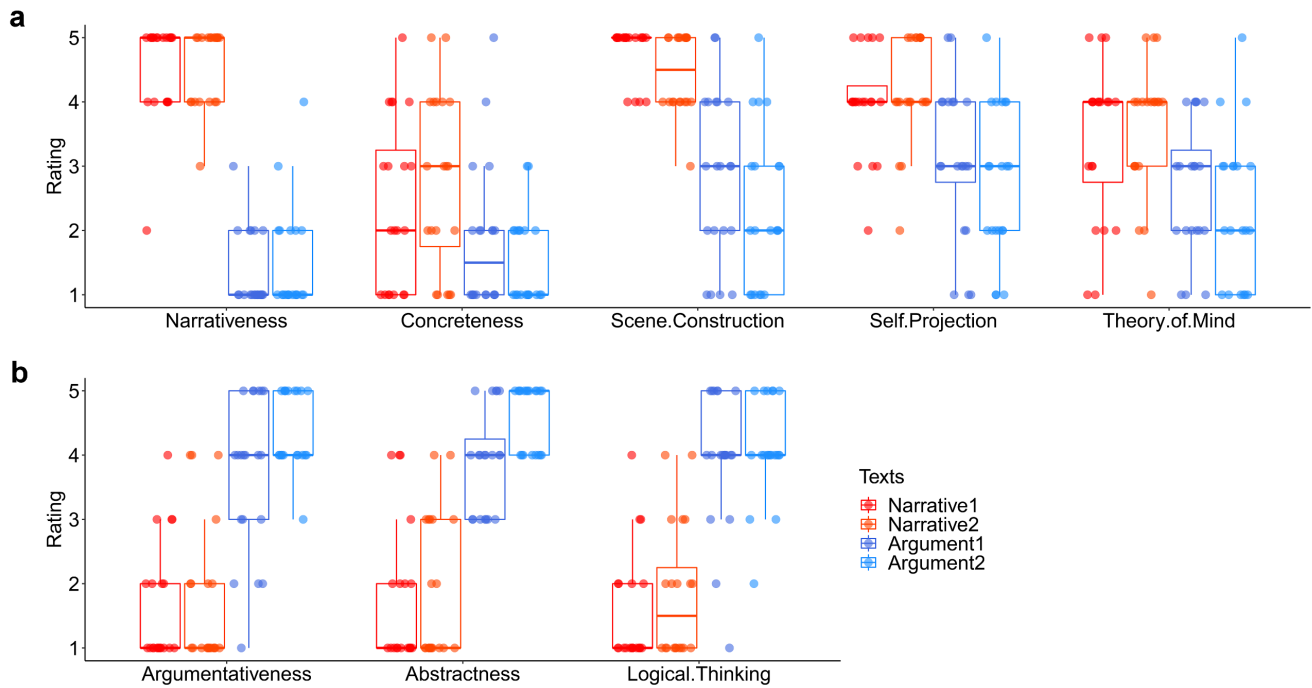


Figure 1. Behavior rating on the four selected texts. The boxplots show the rating scores on the four chosen texts from an independent group of participants who did not participate in the fMRI experiment. Each text was rated by 20 participants. Figure 1a shows the rating scores on the narrative texts were significantly higher than the argumentative texts on the items of narrativeness, concreteness, scene construction, self-projection, and theory of mind. Figure 1b shows the rating scores on argumentative texts were significantly higher than the narrative texts on the items of argumentativeness, abstractness, and logical thinking. The participants who participated in the fMRI experiment did the same rating. The results validated the rating pattern here, as shown in Supplementary Figure 1.

