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5 THE FLOW OF NARRATIVE IN THE MIND UNMOORED: AN ACCOUNT OF
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7 NARRATIVE PROCESSING
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11 ABSTRACT
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13 Verbal narratives provide incomplete information and can be very long. Yet readers
14 and hearers often effortlessly fill in the gaps, and make connections across long
15 stretches of text, sometimes even finding this immersive. How is this done? In the last
16 few decades, event-indexing situation modelling and complementary accounts of
17 narrative emotion have suggested answers. But despite this progress, comparisons
18 between real life perception and narrative experience might underplay both changes to
19 our model of the world in narrative processing-, and the role of reader emotions which
20 are unrelated to characters. I reframe narrative experience in predictive processing
21 and neural networks, capturing continuity between fiction, perception and states like
22 dreaming and imagination, through the flexible instantiation of concepts. In this
23 frame, narrative experience is more clearly revealed as a creative experience that can
24 share some of the phenomenology of dreams.
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41 KEYWORDS
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43 stories; narrative; situation model; event indexing; emotion; neural network;
44 predictive processing; creativity.
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50 Introduction
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52 *The tale of two men who went to look for Old Man Furry.*
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3 And they were strong, both of them, and the one had killed many bears, but the
4 other had not hunted bears before, and he was afraid, and untrained. And when
5 they found Old Man Furry, he was so angry that he rushed upon them in an
6 instant, and they jumped behind a big pine tree (Turi, 1931, p.128).
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13 How might the Sami audience listening to this story have known why the men
14 jumped behind a tree? How did they remember, as the story continued, that only one
15 was an experienced hunter? And why might they have kept listening? These questions
16 can be framed as: how do we infer missing information from a narrative text? how do
17 we connect information across the text so as to experience it as coherent? and why
18 can stories be immersive, rendering us indifferent to our environments and usual
19 trains of thought?
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28 To answer these questions, I begin with a summary of event-indexed
29 processing leading to situation models, currently the dominant account of verbal
30 narrative processing. I suggest that despite many strengths, this account of narrative
31 processing is constrained by ~~by~~ a separation between inferred information and
32 emotion. I suggest a way to redescribe narrative processing using predictive
33 processing (PP) in a high dimensional vector space, allowing a holistic ‘single
34 computation’ of all aspects of narrative experience (Clark 2016, 296). This approach
35 recognises the existence of the situation model (SM) as one level of memory
36 representation arising from narrative processing. Skeletal event sequences identified
37 by anthropologists or oral narrative, used after the event to retell/adapt stories, for
38 example, bear some resemblance as SMs (Bauman 1986, chapter 5; Aarne and
39 Thompson, 1928). It is not the only level, but I argue that the aspects of narrative
40 processing relating to other levels of representation must be recruited to explain the
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3 SM level; that the inferences leading to an SM must draw on the full range of
4 narrative experience The article offers a holistic account of narrative processing
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6 looking at the dynamic interactions of emotion and inference and the ways they depart
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8 from real world perception. Seen like this, narrative processing can not only simulate
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10 the world, but imaginatively remodel it.
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13 Situation models and event indexing

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15 In the 1960s researchers on narrative often assumed modular models of
16 language processing, representing the text's linguistic form rather than directly
17 representing content (Katz & Postal, 1964; Blumenthal, 1967; Sachs, 1967).
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19 Bransford and colleagues challenged these assumptions in the early 1970s, showing
20 how spatial representations are needed to process sentences like this one: "Three
21 turtles rested on a floating log and a turtle swam beneath them". They concluded that
22 sentences should not be "viewed as linguistic objects to be remembered" but as
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24 "information which [people] can use to construct semantic descriptions of situations"
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26 (Bransford, Barclay & Franks, 1972, p.194).
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35 These findings were followed in the 1980s by Johnson-Laird's work (1983) on
36 mental models and van Dijk and Kintsch's (1983) on situation models. Johnson-Laird
37 argued that "human beings understand the world by constructing working models of it
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39 in their minds," models which "are simpler than the entities they represent"
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41 (Johnson-Laird, 1983, p.10). Van Dijk and Kintsch proposed a distinction between
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43 "the text representation proper" and "a model that the reader or hearer constructs
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45 about the relevant information for the adequate comprehension of the text" (Van Dijk
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47 & Kintsch 1983, p.337). This combined body of work suggested that verbal narrative
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49 processing, using spatial representations, enables the creation of SMs (Morrow,
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51 Greenspan & Bower, 1987). This does not commit SM advocates to the claim that
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3 SMs are the only level of memory representation produced by narrative processing,
4 although, as Mar & Oatley observe (2008, p.174), SMs can explain memory for text
5 narrative at both automatic (Gerrig & O'Brien, 2005; McKoon & Ratcliff, 1998) and
6 conscious, intentional levels (Graesser et al, 1994), and support inferences arising not
7 just from spatial relationships, but also of characters' short and long term goals
8 (Glenberg et al, 1987; Trabasso & Wiley 2005).
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16 Narrative text was also increasingly analysed in hierarchically organised
17 chunks. In Van Dijk and Kintsch's "macro structure theory"; for example, plot exists
18 at a macro level and has a rule governed relationship to micro episodes (van Dijk,
19 1977; Kintsch, 1977; Kintsch & van Dijk, 1978). Emerging "story grammar" theories
20 also involved hierarchical organisation around characters and their goals (Rumelhart
21 1975, 1977; Meyer, 1975; Thorndyke, 1977; Mandler & Johnson, 1977; Stein &
22 Glenn, 1979).
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31 These hierarchical organisations of narrative resembled new accounts of event
32 perception. Events are bounded, hierarchically nested, segments of time. "Opening a
33 door"; for example, can be one event within the higher order event of "arriving at a
34 party" (Newtson, 1973; Zacks & Tversky, 2001). An event boundary is perceived
35 when there is simultaneous change across a set of key dimensions (Zacks et al, 2007).
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37 The "event indexing model" provided an explanation of how narrative processing
38 could lead to SMs (Zwaan, Langston & Graesser, 1995; Zwaan, Magliano &
39 Graesser, 1995). In what follows, I suggest that replacing this limited number of
40 commonsense dimensions with a high dimensional vector space can improve our
41 understanding of the relationship between event segmentation, the creation of SMs
42 and narrative experience more broadly.
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3 The existing dimensions of event change indexed by readers are: which
4 character is this?; change in characters' goals; new information about causation;
5 change in location; change in the time of events narrated; and change in characters'
6 interactions with objects (Zwaan & Radvansky, 1998; Zacks, Speer & Reynolds,
7 2009). This is the model is used by most researchers working on narrative processing
8 today (for examples, see Zacks, 2015; Chow et al, 2014; Muijselaar, 2015). The
9 production of SMs can provide readers and hearers of verbal narrative with a global
10 sense of a story, by organising information around the key dimensions (Sanford &
11 Emmott 2013, pp.37 – 38). The production of SMs also relates to narrative inferences:
12 the situation builds in knowledge of the world, which is not always explicit in the text.
13 The process of SM construction has been used to explain immersion in verbal
14 narrative through embodied language processing drawing on behavioural and
15 neuroimaging work in embodied language processing such as that of Reddy (2010),
16 Hauk (2008), Barsalou (2008), Glenburg & Kaschak (2002), Speer et al (2007) and
17 others (Zwaan, 1999). These approaches to narrative processing are compatible with,
18 and sometimes supported by, accounts of emotion and empathy in response to film
19 and verbal narrative by Tan, Sanford & Emmott and others (Tan 1994; Sanford &
20 Emmott, 2013, 44, pp.191 - 232).

21
22 By moving from modular models of verbatim text representation, event
23 indexing and situation modelling have revealed shared elements in narrative
24 processing across media, including film (Zacks, 2015; Speer, Zacks and Reynolds,
25 2007; Magliano, 2012), and a comparative framework for variations in narrative
26 processing between individuals (Kurby, 2011; Bohn-Gettler, 2011). They make clear
27 predictions, for example that processing at event boundaries in the text will be slower
28 (Zacks, Speer & Reynolds, 2000). By recruiting embodied language processing to

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3 verbal narrative, they share in a broader move towards embodiment in the cognitive
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5 sciences (Clark, 1997; Clark, 2016, pp. 109-240).
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7 These gains have been won by recruiting the resources of everyday perception
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9 (Zacks, 2015). However, the current account of the processing behind SMs may
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11 neglect the status of verbal narrative as an artefact, a product of human behaviour,
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13 whose processing may be comparable to cognition of, say, music or handwriting
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15 (Knoblich et al, 2002; Overy & Molnar-Szakacs, 2009). In what follows, I exploit the
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17 flexible frameworks of PP and neural networks to explore differences between the
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19 narrative processing that produces SMs, and everyday perception
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22 I illustrate my account with the case of a child listening to a fairy tale. Fairy
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24 tales come closer to a universal narrative experience than the texts used in many
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26 experiments; they are found in diverse cultures and periods, and are accessible to very
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28 young hearers with a minimum of prior skill in narrative comprehension (Tehrani,
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30 2003, pp.1-11; Aarne and Thompson, 1928).
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33 Listening to *The Juniper Tree*

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35 *The Juniper Tree* was collected and edited by the Grimm brothers in the early
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37 nineteenth century, and has several cognates in other cultures (Grimms 1973, 314-
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39 332; Aarne and Thompson 1928, tale type 720). Very young children, from a wide
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41 range of cultures, frequently become immersed in stories like this, as the tales'
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43 persistence across time and place, and with young audiences, suggests (Tehrani, 2003,
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45 pp.1-11; Whitehead 1999, pp.104-107). I analyse the opening of *The Juniper Tree* in
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47 the light of existing approaches to the processing that leads to SMs and discuss some
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49 problems this analysis identifies:
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3 It is a long time ago now, as much as two thousand years maybe, that there was
4 a rich man and he had a wife and she was beautiful and good, and they loved
5 each other very much but they had no children even though they wanted some
6 so much, the wife prayed and prayed for one both day and night, and still they
7 did not and they did not get one. In front of their house was a garden and in the
8 garden stood a juniper tree. Once, in wintertime, the woman stood under the tree
9 and peeled herself an apple, and as she was peeling the apple she cut her finger
10 and the blood fell onto the snow. “Ah,” said the woman and sighed a deep sigh,
11 and she looked at the blood before her and her heart ached. “If I only had a child
12 as red as blood and as white as snow.” And as she said it, it made her feel very
13 happy, as if it was really going to happen (Grimms, 1973, pp.314-315).

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29 There are several examples here of the five dimensions of change (time, space,
30 causation, motivation and protagonist; Zwaan & Radvansky 1998): longing for a child
31 and peeling an apple (goals); and “in winter” or “under the tree” (changes in time and
32 location). Situation modelling of verbal narrative involves an embodied approach to
33 modelling space, and event-indexing in narrative involves simulating embodied
34 experiences of real life environments (Zacks, 2015, 449). These embodied
35 experiences can be seen as a source of emotion, either intrinsic to creating the SM
36 (Zwaan 2009), or complementary to it (Sanford & Emmott, 2012, pp.191 - 232). The
37 potential for embodied responses to the text through actions - peeling an apple,
38 cutting a finger, looking at blood on snow – can help, then, to explain immersion if it
39 occurs.

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But here also lies a problem. If an embodied response to a text about cutting a
finger and bleeding generates emotion, the emotion ought to be negative, even

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3 distressing, particularly for child hearers. The *character's* happiness might then be
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5 experienced as incoherent. Yet the success of this tale, particularly with children,
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7 included repeatedly in editions of Grimms' tales over 200 years, suggests that it is
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9 not.

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11 Generic experience of fairy tales might help hearers to bridge the gap between
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13 real life experience and narrative. Genre knowledge could certainly prepare the child
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15 hearer for departures from real world experience, such as minimally counterintuitive
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17 concepts, like the talking bird who appears later (Norenzayan 2006; Thompson 1955-
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19 1958). But generic knowledge cannot filter "happiness" from the range of relevant
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21 potential responses to injuring one's finger; a generic example like Sleeping Beauty
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23 could even make this harder (Kibbe et al, 2017).

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25 An alternative solution to explain how processing produces the relevant
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27 information for an SM might be to distinguish reader emotion from the emotion in
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29 response to character alone. Moves in this direction have been made by Tan (1994)
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31 and Sanford & Emmott (2013). Tan attributes to readers/viewers not, or not just, the
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33 simulated emotions of characters, but the emotions of an impotent *witness* of the
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35 characters, and argues that these emotions enable, rather than just arising from,
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37 predictive inferences (Tan 1994, p.184). Sanford and Emmott suggest that "scenario
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39 mapping" and embodied responses allow the emotions of characters to be "built into"
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41 readers' "mental representations". These lead to reader emotions, modulated by
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43 approval, liking or closeness to the characters into macro narrative structures of
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45 curiosity, surprise and suspense, which can generate arousal jags and boosts (pp.196,
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47 207; drawing on Berlyne 1960, 1971; Brewer and Lichtenstein, 1982; Sternberg 1978,
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49 2003).

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3 On their own, however, these accounts cannot solve the problem with *The*
4 *Juniper Tree*. Children are frequently impotent witnesses of scenes involving adults,
5 and it is not clear that in this case the child's response to seeing an adult woman cut
6 her finger would enable her to predict the woman's happiness. This passage may
7 create distance rather than Sanford and Emmott's closeness – the characters exist in
8 an unspecified place and a distant and unspecified time. They have morally attractive
9 characteristics – they love one another, they would love a child – but they perform no
10 actions in this passage which are open to moral evaluation either way. It would be
11 hard to say that a four-year-old child has enough here to generate liking, dislike or
12 (dis)approval. This would be hard to settle without empirical investigation, but it is at
13 least questionable that emotions arising from closeness, approval and liking, in turn
14 leading to hopes and fears, and from there to arousal jags and boosts, can explain why
15 very young children can are not puzzled by the woman's response to a cut finger.

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17 A holistic account of the hearer's emotional responses to narrative, however,
18 can build on Tan's alertness to the role of reader/hearer impotence in narrative
19 experience, and of the distinction between reader emotion and character emotion. In
20 perception, we *act* on the environment to deepen our understanding of it, if only
21 through eye saccades (Grimes, 1996; Smith and Henderson, 2008; Henderson, 2003).
22 In narrative experience, however, we are unmoored from our immediate environment;
23 the hearer of a narrative cannot act on the stimulus to derive greater sensual
24 information about the scene depicted. Both perception and narrative may engage the
25 same machinery of predicting incoming signals, as I discuss below (Clark 2016;
26 Gerrans 2014). But the concepts instantiated by language cannot always be
27 interrogated in the same sensory depth as those arising from perception and action
28 embedded in an environment. Instead, they may be experienced in relationship to one

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3 another, isolated from a shared environment. Even the eye saccades crucial to film
4 comprehension can be highly determined by lighting, camera angle, montage etc, and
5 the film is not fully available for ecological interrogation through the viewer's bodily
6 location and action (Cutting et al 2011; Hasson et al 2008; Loschky et al 2015;
7 Gibson 1979).
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14 In the first part of the passage from *The Juniper Tree*, the hearer encounters
15 the concepts of a rich man, a good and beautiful wife, the absence of a child, longing
16 for a child and praying for a child. The hearer's passivity, her inability to act on the
17 stimulus, means that none of this information can be further probed. The man and the
18 wife may give rise to embodied neural effects in relevant sensory and motor areas, but
19 these are not instantiated in relation to the child's perceiving body. Encountering a
20 "rich man" face to face, for example, would instantiate a power relationship with a
21 child, with embodied consequences (Fiske et al, 2016). Encountering the concept
22 through language, however, potentially neutralises such effects and frees the set of
23 concepts to interact in novel ways. The "feature tuning" of mental images in response
24 to nouns (such as "man" and "wife") can vary considerably with verbal context
25 (Mitchell & Cusack, 2016, pp. 4 – 7). "Man" and "wife", dis-embedded from a rich
26 scene, might mutually influence each other's instantiations. "Rich" in conjunction
27 with "beautiful" might give prominence to the beautiful belongings that wealth can
28 buy, rather than, say, the cruel behaviour that wealth can sometimes enable.
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46 The interactions of this small set of concepts then ("man", "wife", "rich",
47 "beautiful"), when experienced passively (in the sense that the body cannot glean
48 additional sensory information), in isolation from an environment, and unmoored
49 from a perceiving body, may subtly modify the hearer's statistical model of the
50 world's hierarchy of proximal and distal causes and effects (Clark, 2016; Kirchhoff
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3 2018). For example, the conjunction of “good”, “rich”, “loving” and “beautiful” with
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5 “lack” and “longing” may point to a rightly ordered world that has somehow gone
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7 wrong; the blessed can also be unblessed. Similarly, the imagery of blood on snow
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9 can be separated from the embodied experience of the cut, so that the blood and snow
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11 - again, pushed together through isolation from a perceiving body in a richer
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13 environment - can be instantiated through contrasts of colour, temperature and
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15 texture. As their other features drop out, the aesthetic effect of this combination may
16
17 dominate the potential for distress in a child’s simulation of cutting herself and
18
19 watching herself bleed, recalling Miall and Kuiken’s distinction between “narrative
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21 emotions” (relating to characters) and “aesthetic emotions” (Miall & Kuiken, 1994,
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23 1999). The isolation, and then conjunction, of juniper tree, snow, blood, apple,
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25 aesthetic thrill, and a sudden transition from longing to joy then become causally
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27 implicated in the subsequent conception of a child.
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31 This analysis shows the kind of thing that *could* happen, rather than what must
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33 happen, but it is enough to raise a doubt that the existing account of event
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35 segmentation, leading to SMs, using a fixed set of commonsense dimensions,
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37 alongside theories of emotional response to characters, can explain this and similar
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39 narrative inferences which are needed for the SM. In the next section I explore the
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41 mechanisms by which this hearer might be immersed in narrative through the
42
43 unfolding of a subtly unfamiliar trajectory; a succession of points in a multi-
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45 dimensional space.
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48 Stratified versus holistic organisation of narrative information

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50 Zwaan and Radvansky predict that there may turn out to be more than five
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52 narrative dimensions involved in the production of SMs (p.167; see Rapp, 2001 for a
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54 proposed addition). But there is currently no suggestion that the number extends
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3 beyond common sense concepts such as “location” or “goal”. If “Bill is very tall”
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5 turns out to be irrelevant to subsequent situations, it is “relegated” and excluded from
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7 “subsequent situation models”. If the reader later finds that “Bill could see over
8
9 everyone’s head”, the information can be retrieved and “stored directly with the token
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11 in the model” (Zwaan and Radvansky, 1998, pp.11, 17, 19 - 20).

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14 Zwaan and Radvansky are not proposing, then, a division of information into
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16 “modelled” and “discarded”. But their account does imply that incoming information
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18 can and should be identified as having greater or lesser importance for the model. If
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20 *all* the incoming information could immediately be incorporated in the model without
21
22 compromising it, there would be no need to monitor the dimensions. The power of an
23
24 SM is not just, as Zwaan and Radvansky correctly point out (pp.162-163), that it is
25
26 more efficient than storing representations of verbatim text, but that it is more
27
28 efficient than treating all of the *information* provided by verbatim text as equally
29
30 important. While other levels of narrative memory and representation may operate
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32 outside an informational hierarchy of this kind, it would seem to be essential for event
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34 segmentation and the formation of SMs.