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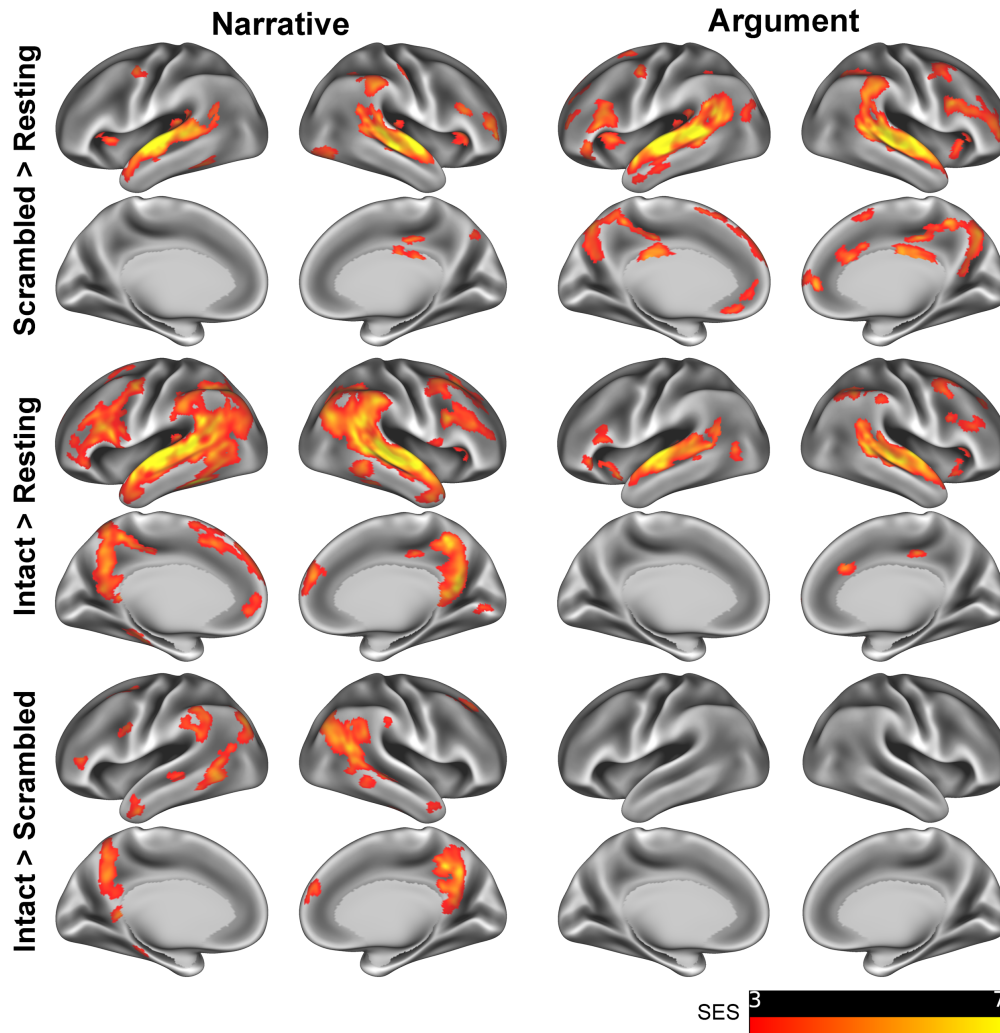


Figure 2. ISC revealed the narrative-induced activity in DMN but not the argumentative one. ISC contrast maps illustrate the significant areas of each contrast in the narrative (left) and the argumentative (right) conditions ($P < 0.05$, FDR corrected, Area $> 200 \text{ mm}^2$). The first row shows the results in the contrast between the scrambled-sentence conditions and the resting state. For both narrative and argumentative conditions, mainly the auditory system, the language system, and the domain-general system are involved. The second row shows the results of the contrast between the intact-text conditions and the resting state. While the neural distribution in the intact-narrative condition extended to other brain systems like the DMN, the neural distribution in the intact-argumentative condition was confined to the areas in the scrambled-argumentative condition. The third row shows the results of the direct contrast between the intact-text condition and the scrambled-sentence condition. Areas in the default mode, language, control, and attention systems were more engaged in the intact narratives. We did not find any significant areas in this contrast for the argumentative condition. SES: standard effect size.

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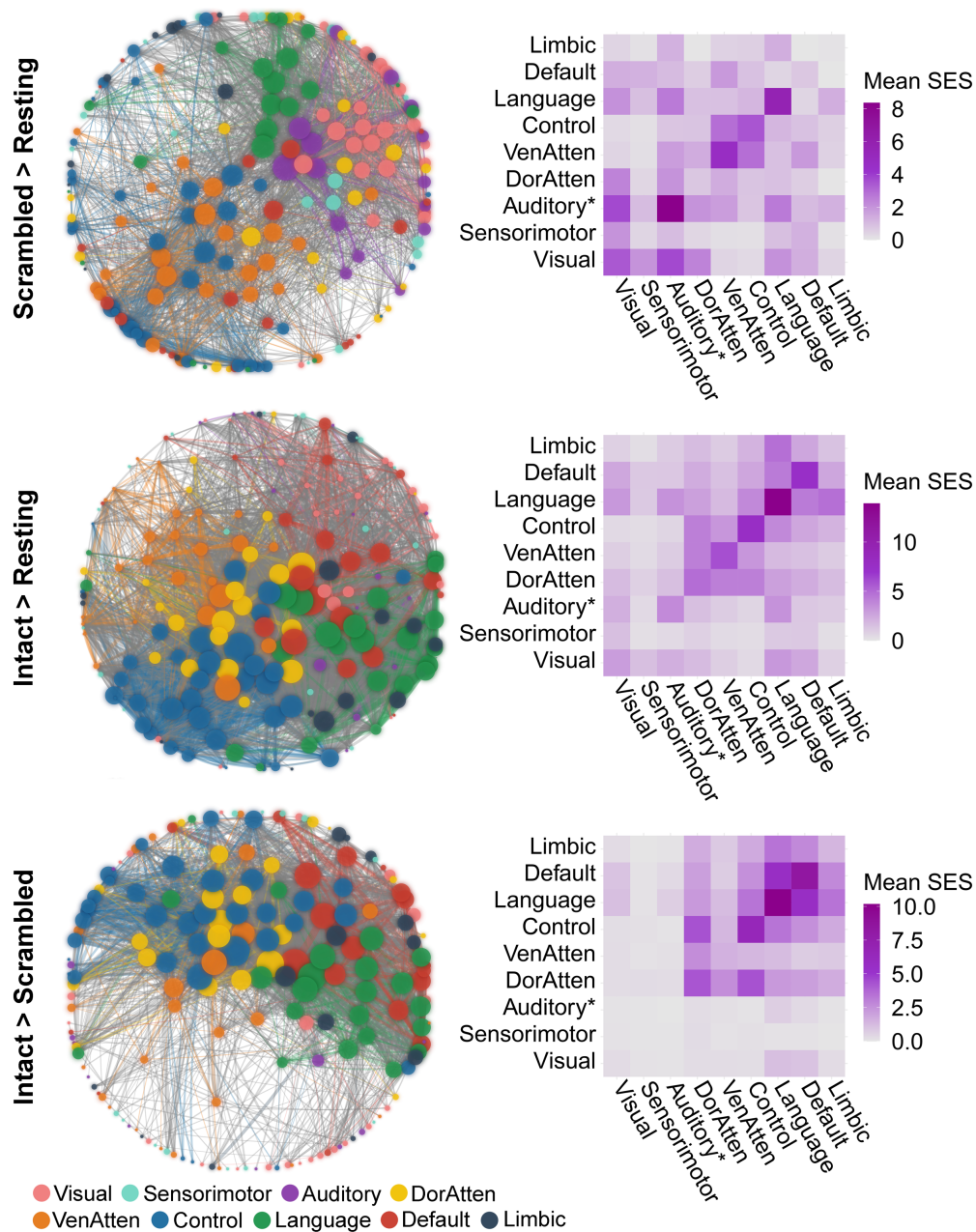


Figure 3. Network reconfiguration for narrative comprehension. The figure illustrates the significant ISFC difference ($P < 0.05$, FWE corrected) between the scrambled-narrative condition and the resting state (the first row), the intact-narrative condition and the resting state (the second row), and the intact- and scrambled-narrative condition (the third row). The left column shows the network layout, where the nodes represent the brain areas, and the edges represent the significant interregional ISFC differences between conditions. This layout was generated using the force-directed graph drawing algorithm: strongly connected nodes cluster together, and weakly connected nodes are pushed apart. The size of the nodes denotes the node degree of each brain area. The color of the nodes denotes to which brain system they belong. The width of the edges denotes the standardized effect size (SES). Intra-system edges are in the color of that network; inter-system edges are in gray. The right column shows the distribution of all the significant edges of each contrast within or between brain systems. Each cell indicates the mean SES of each contrast, i.e., the ratio between the sum of the SES and the number of the edges in the fully connected situation. "Auditory*" denotes the network including not only the auditory cortex but also the ventral somatosensory and motor brain areas corresponding to the body parts above the neck. VenAtten = Ventral Attention; DorAtten = Dorsal Attention.