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37 I suggest, however, that in the case of *The Juniper Tree*, dividing the textual
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39 information in this way can only be done by sacrificing, among other things, the
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41 contribution of emotion to narrative inference and coherence. Look again at the
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43 quotation above, from, “In front of their house...”. To update her SM as she hears this
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45 passage, the child hearer must identify information relevant to goals and causes, two
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47 of Zwaan’s and Radvansky’s dimensions; that the woman sighed, and that her heart
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49 ached, not because her finger was sore or her apple spoiled, but because the
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51 experience seemed somehow relevant to her desire to have a child.
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3 But the fine detail of the “irrelevant” information, I suggest, is important to
4 emotion, and the role of emotion in processing. In combination, these elements
5 configure an emotional experience which has no counterpart in the child’s real life
6 experiences of apples and knives, an experience which reveals that the woman’s
7 longing will be fulfilled because, in mysterious ways, nature wills it so.
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13 We can illustrate this point in a different way by reverse engineering a
14 segment of Zwaan and Radvansky’s illustration of the processing behind SMs - “Peter
15 took the elevator to the fifth floor. He went to talk to his professor”:
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22 ...When reading the first sentence, the reader creates a situation model
23 involving a token that represents a male individual named Peter who rides an
24 elevator for as yet unknown reasons. We assume that the reader infers that Peter
25 is in a building and that the event took place before the moment of utterance of
26 the sentence....This [second] sentence is integrated with the first one on several
27 dimensions. First, the pronoun is a cue to the comprehender to look
28 backward...in the integrated model for an appropriate referent. This referent is
29 found in Peter, who is the only available referent and shares the feature “male”.
30 Second, a goal is constructed (“went to” suggests intentionality...). Third, the
31 absence of a shift in tense or any other explicit temporal marker indicates that
32 we are still in the same temporal interval... Fourth, the absence of a spatial
33 marker indicates we are still in the same spatial region.... Fifth, a second token
34 is created representing the professor. The reader probably also infers that Peter
35 is a student. This is the content of the current model at Time t_2 .
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55 | This can be represented schematically:-
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5 t_1 Create PETER^{TOKEN (male)}

6 t_1 Create ELEVATOR IN BUILDING IN PAST^{SPATIO-TEMPORAL FRAMEWORK}

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8 t_1 Combine PETER^{TOKEN (male)} in ELEVATOR IN BUILDING IN PAST^{SPATIO-TEMPORAL FRAMEWORK}

9
10 t_2 Create PROFESSOR^{TOKEN (male)}

11
12 t_2 Modify PETER^{TOKEN (male)} with GOAL^{VISIT PROFESSOR} and with ^(student)

13
14 t_2 Incorporate t_2 elements with t_1 elements.

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17 If we use this set of instructions to generate a new text, one possibility of many is this:

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19 “Peter rode in the elevator up, up, up. His professor waited as Peter came nearer and

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21 nearer.” This text is different from the initial one in many ways, from the professor

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23 waiting, to the absence of “the fifth floor”. But it is as compatible with the *situation*

24
25 *model* above as the original. The reader’s emotion, however, is likely to be different.

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27 The stylistic emphasis on the changing relative distance between Peter and the

28
29 professor may create an element of anxious anticipation. Emotion arising from verbal

30
31 form may *underpin* the inference of information, rather than the reverse (compare

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33 Barrett and Bar, 2009). The verbal form suggests that either Peter or the Professor has

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35 something to fear from the encounter. Peter’s goal may not be related to their roles of

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37 student and professor; Peter may not be a student at all if his relationship to the

38
39 professor may be that of, say, victim or aggressor. The repetitions of “up” and

40
41 “nearer” do not provide new information on the SM’s dimensions. Yet their emotional

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43 impact on the reader is important for identifying precisely the information – such as

44
45 characters’ goals - which an SM is intended to capture. While the SM itself need not

46
47 capture reader emotion, the processing leading up to it must if the information in the

48
49 SM is to be correct (for earlier work pointing in this direction, see McNamara &

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51 Magliano, 2009 and Graesser, Olde & Klettke 2002).

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3 Suppose the repetitions in “up and up” and “nearer and nearer” cause fear,
4
5 telling the reader that either Peter or the professor has a sinister goal. Could this
6
7 simply mean a different “goal” node than the model of the first passage? The spatio-
8
9 temporal information still models Peter in an elevator and the professor in a room, just
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11 as in the first case.
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14 But if the repetitions of “up” and “nearer” simply switch the goal node from
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16 “visit professor, probably in relation to studies” to “go to professor’s room, not clear
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18 why, but this may involve danger either to Peter or the professor”, does this bundle of
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20 information, a bundle which must be expanded if it is to include *all* the implications
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22 of fear, deserve the name of “goal node”? Recall that the strength of SMs is saving the
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24 hearer or reader from remembering not only all the verbatim text, but all of the
25
26 information conveyed by that text. If the model is to incorporate all the *implicit*
27
28 information generated by emotion, it will be burdened with even more information
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30 than that of the verbatim text. If emotion is treated as information encoded in the text,
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32 then it cannot be incorporated in an SM. Yet, as we have seen, emotion may be
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34 crucial to help a child make correct inferences about texts like *The Juniper Tree*. An
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36 improved account of narrative processing, then, will be holistic in its approach to
37
38 information, and distinguish more clearly between the experiential aspects of
39
40 perceiving something, and those of hearing or reading about it.
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44 A first step is to rethink the processing behind SMs as structured not by five or
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46 six common sense dimensions, but by dimensions too many to enumerate, resisting
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48 commonplace psychological categorisation. A neural network model of processing in
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50 this high dimensional vector space (explained below) can capture recurring
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52 experiences in processing a given text, including the effects of verbal patterning,
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54 emotion and the perception of language as agent guided behaviour. Characterising
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3 those recurrent, downward projections as predictive can also suggest a convincing
4 story about immersion in a flow of inner states, and explain overlaps in
5 phenomenology between dreaming and narrative immersion.
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8 9 High dimensional vector spaces and verbal narrative

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11 Think of a word as a sequence of sounds, where each sound has the potential
12 to differentially activate every cell in an array. Each phoneme will come to be
13 associated with a different pattern, or vector, of activation. The array activates
14 another, higher, array through a set of connecting links or synapses, which in turn
15 activates the next, and so on. The varying strengths or weights of these connections
16 between layers have been determined by past experience, and form matrices which
17 transform the vectors and allow recognition of groups of sounds, then words, phrases,
18 clauses, sentences and so on (Rumelhart & McClelland, 1986; Churchland, 2012;
19 Jordan, 1986).
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31 As well as these upward connections, each array has downward connections to
32 the one below. This means that the effect of one input on the system can affect the
33 way the next input is received, so that frequently repeated sequences of inputs are
34 more easily recognised than others (Churchland, 2012, pp.165-170). At a certain level
35 or levels, the points in the vector space initially activated by speech sounds move into
36 spaces generated by a much wider range of stimuli associated with those speech
37 sounds. On hearing the sounds for the word “apple”, for example, a processing
38 journey begins which, depending on the context, may end in an area of vector space
39 overlapping, though not identical with, that activated by seeing a real apple (Reddy et
40 al, 2010).
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52 Now let us revisit *The Juniper Tree*. How does the hearer make the link
53 between the interactions of a cluster of concepts (juniper, apple, blood, snow), the
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3 emotion associated with those interactions, and a character's conception of a longed
4 for child? At first blush, adopting a vector space framework takes us no further
5 forward with this problem. The world model of interacting causes built into this
6 framework is embedded in the matrices of connection weights, and altering these
7 weights is a slow and cumulative process, a matter of weeks or years, not the seconds
8 or fractions of seconds involved in responding to a section of a story. How can
9 hearing a brief text, or fragment of text, temporarily modify these weights to
10 accommodate a different analysis, one in which cut fingers activate representations
11 involving beauty and yearning rather than pain and distress, for example?
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22 One possibility is that instead of modifying the matrices of *weights*, the
23 recurrent, downward connections can modify the stream of *inputs*. In the case of *The*
24 *Juniper Tree*, all of the effects of the text to date influence the pattern of downward
25 connections in ways that affect the upward impact of new inputs. The succession of
26 states and their direction of travel form a trajectory through vector space. In what
27 follows, I suggest that verbal narratives can stimulate trajectories of this kind that
28 depart from normal perceptual experience, while staying within the bounds of a pre-
29 existing world model.
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39 Behavioural, neuro-psychological and neuroimaging evidence suggests that
40 "concepts are flexible, distributed representations comprised of modality specific
41 conceptual features" (Kiefer and Pulvermüller 2012, 805). This flexibility is
42 consistent with accounts by Paul Churchland and Margaret Boden characterising the
43 reconceptualization of an input in the "hidden" layers of a neural network as a
44 creative process. Each cycle of Newton's meditations on the moon could modify his
45 existing concept a little more, until the moon is less like a wheel running on a track
46 and more like a ball thrown by a force (Churchland 2012, pp.187-196; Boden 2004).
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3 The everyday experience of narrative text may similarly push us through otherwise
4 unfamiliar trajectories in vector space.
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6 7 Vector spaces and inference 8