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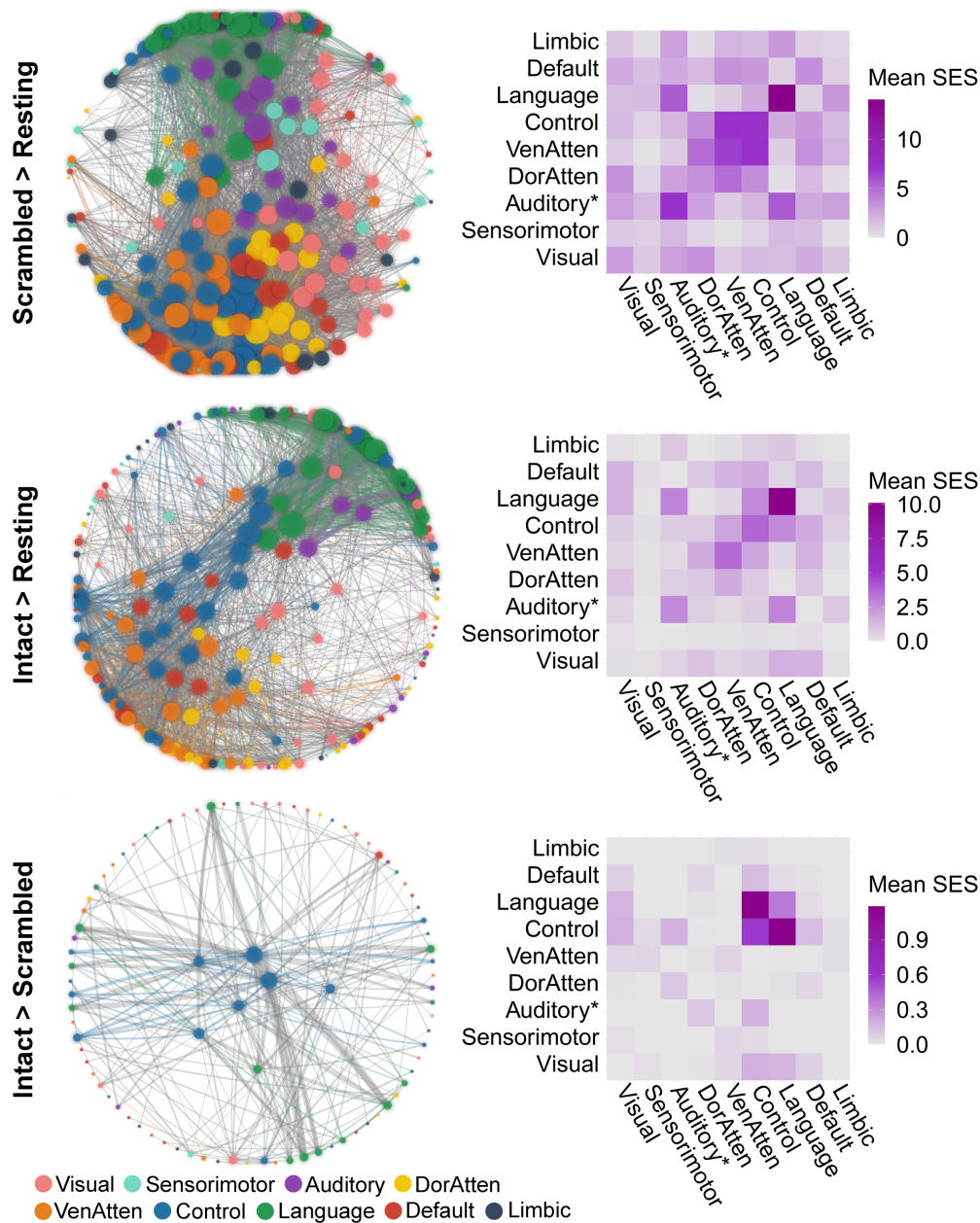


Figure 4. Network reconfiguration for argumentative comprehension. The figure illustrates the significant ISFC difference ($P < 0.05$, FWE corrected) between the scrambled-argumentative condition and the resting state (the first row), the intact-argumentative condition and the resting state (the second row), and the intact- and scrambled-argumentative conditions (the third row). The left column shows the network layout, where the nodes represent the brain areas, and the edges represent the significant inter-regional ISFC differences between conditions. This layout was generated using the force-directed graph drawing algorithm: strongly connected nodes cluster together, and weakly connected nodes are pushed apart. The size of the nodes denotes the node degree of each brain area. The color of the nodes denotes to which brain system they belong. The width of the edges denotes the standardized effect size (SES). Intra-system edges are in the color of that network; inter-system edges are in gray. The right column shows the distribution of all the significant edges of each contrast within or between brain systems. Each cell indicates the mean SES of each contrast, i.e., the ratio between the sum of the SES and the number of the edges in the fully connected situation. "Auditory*" denotes the network including not only the auditory cortex but also the ventral somatosensory and motor brain areas corresponding to the body parts above the neck. VenAtten = Ventral Attention; DorAtten = Dorsal Attention.

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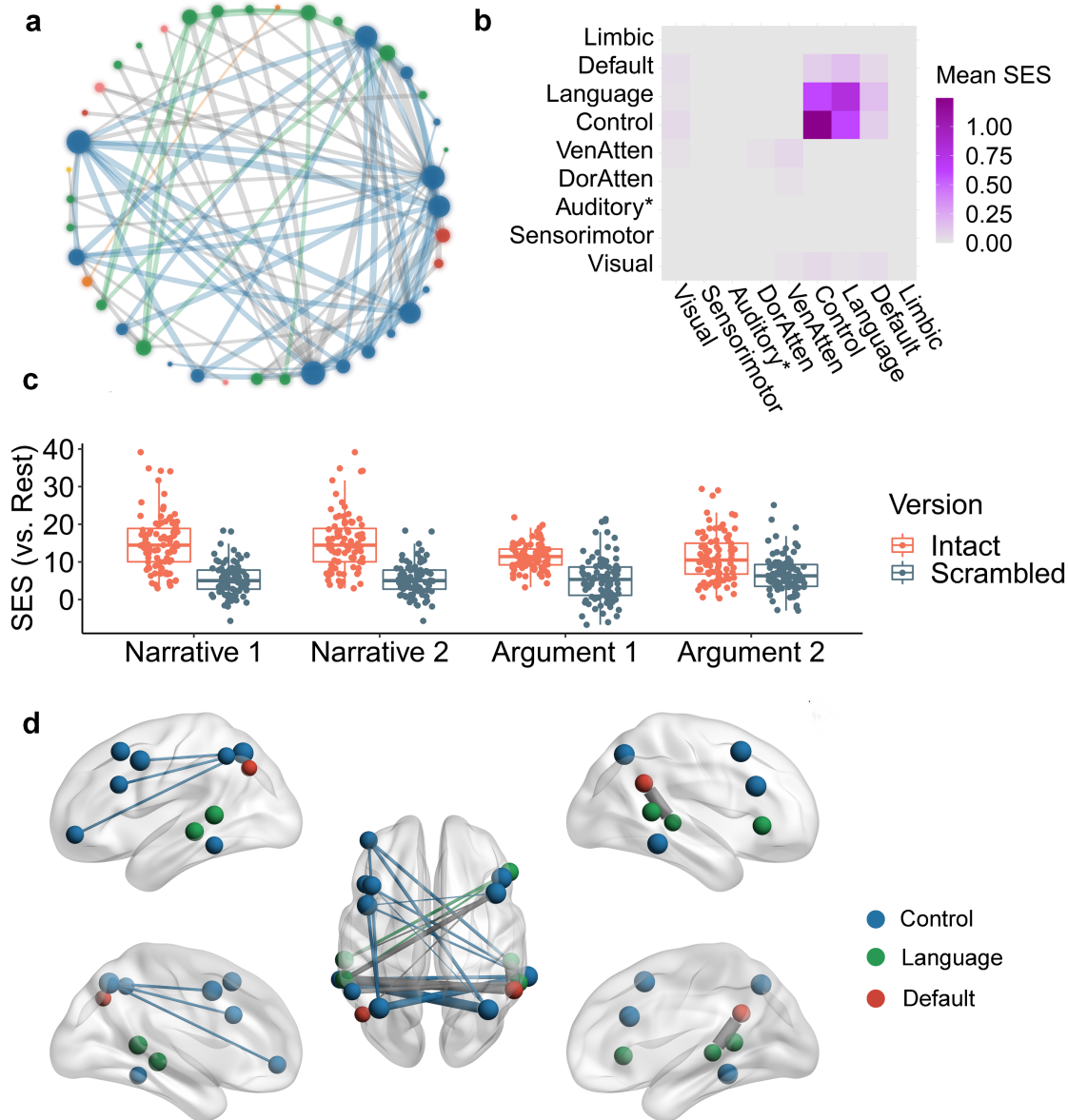


Figure 5. The shared network for both narrative and argumentative thought. Figure a illustrates the network layout of the shared brain network for narrative and argumentative thought using the force-directed graph drawing algorithm. It consisted of 88 edges. The color legend is the same as the one in Figure 3 and Figure 4. Figure b illustrates the distribution of 88 edges within and between brain systems, where each cell indicates the mean standardized effect size (SES) in