9 The extract from *The Juniper Tree*, typically of fairy tales (Thompson, 1946,
10 p.8), provides minimal information about particulars of place or time. The event
11 happened “once” and “in winter time” rather than on, say, 4 January 1822. The time,
12 then, is indeterminate, as are the unmodified nouns “woman”, “tree”, “apple” and so
13 on. Adjectival modification affects the ways in which nouns are processed
14 (Westerlund et al, 2015; Bemis & Pylkkänen, 2013). Each of the unmodified concrete
15 nouns in this case, then, could potentially activate an area of vector space associated
16 with a prototypical representation (of women, trees, apples and so on), areas which
17 capture averages of similarity and difference across multiple dimensions, thus
18 enabling real life recognition of a particular woman, tree or apple by its location
19 relative to the average. Coming as they do in a sequence, the downward, recurring
20 connections generated by these nouns create a context in which singular entities (the
21 particular woman, tree, apple of the story) are reconceptualised as prototypical ones
22 (compare the comments on style and prediction in Kuperberg & Jaeger, 2016, p.48).
23 The later nouns “blood” and “snow” arrive in, and reinforce, a landscape of
24 prototypes. A real life encounter with objects and people that all coincided precisely
25 with the average of their type might create a sense of the uncanny, and “seemingly
26 invite a supernatural explanation” (Bouvet and Bonnefon, 2015, p. 956).
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48 A second contextual effect could arise from repeated syntactic patterns. The
49 text consists mainly of additive clauses – “and as she was peeling...and the blood
50 fell...and she looked...and her heart ached” – with little of the subordination (“she cut
51 her finger causing the blood to fall”, “her heart ached because...”) that can point
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3 directly to causal relationships (Morera et al, 2017). In perception, a repeated
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5 temporal sequence can have a strong, sometimes misleading, association with
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7 causality (Churchland, 2012, pp.177-178). However, the recurrent connections
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9 generated by a repeated syntactic pattern of additive clauses could undo this because
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11 the hearer is not free to probe causation as she would in a richer environment.
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14 By contrast, perception of a scene like this in a real world, rich environment
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16 *would* be structured by causal relationships. The appearance of the woman would be
17
18 modulated by effects of light and shadow caused by the tree and the snow (Kersten et
19
20 al 1997). Spatial structure has long been understood as important to perceiving causal
21
22 narrative structure (Heider 1944), just as internal scene construction is critical to both
23
24 episodic memory and verbal narrative (Mullally et al 2012). In this case, in the
25
26 absence of a causal structure relating many of the elements in the scene, and in a
27
28 landscape of syntactically weakened causal links, other patterns of similarity and
29
30 difference can interpret the relationships between inputs. The tastes and textures of
31
32 apples, for example, and the texture and temperature of snow could be located in
33
34 adjacent or overlapping areas of vector space, as multisensory integration (Stein et al,
35
36 1988) is released from the constraints imposed by real world stimuli. The pain of a cut
37
38 might be measured against the colour and temperature of blood. In a real world scene
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40 these modality specific overlaps may be unimportant, but here, in a sparser, less
41
42 defined scene, they take on new power. The synaesthetic effects of this process
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44 would, moreover, have an aesthetic reward (Ward et al, 2008).
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48 Now let us imagine that the hearer has had many disappointed hopes, but has
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50 also experienced a powerful hope turning into a belief. The move from hope to belief,
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52 then, is a possible sequence for her, but not a necessary one. In a context coloured by
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54 the uncanny and by aesthetic reward, a context in which normal causal relations have
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3 been muted, this sequence (of hope turning to belief) may become the most likely
4 path for upcoming activation (compare Clark, 2016, pp.231 – 237). The hearer can
5 hypothesise that the woman sighs because of longing, not physical pain, without
6 modifying her world model's matrix of weights.
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10 11 A vector space account of narrative coherence

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13 In 1990, the cognitive scientist Jeffrey Elman discussed the problems of
14 representing time in parallel, distributed, connectionist models of cognition, similar to
15 the neural networks outlined above. Until then, Elman explained, a common approach
16 to the parallel processing of sequentially structured inputs, like language, had been to
17 treat time as “an additional dimension of the input” by giving it an explicit “spatial
18 representation”. The first item in a verbal sequence could be represented in the first
19 space in a vector, and so on. Elman argued that this approach runs into intractable
20 problems (which I do not discuss here; Elman, 1990). Time is an explicit dimension
21 of the input to SMs in existing accounts: a complete SM, ‘stored in long-term memory
22 after all the textual input has been processed’ will consist of ‘the situations at Times t_1
23 through t_x ’, allowing comprehenders to ‘ruminate over a story’ later (Zwaan &
24 Radvansky 1998, 166). While not described as a spatial representation in the form of
25 a numerical matrix, this is an approach which makes time an explicit dimension in
26 both processing (one of the five associated with SMs) and output (the SM itself).
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44 Instead of treating time as a dimension of the input, Elman suggested instead
45 an implicit representation of time in which a layer of “context” cells is added to the
46 layers of “hidden” cells. At time t :
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52 Both the input units and context units activate the hidden units; the hidden
53 units then feed forward to activate the output units. The hidden units also feed
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3 back to activate the context units. (Elman 1990, p.182).
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7 The context units modify future inputs by responding to previous inputs. In this way,
8 time can be represented through its cumulative effects “on processing and not as an
9 additional dimension of the input”.
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13 A “spatial metaphor for time” of the kind identified by Elman as problematic
14 is implied by the SM’s linear structure from t_1 to t_x , which ensures coherence, letting
15 the reader ‘know when the described events took place both relative to each other and
16 relative to the time at which they were narrated’ (Elman, 1990, p.181; Zwaan &
17 Radvansky, 1998, p.181). But are such representations of time always essential to the
18 processing that enables SMs? If I am asked to write a reference, I might try to recall
19 specific instances of the candidate’s past behaviour. However, if I predict what my
20 friend will order at a restaurant, I need not bring to mind all or any of the past
21 episodes underwriting that prediction, even if I could. To test narrative
22 comprehension, researchers need to resolve the experience of verbal narrative into
23 actions after the event, such as answering questions about a story accurately, or
24 retelling it (Ennemoser 2007, p. 354; Strong 1998). One way to describe this is the
25 ability to interrogate the SM which arose from processing the narrative.
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41 But there is another way to think about, and potentially even measure, verbal
42 narrative comprehension: the success of a cognitive system in continually moving
43 towards stasis in response to an incoming flow of text (Spivey, 2007, p.36 and
44 elsewhere). A child hearer could experience this move to stasis yet still perhaps be
45 unable, if asked, to accurately reconstruct a timeline of the story or answer questions
46 accurately. Even scrub jays can “remember” sequences of their own actions without,
47 presumably, being able to represent those sequences to themselves or to others
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3 (Clayton and Dickinson 1998, 1999; Suddendorf and Busby, 2003). As Elman points
4 out, “The representation of time – and memory – is highly task-dependent”. A
5 potentially explicit spatial representation of time may be essential to the task of
6 *reproducing* a story. But it is not necessarily essential to *experiencing* the flow of
7 verbal narrative as coherent.
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13 *The Juniper Tree* continues with the woman’s pregnancy, her death from
14 happiness on giving birth, and her husband’s remarriage:
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20 By the second wife he had a daughter, but the child of his first wife was a little
21 son as red as blood and as white as snow. Now when the woman looked at her
22 daughter she loved her so, but looking at the little boy cut her to the heart.
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28 Not long after, the stepmother kills the boy and hides the evidence by cooking the
29 body parts in a stew. The text never refers to her as “the stepmother” but as “the
30 woman” or, when addressed by the boy himself, “mother”: “Mother,” said the little
31 boy, “how strange and wild you look!”. To avoid confusion with the real mother, and
32 experience the story as coherent, the child hearer must remember that the real mother
33 died and was replaced by a wicked stepmother. One solution is to tag the mother’s
34 death and the stepmother’s arrival as t_x and t_{x+1} , ~~is~~ ready for incorporation in an SM
35 by situating them on a timeline. But the child’s experience of the text as coherent can
36 be explained without this explicit representation of time:
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50 And so the mother took the little boy and hacked him in pieces and put the
51 pieces in the pot and stewed him in the sour broth. But Ann Marie stood by and
52 cried and cried and the tears fell in the pot so that it didn’t need any salt.
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3 When the father came home he sat down to supper and said, “And where is my
4 son?” And so the mother brought a big dish of black stew and Ann Marie cried
5 and couldn’t stop crying.
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11 I argued above that the real mother could be generated in areas of vector space which
12 involved the uncanny and the aesthetic effects of synaesthesia. The stepmother, on the
13 other hand, is developed through “taking” and “hacking”, and the objects surrounding
14 her are “the pot” and “the sour broth”, reinforced soon after as “a big dish” and “black
15 stew”. The difference in the areas of vector space activated in each case mean that
16 neither a timeline of death and remarriage, nor a consistent verbal distinction between
17 “mother” and “stepmother”, are needed for the child hearer to experience the text as
18 coherent. Indeed, at this point in the story she need not even explicitly remember that
19 there ever was a good mother. After all, many stories, including oral epic and
20 medieval romance, are experienced as coherent even when found, after performance,
21 to be incoherent and flawed by “continuity errors” (Griffith, 2012).
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34 A predictive, vector space account of narrative immersion

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37 There is growing evidence that language comprehension is predictive at every
38 level, from phonemes and words to discourse. Probabilistic processing, for example,
39 can pre-activate words in comprehension (DeLong et al, 2005). Grammatical
40 inflections can be anticipated through semantic integration, and word meanings can
41 be predicted on the basis of discourse context (Wicha et al, 2004; Van Berkum et al,
42 2005; Otten and Van Berkum, 2008). These findings are drawn from different
43 languages, multiple linguistic levels and using varied methodologies (Kamide et al,
44 2003a; Kamide et al, 2003b; Knoeferle et al, 2005).
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3 We can, then, characterise the downward connections discussed above as
4 predictions about the incoming verbal signal (Clark, 2016, 285-286). In a PP
5 framework, downward hypotheses are met by upward prediction error. Patterns of
6 prediction error simultaneously modify the next wave of downward hypotheses and
7 allocate precision, or increased weight, to the most reliable sources of error for the
8 task at hand. Action is integral to this cycle of hypotheses, prediction error and
9 precision allocation, through, for example, eye saccades.
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18 One outcome of a move to PP, or hypothesising controlled by prediction error
19 (Clark, 2016), is a new account of relationships between cognitive states such as
20 dreaming, hallucination, delusion and imagination (Gerrans, 2014, p. 1; Kirchhoff,
21 2018; Seth, 2014, p.101). In what follows I characterise hearing or reading a narrative
22 as a cognitive state in which prediction error is limited to the incoming verbal stream,
23 so that the hearer or reader, to successfully predict the incoming signal, must predict
24 her own inner states, sequestering her sensorimotor responses from the machinery of
25 the world around her.
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35 Actions to probe the environment can help the hearer to predict the stream of
36 words in *The Juniper Tree* only to a limited extent. Perhaps the storyteller has a lisp,
37 and she must compensate for this when predicting phonemes, or perhaps he uses
38 particular gestures in their shared space, and her predictive system might direct
39 saccades to his face and body (Lwin, 2010). But greater attention to arm movements
40 and sound articulation will not help her predict the states of higher levels in her own
41 system, such as the combined effects of synaesthesia and the uncanny identified
42 above. For these, her best – indeed her only – source of information is the trajectory
43 of inner states arising from the experience of the text itself. It is these higher-level
44 inner states which must be explored and probed through the mechanism of precision
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3 weighting. The hearer's own states become her environment as far as predicting the
4 text goes. In this light, the potential for immersion is not surprising.
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7 Seen like this, narrative experience in one respect resembles dreaming. Both
8 experiences engage the mind in actively predicting an incoming stream of data, but
9 without the body being able to act on its environment to direct that stream. Hobson
10 and Friston characterise sleep as a state "in which internal predictions are sequestered
11 from sensory constraints" (Hobson and Friston, 2012, p.92).
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17 Embodied responses to language suggest that the reader or hearer of narrative
18 may similarly find her sensorimotor system engaged while sequestered from any
19 stimulus but the verbal stream, and inhibited from *acting* on any stimulus *but* the
20 verbal stream (for example by re-reading a sentence, or asking a reader to pause).
21 Narrative comprehension then, might be characterised as simultaneously active, in the
22 sense that the system has considerable work to do on internal states as it seeks to
23 optimise prediction and achieve stasis, and passive, in that the body has only very
24 limited opportunities to act on its environment in pursuit of that stasis, and must
25 develop new trajectories from existing resources to account for the succession of
26 internal states.
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39 The analogy between narrative immersion and dreaming should not be
40 overdone. Narrative stimuli are artefacts, dreams are not. Readers can re-read, but
41 dreamers cannot pause and repeat a section of a stimulus. Narrative can engage and
42 require conscious effort at problem solving in way that dreams cannot. And readers
43 can stop at will. But shared constraints in the two conditions may explain at least
44 some of the dream-like phenomenology of narrative immersion.
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52 This account of immersion does not require hearers and readers to feel
53 emotions for characters, as some existing theories of transportation do (Gerrig, 1993;
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3 Green & Brock, 2002). Fairy stories like *The Juniper Tree* can be immersive, but do
4
5 not necessarily encourage direct emotional responses to characters. Stock characters
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7 are central, not peripheral, to this and other oral genres (Propp, 2010; Lord, 2000).
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9 The same could be said of immersive responses to a range of other non-realist (in
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11 Barthes' sense of 'the reality effect'; 1986) fictions, which some readers/hearers find
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13 immersive, from Homer to Virginia Woolf.
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16 The sketch above does not assume immersion always happens, just as existing
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18 models do not assume that comprehension always happens. Some stories, or some
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20 readers, might reveal an easy to predict causal structure involving little emotion, so
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22 that attention wanders. With others, prediction might be too hard to permit flow, at
23
24 least on a first reading (Csikszentmihalyi, 1990). But a predictive account can explain
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26 the possibility of later immersion through practice and re-reading, as readers grow
27
28 more expert at predicting a text, like Joyce's *Ulysses* (a tough first read for many, an
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30 immersive re-read for some), an author or a genre (Kibbe et al, 2017).
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33 Problems

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35 There are potential problems in at least three areas: the cognitive framework;
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37 a role for conscious reflection; and empirical testing.
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40 I have drawn on Clark's (2016) account of Bayesian predictive processing
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42 implemented in a neural network. Clark himself has identified some problems with
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44 both elements (pp.297-300). Alternative approaches to probabilistic inference have
45
46 been explored in both neural simulations and in studies of the biological brain (Egner
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48 & Summerfield, 2013). Neural networks may not be the best, or even a possible,
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50 architecture for a generative, probabilistic approach to cognition (Hinton, 2006;
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52 Wacogne et al, 2012).
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3 Another concern is the role of higher domain areas, such as conscious verbal
4 reasoning, in probabilistic, generative predictive processing (pp.299-300). I have
5 argued that implicit, rather than explicit, representations of time may be enough to
6 support at least some narrative processing. But conscious reflection on narrative
7 experience may be needed to retell, interpret and experience stories as meaningful and
8 instructive. Reducing the role of reflection may mean missing some of the point of
9 narrative in the first place (Mulhall, 2007; Malinowski, 1926).
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18 A third issue concerns making and testing predictions. Spivey and others have
19 pioneered methods to measure language processing in real time (Spivey, 2007, pp.74-
20 77). In combination with real time measures of affect, these could test predictions
21 about how, for example, affect guides hearers towards inferences in narrative
22 processing. Rapid advances in the verbal classification of images by neural networks
23 suggest that upending these networks to produce images from text (as readers do) may
24 reveal surprising implicit causal frameworks (Mordvintsev, 2015).
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33 Conclusion

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35 Describing narrative experience in a PP, neural network framework reveals
36 that the range of benefits we reap from stories may be both more subtle and more
37 widely diffused than we realise. Narrative experience may be a highly creative
38 process, reconceiving the world as recognisable, yet with a different causal structure
39 to that in which we live and move and have our being.
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5 THE FLOW OF NARRATIVE IN THE MIND UNMOORED: AN ACCOUNT OF
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7 NARRATIVE PROCESSING
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11 *Philosophical Psychology*

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38 **ABSTRACT**

39
40 Verbal narratives provide incomplete information and can be very long. Yet readers
41
42 and hearers often effortlessly fill in the gaps, and make connections across long
43
44 stretches of text, sometimes even finding this immersive. How is this done? In the last
45
46 few decades, event-indexing situation modelling and complementary accounts of
47
48 narrative emotion have suggested answers. ~~But~~ despite this progress, comparisons
49
50 between real life perception and narrative experience might underplay they way
51
52 narrative processing modifies our world model, and the role of those emotions that do
53
54 not relate to characters ~~both changes to our model of the world in narrative processing,~~
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3 ~~and the role of reader emotions which are unrelated to characters.~~ I reframe narrative
4
5 experience in predictive processing and neural networks, capturing continuity
6
7 between fiction, perception and states like dreaming and imagination, enabled
8
9 ~~by~~through the flexible instantiation of concepts. In this framework, narrative
10
11 experience is more clearly revealed as a creative experience that can share some of
12
13 the phenomenology of dreams.
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16 17 18 KEYWORDS

19
20 stories; narrative; situation model; event indexing; emotion; neural ~~network~~;
21
22 predictive processing; creativity.
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26 27 Introduction

28
29 *The tale of two men who went to look for Old Man Furry.*

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31 And they were strong, both of them, and the one had killed many bears, but the
32
33 other had not hunted bears before, and he was afraid, and untrained. And when
34
35 they found Old Man Furry, he was so angry that he rushed upon them in an
36
37 instant, and they jumped behind a big pine tree (Turi, 1931, p.128).
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41
42 How might the Sami audience listening to this story have known why the men
43
44 jumped behind a tree? How did they remember, as the story continued, that only one
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46 was an experienced hunter? And why might they have kept listening? These questions
47
48 can be framed as: how do we infer missing information from a narrative text? how do
49
50 we connect information across the text so as to experience it as coherent? and why
51
52 can stories be immersive, rendering us indifferent to our environments and usual
53
54 trains of thought?
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3 To answer these questions, I begin with a summary of event-indexed
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5 processing leading to situation models, currently the dominant account of verbal
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7 narrative processing. I suggest that despite many strengths, this account of narrative
8
9 processing is constrained by a separation between inferred information and emotion. I
10
11 suggest a way to redescribe narrative processing using predictive processing (PP) in a
12
13 high dimensional vector space, allowing a holistic ‘single computation’ of all aspects
14
15 of narrative experience (Clark 2016, 296). This approach recognises the existence of
16
17 the situation model (SM) as one level of memory representation arising from narrative
18
19 processing. Skeletal event sequences identified by anthropologists of oral narrative,
20
21 used after the event to retell/adapt stories, for example, bear some resemblance to
22
23 SMs (Bauman 1986, chapter 5; Aarne and Thompson, 1928). It is not the only level,
24
25 but I argue that the aspects of narrative processing relating to other levels of
26
27 representation must be recruited to explain the SM level; that the inferences leading to
28
29 an SM must draw on the full range of narrative experience. The article offers a holistic
30
31 account of narrative processing looking at the dynamic interactions of emotion and
32
33 inference and the ways they depart from real world perception. Seen like this,
34
35 narrative processing can not only simulate the world, but imaginatively remodel it.

36 37 38 39 Situation models and event indexing

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41 In the 1960s researchers on narrative often assumed modular models of
42
43 language processing, representing the text’s linguistic form rather than directly
44
45 representing content (Katz & Postal, 1964; Blumenthal, 1967; Sachs, 1967).
46
47 Bransford and colleagues challenged these assumptions in the early 1970s, showing
48
49 how spatial representations are needed to process sentences like this one: “Three
50
51 turtles rested on a floating log and a turtle swam beneath them”. They concluded that
52
53 sentences should not be “viewed as linguistic objects to be remembered” but as
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3 “information which [people] can use to construct semantic descriptions of situations”
4
5 (Bransford, Barclay & Franks, 1972, p.194).
6