the contrast between the narrative and the scrambled conditions, i.e., the ratio between the sum of the SES and the number of the edges in the fully connected situation. Figure c illustrates the SES of the 88 edges of all the conditions in contrast to the resting state. Figure d illustrates the top 20 edges with the largest SES in the contrast between narrative and scrambled conditions. In Figure a and Figure d, the size of the nodes denotes the node degree of each brain area in the whole graph comprising 88 edges. The color of the nodes denotes to which brain system they belong. The width of the edges denotes the SES. Intra-system edges are in the color of that network; inter-system edges are in gray.

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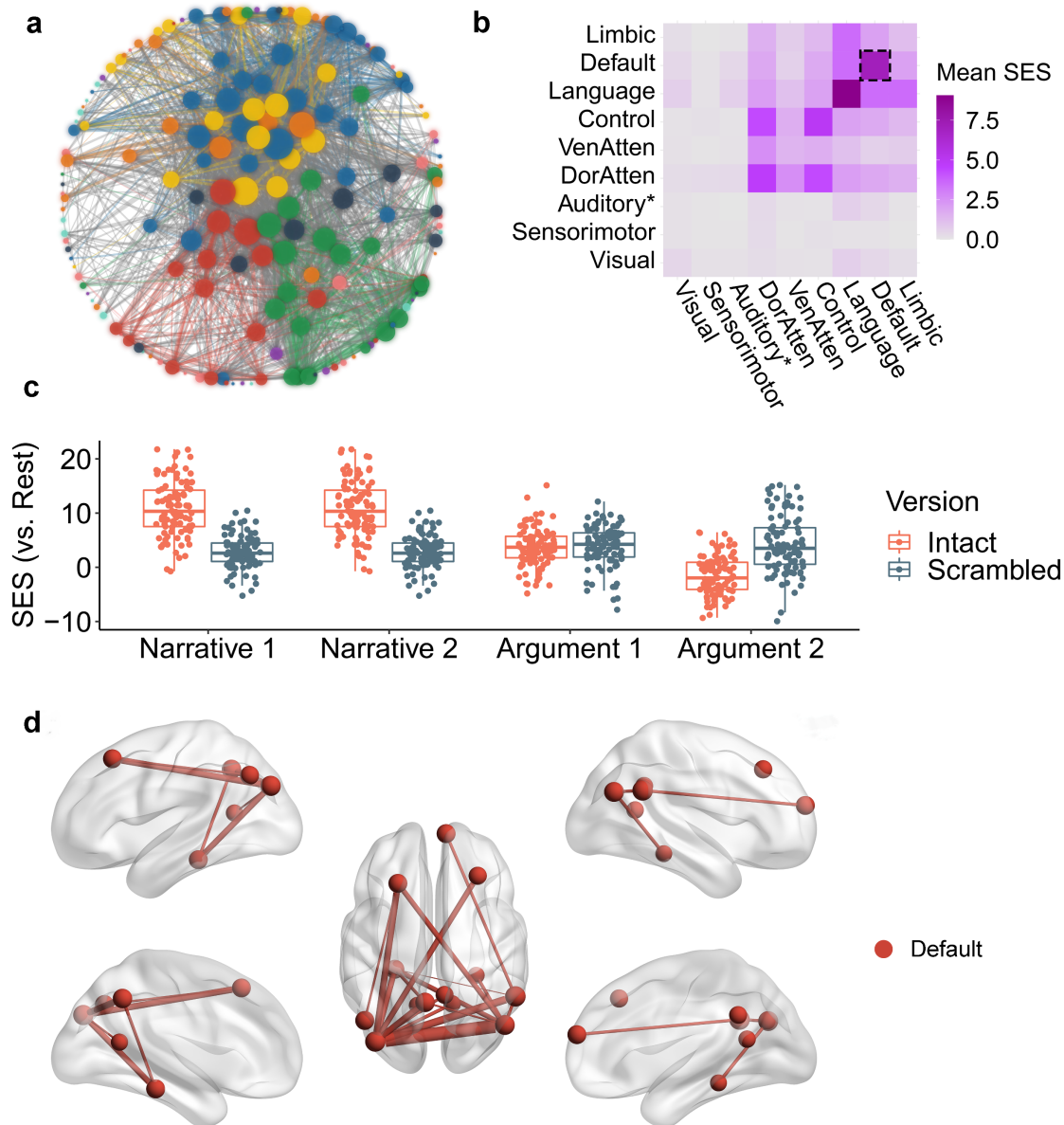


Figure 6. The brain network specific to narrative thought. Figure a illustrates the network layout of the brain network more sensitive to narrative thought using the force-directed graph drawing algorithm. It consisted of 2348 edges. The color legend is the same as the one in Figure 3 and Figure 4. Figure b illustrates the distribution of the 2348 edges within and between brain systems, where each cell indicates the mean standardized effect size (SES) in the "(intact-narrative – scrambled narrative) > (intact argumentative – scrambled argumentative)" contrast, i.e., the ratio between the sum of the SES and the number of the edges in the fully connected situation. There were 96 edges in DMN, which are highlighted using the dotted lines. Figure c illustrates the SES of the 96 edges in the DMN of all the conditions in contrast to the resting state. Figure d illustrates the top 20 edges within the 96 edges in the DMN with the largest SES in the "(intact-narrative – scrambled-narrative) > (intact-argumentative – scrambled-argumentative)" contrast. In Figure a and Figure d, the size of the nodes denotes the node degree of each brain area in the whole graph comprising 2348 edges. The color of the nodes denotes to which brain system they belong. The width of the edges denotes the SES. Intra-system edges are in the color of that network; inter-system edges are in gray.