7 These findings were followed in the 1980s by Johnson-Laird’s work (1983) on
8
9 mental models and van Dijk and Kintsch’s (1983) on situation models. Johnson-Laird
10 argued that “human beings understand the world by constructing working models of it
11
12 in their minds,” models which “are simpler than the entities they represent” (Johnson-
13
14 Laird, 1983, p.10). Van Dijk and Kintsch proposed a distinction between “the text
15
16 representation proper” and “a model that the reader or hearer constructs about the
17
18 relevant information for the adequate comprehension of the text” (Van Dijk &
19
20 Kintsch 1983, p.337). This combined body of work suggested that verbal narrative
21
22 processing, using spatial representations, enables the creation of SMs (Morrow,
23
24 Greenspan & Bower, 1987). This does not commit SM advocates to the claim that
25
26 SMs are the only level of memory representation produced by narrative processing,
27
28 although, as Mar & Oatley observe (2008, p.174), SMs can explain memory for text
29
30 narrative at both automatic (Gerrig & O’Brien, 2005; McKoon & Ratcliff, 1998) and
31
32 conscious, intentional levels (Graesser et al, 1994), and support inferences arising not
33
34 just from spatial relationships, but also ~~from~~ characters’ short and long term goals
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36 (Glenberg et al, 1987; Trabasso & Wiley 2005).
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41 Narrative text was also increasingly analysed in hierarchically organised
42
43 chunks. In Van Dijk and Kintsch’s “macro structure theory,” for example, plot exists
44
45 at a macro level and has a rule governed relationship to micro episodes (van Dijk,
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47 1977; Kintsch, 1977; Kintsch & van Dijk, 1978). Emerging “story grammar” theories
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49 also involved hierarchical organisation around characters and their goals (Rumelhart
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51 1975, 1977; Meyer, 1975; Thorndyke, 1977; Mandler & Johnson, 1977; Stein &
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53 Glenn, 1979).
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3 These hierarchical organisations of narrative resembled new accounts of event
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5 perception. Events are bounded, hierarchically nested, segments of time. “Opening a
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7 door,” for example, can be one event within the higher order event of “arriving at a
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9 party” (Newtson, 1973; Zacks & Tversky, 2001). An event boundary is perceived
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11 when there is simultaneous change across a set of key dimensions (Zacks et al, 2007).
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13 The “event indexing model” provided an explanation of how narrative processing
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15 could lead to SMs (Zwaan, Langston & Graesser, 1995; Zwaan, Magliano &
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17 Graesser, 1995). In what follows, I suggest that replacing this limited number of
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19 commonsense dimensions with a high dimensional vector space can improve our
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21 understanding of the relationship between event segmentation, the creation of SMs
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23 and narrative experience more broadly.
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26 The existing dimensions of event change indexed by readers are: which
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28 character is this?; change in characters’ goals; new information about causation;
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30 change in location; change in the time of events narrated; and change in characters’
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32 interactions with objects (Zwaan & Radvansky, 1998; Zacks, Speer & Reynolds,
33
34 2009). This model is used by most researchers working on narrative processing ~~today~~
35
36 (for examples, see Zacks, 2015; Chow et al, 2014; Muijselaar, 2015). The production
37
38 of SMs can provide readers and hearers of verbal narrative with a global sense of a
39
40 story, by organising information around the key dimensions (Sanford & Emmott
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42 2013, pp.37 – 38). The production of SMs also relates to narrative inferences: the
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44 situation builds in knowledge of the world, which is not always explicit in the text.
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46 The process of SM construction has been used to explain immersion in verbal
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48 narrative through embodied language processing drawing on behavioural and
49
50 neuroimaging work in embodied language processing such as that of Reddy (2010),
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52 Hauk (2008), Barsalou (2008), Glenburg & Kaschak (2002), Speer et al (2007) and
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3 | others (Zwaan, 1999). These approaches to narrative processing are compatible with,
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5 | and sometimes supported by, accounts of emotion and empathy in response to film
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7 | and verbal narrative by Tan, Sanford & Emmott and others (Tan 1994; Sanford &
8
9 | Emmott, 2013, 44, pp.191 - 232).
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11 | By moving from modular models of verbatim text representation, event
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13 | indexing and situation modelling have revealed shared elements in narrative
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15 | processing across media, including film (Zacks, 2015; Speer, Zacks and Reynolds,
16
17 | 2007; Magliano, 2012), and a comparative framework for variations in narrative
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19 | processing between individuals (Kurby, 2011; Bohn-Gettler, 2011). They make clear
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21 | predictions, for example that processing at event boundaries in the text will be slower
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23 | (Zacks, Speer & Reynolds, 2000). By recruiting embodied language processing to
24
25 | verbal narrative, they share in a broader move towards embodiment in the cognitive
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27 | sciences (Clark, 1997; Clark, 2016, pp. 109-240).
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31 | These gains have been won by recruiting the resources of everyday perception
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33 | (Zacks, 2015). However, the current account of the processing behind SMs may
34
35 | neglect the status of verbal narrative as an artefact, a product of human behaviour,
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37 | whose processing may be comparable to cognition of, say, music or handwriting
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39 | (Knoblich et al, 2002; Overy & Molnar-Szakacs, 2009). In what follows, I exploit the
40
41 | flexible frameworks of PP and neural networks to explore differences between the
42
43 | narrative processing that produces SMs, and everyday perception.
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45 |

46 | I illustrate my account with the case of a child listening to a fairy tale. Fairy
47
48 | tales come closer to a universal narrative experience than the texts used in many
49
50 | experiments; they are found in diverse cultures and periods, and are accessible to very
51
52 | young hearers with a minimum of prior skill in narrative comprehension (Tehrani,
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54 | 2003, pp.1-11; Aarne and Thompson, 1928).
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Listening to *The Juniper Tree*

The Juniper Tree was collected and edited by the Grimm brothers in the early nineteenth century, and has several cognates in other cultures (Grimms 1973, 314-332; Aarne and Thompson 1928, tale type 720). Very young children, from a wide range of cultures, frequently become immersed in stories like this, as the tales' persistence across time and place, and with young audiences, suggests (Tehrani, 2003, pp.1-11; Whitehead 1999, pp.104-107). I analyse the opening of *The Juniper Tree* in the light of existing approaches to the processing that leads to SMs and discuss some problems this analysis identifies:

It is a long time ago now, as much as two thousand years maybe, that there was a rich man and he had a wife and she was beautiful and good, and they loved each other very much but they had no children even though they wanted some so much, the wife prayed and prayed for one both day and night, and still they did not and they did not get one. In front of their house was a garden and in the garden stood a juniper tree. Once, in wintertime, the woman stood under the tree and peeled herself an apple, and as she was peeling the apple she cut her finger and the blood fell onto the snow. "Ah," said the woman and sighed a deep sigh, and she looked at the blood before her and her heart ached. "If I only had a child as red as blood and as white as snow." And as she said it, it made her feel very happy, as if it was really going to happen (Grimms, 1973, pp.314-315).

There are several examples here of the five dimensions of change (time, space, causation, motivation and protagonist; Zwaan & Radvansky 1998): longing for a child and peeling an apple (goals); and "in winter" or "under the tree" (changes in time and

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3 location). Situation modelling of verbal narrative involves an embodied approach to
4 modelling space, and event-indexing in narrative involves simulating embodied
5 experiences of real life environments (Zacks, 2015, 449). These embodied
6 experiences can be seen as a source of emotion, either intrinsic to creating the SM
7 (Zwaan 2009), or complementary to it (Sanford & Emmott, 2012, pp.191 - 232). The
8 potential for embodied responses to the text through actions - peeling an apple,
9 cutting a finger, looking at blood on snow – can help, then, to explain immersion if it
10 occurs.
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20 But here also lies a problem. If an embodied response to a text about cutting a
21 finger and bleeding generates emotion, the emotion ought to be negative, even
22 distressing, particularly for child hearers. The *character's* happiness might then be
23 experienced as incoherent. Yet the success of this tale, particularly with children,
24 included repeatedly in editions of Grimms' tales over 200 years, suggests that it is
25 not.
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33 Generic experience of fairy tales might help hearers to bridge the gap between
34 real life experience and narrative. Genre knowledge could certainly prepare the child
35 hearer for departures from real world experience, such as minimally counterintuitive
36 concepts, like the talking bird who appears later [in the tale](#) (Norenzayan 2006;
37 Thompson 1955-1958). But generic knowledge cannot filter “happiness” from the
38 range of relevant potential responses to injuring one's finger; a generic example like
39 Sleeping Beauty could even make this harder (Kibbe et al, 2017).
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48 An alternative solution to explain how processing produces the relevant
49 information for an SM might be to distinguish reader emotion from the emotion in
50 response to character alone. Moves in this direction have been made by Tan (1994)
51 and Sanford & Emmott (2013). Tan attributes to readers/viewers not, or not just, the
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3 simulated emotions of characters, but the emotions of an impotent *witness* of the
4 characters, and argues that these emotions enable, rather than just arising from,
5 predictive inferences (Tan 1994, p.184). Sanford and Emmott suggest that “scenario
6 mapping” and embodied responses allow the emotions of characters to be “built into”
7 readers’ “mental representations”. These lead to reader emotions, modulated by
8 approval, liking or closeness to the characters into macro narrative structures of
9 curiosity, surprise and suspense, which can generate arousal jags and boosts (pp.196,
10 207; drawing on Berlyne 1960, 1971; Brewer and Lichtenstein, 1982; Sternberg 1978,
11 2003).

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22 On their own, however, these accounts cannot solve the problem with *The*
23 *Juniper Tree*. Children are frequently impotent witnesses of scenes involving adults,
24 and it is not clear that in this case the child’s response to seeing an adult woman cut
25 her finger would enable her to predict the woman’s happiness. This passage may
26 create distance rather than Sanford and Emmott’s closeness – the characters exist in
27 an unspecified place and a distant and unspecified time. They have morally attractive
28 characteristics – they love one another, they would love a child – but they perform no
29 actions in this passage ~~that~~ which are open to moral evaluation either way. It would be
30 hard to say that a four-year-old child has enough here to generate liking, dislike or
31 (dis)approval. This would be hard to settle without empirical investigation, but it is at
32 least questionable that emotions arising from closeness, approval and liking, in turn
33 leading to hopes and fears, and from there to arousal jags and boosts, can explain why
34 very young children ~~can~~ are not puzzled by the woman’s response to a cut finger.

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50 A holistic account of the hearer’s emotional responses to narrative, however,
51 can build on Tan’s alertness to the role of reader/hearer impotence in narrative
52 experience, and of the distinction between reader emotion and character emotion. In

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3 perception, we *act* on the environment to deepen our understanding of it, if only
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5 through eye saccades (Grimes, 1996; Smith and Henderson, 2008; Henderson, 2003).
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7 In narrative experience, however, we are unmoored from our immediate environment;
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9 the hearer of a narrative cannot act on the stimulus to derive greater sensual
10
11 information about the scene depicted. Both perception and narrative may engage the
12
13 same machinery of predicting incoming signals, as I discuss below (Clark 2016;
14
15 Gerrans 2014). But the concepts instantiated by language cannot always be
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17 interrogated in the same sensory depth as those arising from perception and action
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19 embedded in an environment. Instead, they may be experienced in relationship to one
20
21 another, isolated from a shared environment. Even the eye saccades crucial to film
22
23 comprehension can be highly determined by lighting, camera angle, montage etc, and
24
25 the film is not fully available for ecological interrogation through the viewer's bodily
26
27 location and action (Cutting et al 2011; Hasson et al 2008; Loschky et al 2015;
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29 Gibson 1979).
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33 In the first part of the passage from *The Juniper Tree*, the hearer encounters
34
35 the concepts of a rich man, a good and beautiful wife, the absence of a child, longing
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37 for a child and praying for a child. The hearer's passivity, her inability to act on the
38
39 stimulus, means that none of this information can be further probed. The man and the
40
41 wife may give rise to embodied neural effects in relevant sensory and motor areas, but
42
43 these are not instantiated in relation to the child's perceiving body. Encountering a
44
45 "rich man" face to face, for example, would instantiate a power relationship with a
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47 child, with embodied consequences (Fiske et al, 2016). Encountering the concept
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49 through language, however, potentially neutralises such effects and frees the set of
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51 concepts to interact in novel ways. The "feature tuning" of mental images in response
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53 to nouns (such as "man" and "wife") can vary considerably with verbal context
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3 (Mitchell & Cusack, 2016, pp. 4 – 7). “Man” and “wife”, dis-embedded from a rich
4 scene, might mutually influence each other’s instantiations. “Rich” in conjunction
5 with “beautiful” might give prominence to the beautiful belongings that wealth can
6 buy, rather than, say, the cruel behaviour that wealth can sometimes enable.
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11 The interactions of this small set of concepts then (“man”, “wife”, “rich”,
12 “beautiful”), when experienced passively (in the sense that the body cannot glean
13 additional sensory information), in isolation from an environment, and unmoored
14 from a perceiving body, may subtly modify the hearer’s statistical model of the
15 world’s hierarchy of proximal and distal causes and effects (Clark, 2016; Kirchhoff
16 2018). For example, the conjunction of “good”, “rich”, “loving” and “beautiful” with
17 “lack” and “longing” may point to a rightly ordered world that has somehow gone
18 wrong; the blessed can also be unblessed. Similarly, the imagery of blood on snow
19 can be separated from the embodied experience of the cut, so that the blood and snow
20 - again, pushed together through isolation from a perceiving body in a richer
21 environment - can be instantiated through contrasts of colour, temperature and
22 texture. As their other features drop out, the aesthetic effect of this combination may
23 dominate the potential for distress in a child’s simulation of cutting herself and
24 watching herself bleed, recalling Miall and Kuiken’s distinction between “narrative
25 emotions” (relating to characters) and “aesthetic emotions” (Miall & Kuiken, 1994,
26 1999). The isolation, and then conjunction, of juniper tree, snow, blood, apple,
27 aesthetic thrill, and a sudden transition from longing to joy then become causally
28 implicated in the subsequent conception of a child.
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50 This analysis shows the kind of thing that *could* happen, rather than what must
51 happen, but it is enough to raise a doubt that the existing account of event
52 segmentation, leading to SMs, using a fixed set of commonsense dimensions,
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3 alongside theories of emotional response to characters, can explain this and similar
4 narrative inferences which are needed for the SM. In the next section I explore the
5 mechanisms by which this hearer might be immersed in narrative through the
6 unfolding of a subtly unfamiliar trajectory; a succession of points in a multi-
7 dimensional space.
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13 Stratified versus holistic organisation of narrative information

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15 Zwaan and Radvansky predict that there may turn out to be more than five
16 narrative dimensions involved in the production of SMs (p.167; see Rapp, 2001 for a
17 proposed addition). But there is currently no suggestion that the number extends
18 beyond common sense concepts such as “location” or “goal”. If “Bill is very tall”
19 turns out to be irrelevant to subsequent situations, it is “relegated” and excluded from
20 “subsequent situation models”.- If the reader later finds that “Bill could see over
21 everyone’s head”, the information can be retrieved and “stored directly with the token
22 in the model” (Zwaan and Radvansky, 1998, pp.11, 17, 19 - 20).
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33 Zwaan and Radvansky are not proposing, then, a division of information into
34 “modelled” and “discarded”. But their account does imply that incoming information
35 can and should be identified as having greater or lesser importance for the model. If
36 *all* the incoming information could immediately be incorporated in the model without
37 compromising it, there would be no need to monitor the dimensions. The power of an
38 SM is not just, as Zwaan and Radvansky correctly point out (pp.162-163), that it is
39 more efficient than storing representations of verbatim text, but that it is more
40 efficient than treating all of the *information* provided by verbatim text as equally
41 important. While other levels of narrative memory and representation may operate
42 outside an informational hierarchy of this kind, it would seem to be essential for event
43 segmentation and the formation of SMs.
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3 I suggest, however, that in the case of *The Juniper Tree*, dividing the textual
4 information in this way can only be done by sacrificing, among other things, the
5 contribution of emotion to narrative inference and coherence. Look again at the
6 quotation above, from, “In front of their house...”. To update her SM as she hears this
7 passage, the child hearer must identify information relevant to goals and causes, two
8 of Zwaan’s and Radvansky’s dimensions; that the woman sighed, and that her heart
9 ached, not because her finger was sore or her apple spoiled, but because the
10 experience seemed somehow relevant to her desire to have a child.
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20 But the fine detail of the “irrelevant” information, I suggest, is important to
21 emotion, and the role of emotion in processing. In combination, these elements
22 configure an emotional experience which has no counterpart in the child’s real life
23 experiences of apples and knives, an experience which reveals that the woman’s
24 longing will be fulfilled because, in mysterious ways, nature wills it so.
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31 We can illustrate this point in a different way by reverse engineering a
32 segment of Zwaan and Radvansky’s illustration of the processing behind SMs - “Peter
33 took the elevator to the fifth floor. He went to talk to his professor”:
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40 ...When reading the first sentence, the reader creates a situation model
41 involving a token that represents a male individual named Peter who rides an
42 elevator for as yet unknown reasons. We assume that the reader infers that Peter
43 is in a building and that the event took place before the moment of utterance of
44 the sentence....This [second] sentence is integrated with the first one on several
45 dimensions. First, the pronoun is a cue to the comprehender to look
46 backward...in the integrated model for an appropriate referent. This referent is
47 found in Peter, who is the only available referent and shares the feature “male”.
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Second, a goal is constructed (“went to” suggests intentionality...). Third, the absence of a shift in tense or any other explicit temporal marker indicates that we are still in the same temporal interval... Fourth, the absence of a spatial marker indicates we are still in the same spatial region.... Fifth, a second token is created representing the professor. The reader probably also infers that Peter is a student. This is the content of the current model at Time t_2 .

This can be represented schematically:

t_1 Create PETER^{TOKEN (male)}

t_1 Create ELEVATOR IN BUILDING IN PAST^{SPATIO-TEMPORAL FRAMEWORK}

t_1 Combine PETER^{TOKEN (male)} in ELEVATOR IN BUILDING IN PAST^{SPATIO-TEMPORAL FRAMEWORK}

t_2 Create PROFESSOR^{TOKEN (male)}

t_2 Modify PETER^{TOKEN (male)} with GOAL^{VISIT PROFESSOR} and with ^(student)

t_2 Incorporate t_2 elements with t_1 elements.

If we use this set of instructions to generate a new text, one possibility of many is this:

“Peter rode in the elevator up, up, up. His professor waited as Peter came nearer and nearer.” This text is different from the initial one in many ways, from the professor waiting, to the absence of “the fifth floor”. But it is as compatible with the *situation model* above as the original. The reader’s emotion, however, is likely to be different. The stylistic emphasis on the changing relative distance between Peter and the professor may create an element of anxious anticipation. Emotion arising from verbal form may *underpin* the inference of information, rather than the reverse (compare Barrett and Bar, 2009). The verbal form suggests that either Peter or the Professor has

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3 something to fear from the encounter. Peter's goal may not be related to their roles of
4 student and professor; Peter may not be a student at all if his relationship to the
5 professor may be that of, say, victim or aggressor. The repetitions of "up" and
6
7 "nearer" do not provide new information on the SM's dimensions. Yet their emotional
8
9 impact on the reader is important for identifying precisely the information – such as
10
11 characters' goals - which an SM is intended to capture. While the SM itself need not
12
13 capture reader emotion, the processing leading up to it must if the information in the
14
15 SM is to be correct (for earlier work pointing in this direction, see McNamara &
16
17 Magliano, 2009 and Graesser, Olde & Klettke 2002).
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22 Suppose the repetitions in "up and up" and "nearer and nearer" cause fear,
23
24 telling the reader that either Peter or the professor has a sinister goal. Could this
25
26 simply mean a different "goal" node than the model of the first passage? The spatio-
27
28 temporal information still models Peter in an elevator and the professor in a room, just
29
30 as in the first case.
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33 But if the repetitions of "up" and "nearer" simply switch the goal node from
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35 "visit professor, probably in relation to studies" to "go to professor's room, not clear
36
37 why, but this may involve danger either to Peter or the professor", does this bundle of
38
39 information, a bundle which must be expanded if it is to include *all* the implications
40
41 of fear, deserve the name of "goal node"? Recall that the strength of SMs is saving the
42
43 hearer or reader from remembering not only all the verbatim text, but all of the
44
45 information conveyed by that text. If the model is to incorporate all the *implicit*
46
47 information generated by emotion, it will be burdened with even more information
48
49 than that of the verbatim text. If emotion is treated as information encoded in the text,
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51 then it cannot be incorporated in an SM. Yet, as we have seen, emotion may be
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53 crucial to help a child make correct inferences about texts like *The Juniper Tree*. An
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3 improved account of narrative processing, then, will be holistic in its approach to
4 information, and distinguish more clearly between the experiential aspects of
5 perceiving something, and those of hearing or reading about it.
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9 A first step is to rethink the processing behind SMs as structured not by five or
10 six common sense dimensions, but by dimensions too many to enumerate, resisting
11 commonplace psychological categorisation. A neural network model of processing in
12 this high dimensional vector space (explained below) can capture recurring
13 experiences in processing a given text, including the effects of verbal patterning,
14 emotion and the perception of language as agent guided behaviour. Characterising
15 those recurrent, downward projections as predictive can also suggest a convincing
16 story about immersion in a flow of inner states, and explain overlaps in
17 phenomenology between dreaming and narrative immersion.
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20 High dimensional vector spaces and verbal narrative

21
22 Think of a word as a sequence of sounds, where each sound has the potential
23 to differentially activate every cell in an array. Each phoneme will come to be
24 associated with a different pattern, or vector, of activation. The array activates
25 another, higher, array through a set of connecting links or synapses, which in turn
26 activates the next, and so on. The varying strengths or weights of these connections
27 between layers have been determined by past experience, and form matrices which
28 transform the vectors and allow recognition of groups of sounds, then words, phrases,
29 clauses, sentences and so on (Rumelhart & McClelland, 1986; Churchland, 2012;
30 Jordan, 1986).
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34 As well as these upward connections, each array has downward connections to
35 the one below. This means that the effect of one input on the system can affect the
36 way the next input is received, so that frequently repeated sequences of inputs are
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3 more easily recognised than others (Churchland, 2012, pp.165-170). At a certain level
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5 or levels, the points in the vector space initially activated by speech sounds move into
6
7 spaces generated by a much wider range of stimuli associated with those speech
8
9 sounds. On hearing the sounds for the word “apple”, for example, a processing
10
11 journey begins which, depending on the context, may end in an area of vector space
12
13 overlapping, though not identical with, that activated by seeing a real apple (Reddy et
14
15 al, 2010).