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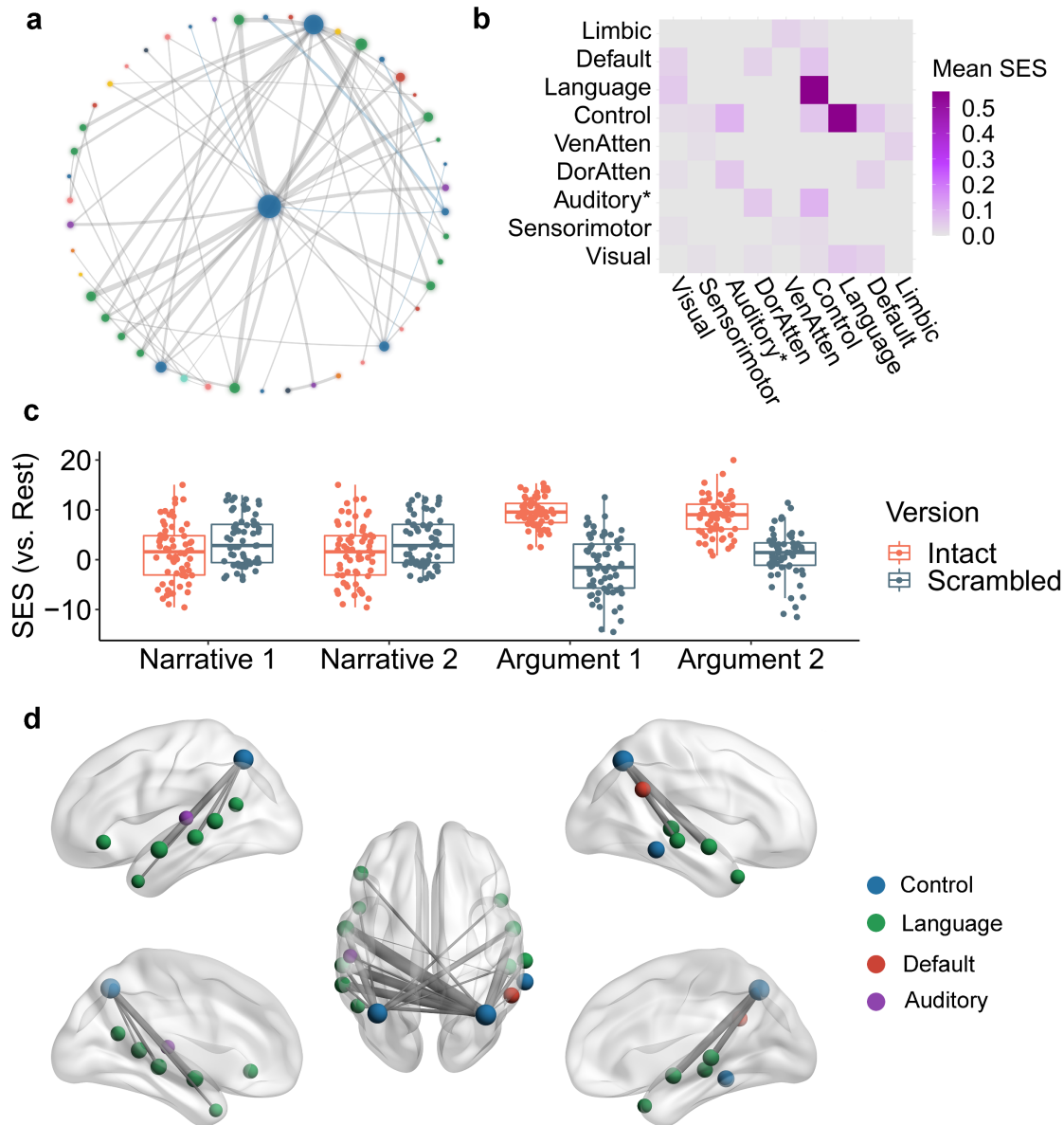


Figure 7. The brain network specific to argumentative thought. Figure a illustrates the network layout of the brain network specific to argumentative thought using the force-directed graph drawing algorithm. It consisted of 64 edges. The color legend is the same as the one in Figure 3 and Figure 4. Figure b illustrates the distribution of 64 edges within and between brain systems, where each cell indicates the mean standardized effect size (SES) in the "(intact argumentative – scrambled argumentative) > (intact-narrative – scrambled narrative)" contrast, i.e., the ratio between the sum of the SES and the number of the edges in the fully connected situation. Figure c illustrates the SES of the 64 edges of all the conditions in contrast to the resting state. Figure d illustrates the top 20 edges with the largest SES in the "(intact argumentative – scrambled argumentative) > (intact-narrative – scrambled narrative)" contrast. In Figure a and Figure d, the size of the nodes denotes the node degree of each brain area in the whole graph comprising 64 edges. The color of the nodes denotes to which brain system they belong. The width of the edges denotes the SES. Intra-system edges are in the color of that network; inter-system edges are in gray.