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18 Now let us revisit *The Juniper Tree*. How does the hearer make the link
19
20 between the interactions of a cluster of concepts (juniper, apple, blood, snow), the
21
22 emotion associated with those interactions, and a character’s conception of a longed
23
24 for child? At first blush, adopting a vector space framework takes us no further
25
26 forward with this problem. The world model of interacting causes built into this
27
28 framework is embedded in the matrices of connection weights, and altering these
29
30 weights is a slow and cumulative process, a matter of weeks or years, not the seconds
31
32 or fractions of seconds involved in responding to a section of a story. How can
33
34 hearing a brief text, or fragment of text, temporarily modify these weights to
35
36 accommodate a different analysis, one in which cut fingers activate representations
37
38 involving beauty and yearning rather than pain and distress, for example?
39
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42 One possibility is that instead of modifying the matrices of *weights*, the
43
44 recurrent, downward connections can modify the stream of *inputs*. In the case of *The*
45
46 *Juniper Tree*, all of the effects of the text to date influence the pattern of downward
47
48 connections in ways that affect the upward impact of new inputs. The succession of
49
50 states and their direction of travel form a trajectory through vector space. In what
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52 follows, I suggest that verbal narratives can stimulate trajectories of this kind that
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3 depart from normal perceptual experience, while staying within the bounds of a pre-
4 existing world model.
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7 Behavioural, neuro-psychological and neuroimaging evidence suggests that
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9 “concepts are flexible, distributed representations comprised of modality specific
10 conceptual features” (Kiefer and Pulvermüller 2012, 805). This flexibility is
11
12 consistent with accounts by Paul Churchland and Margaret Boden characterising the
13 reconceptualization of an input in the “hidden” layers of a neural network as a
14
15 creative process. Each cycle of Newton’s meditations on the moon could modify his
16
17 existing concept a little more, until the moon is less like a wheel running on a track
18
19 and more like a ball thrown by a force (Churchland 2012, pp.187-196; Boden 2004).
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21 The everyday experience of narrative text may similarly push us through otherwise
22
23 unfamiliar trajectories in vector space.
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28 Vector spaces and inference

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31 The extract from *The Juniper Tree*, typically of fairy tales (Thompson, 1946,
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33 p.8), provides minimal information about particulars of place or time. The event
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35 happened “once” and “in winter time” rather than on, say, 4 January 1822. The time,
36
37 then, is indeterminate, as are the unmodified nouns “woman”, “tree”, “apple” and so
38
39 on. Adjectival modification affects the ways in which nouns are processed
40
41 (Westerlund et al, 2015; Bemis & Pylkkänen, 2013). Each of the unmodified concrete
42
43 nouns in this case, then, could potentially activate an area of vector space associated
44
45 with a prototypical representation (of women, trees, apples and so on), areas which
46
47 capture averages of similarity and difference across multiple dimensions, thus
48
49 enabling real life recognition of a particular woman, tree or apple by its location
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51 relative to the average. Coming as they do in a sequence, the downward, recurring
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53 connections generated by these nouns create a context in which singular entities (the
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3 particular woman, tree, apple of the story) are reconceptualised as prototypical ones
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5 (compare the comments on style and prediction in Kuperberg & Jaeger, 2016, p.48).
6
7 The later nouns “blood” and “snow” arrive in, and reinforce, a landscape of
8
9 prototypes. A real life encounter with objects and people that all coincided precisely
10
11 with the average of their type might create a sense of the uncanny, and “seemingly
12
13 invite a supernatural explanation” (Bouvet and Bonnefon, 2015, p. 956).
14

15
16 A second contextual effect could arise from repeated syntactic patterns. The
17
18 text consists mainly of additive clauses – “and as she was peeling...and the blood
19
20 fell...and she looked...and her heart ached” – with little of the subordination (“she cut
21
22 her finger causing the blood to fall”, “her heart ached because...”) that can point
23
24 directly to causal relationships (Morera et al, 2017). In perception, a repeated
25
26 temporal sequence can have a strong, sometimes misleading, association with
27
28 causality (Churchland, 2012, pp.177-178). However, the recurrent connections
29
30 generated by a repeated syntactic pattern of additive clauses could undo this because
31
32 the hearer is not free to probe causation as she would in a richer environment.
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35
36 By contrast, perception of a scene like this in a real world, rich environment
37
38 *would* be structured by causal relationships. The appearance of the woman would be
39
40 modulated by effects of light and shadow caused by the tree and the snow (Kersten et
41
42 al 1997). Spatial structure has long been understood as important to perceiving causal
43
44 narrative structure (Heider 1944), just as internal scene construction is critical to both
45
46 episodic memory and verbal narrative (Mullally et al 2012). In this case, in the
47
48 absence of a causal structure relating many of the elements in the scene, and in a
49
50 landscape of syntactically weakened causal links, other patterns of similarity and
51
52 difference can interpret the relationships between inputs. The tastes and textures of
53
54 apples, for example, and the texture and temperature of snow could be located in
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3 adjacent or overlapping areas of vector space, as multisensory integration (Stein et al,
4 1988) is released from the constraints imposed by real world stimuli. The pain of a cut
5 might be measured against the colour and temperature of blood. In a real world scene
6 these modality specific overlaps may be unimportant, but here, in a sparser, less
7 defined scene, they take on new power. The synaesthetic effects of this process
8 would, moreover, have an aesthetic reward (Ward et al, 2008).

9
10
11 Now let us imagine that the hearer has had many disappointed hopes, but has
12 also experienced a powerful hope turning into a belief. The move from hope to belief,
13 then, is a possible sequence for her, but not a necessary one. In a context coloured by
14 the uncanny and by aesthetic reward, a context in which normal causal relations have
15 been muted, this sequence (of hope turning to belief) may become the most likely
16 path for upcoming activation (compare Clark, 2016, pp.231 – 237). The hearer can
17 hypothesise that the woman sighs because of longing, not physical pain, without
18 modifying her world model's matrix of weights.

19 A vector space account of narrative coherence

20
21 In 1990, the cognitive scientist Jeffrey Elman discussed the problems of
22 representing time in parallel, distributed, connectionist models of cognition, similar to
23 the neural networks outlined above. Until then, Elman explained, a common approach
24 to the parallel processing of sequentially structured inputs, like language, had been to
25 treat time as “an additional dimension of the input” by giving it an explicit “spatial
26 representation”. The first item in a verbal sequence could be represented in the first
27 space in a vector, and so on. Elman argued that this approach runs into intractable
28 problems (which I do not discuss here; Elman, 1990). Time is an explicit dimension
29 of the input to SMs in existing accounts: a complete SM, ‘stored in long-term memory
30 after all the textual input has been processed’ will consist of ‘the situations at Times t_1

1
2
3 through t_x ', allowing comprehenders to 'ruminate over a story' later (Zwaan &
4 Radvansky 1998, 166). While not described as a spatial representation in the form of
5 a numerical matrix, this is an approach which makes time an explicit dimension in
6
7 both processing (one of the five associated with SMs) and output (the SM itself).
8
9

10
11 Instead of treating time as a dimension of the input, Elman suggested instead
12 an implicit representation of time in which a layer of "context" cells is added to the
13 layers of "hidden" cells. At time t :
14
15

16
17 Both the input units and context units activate the hidden units; the hidden
18 units then feed forward to activate the output units. The hidden units also feed
19
20 back to activate the context units. (Elman 1990, p.182).
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29 The context units modify future inputs by responding to previous inputs. In this way,
30 time can be represented through its cumulative effects "on processing and not as an
31 additional dimension of the input".
32
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34
35 A "spatial metaphor for time" of the kind identified by Elman as problematic
36 is implied by the SM's linear structure from t_1 to t_x , which ensures coherence, letting
37 the reader 'know when the described events took place both relative to each other and
38
39 relative to the time at which they were narrated' - (Elman, 1990, p.181; Zwaan &
40 Radvansky, 1998, p.181).- But are such representations of time always essential to the
41
42 processing that enables SMs? If I am asked to write a reference, I might try to recall
43
44 specific instances of the candidate's past behaviour. However, if I predict what my
45
46 friend will order at a restaurant, I need not bring to mind all or any of the past
47
48 episodes underwriting that prediction, even if I could. To test narrative
49
50 comprehension, researchers need to resolve the experience of verbal narrative into
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3 actions after the event, such as answering questions about a story accurately, or
4 retelling it (Ennemoser 2007, p. 354; Strong 1998). One way to describe this is the
5 ability to interrogate the SM which arose from processing the narrative.
6
7

8
9 But there is another way to think about, and potentially even measure, verbal
10 narrative comprehension: the success of a cognitive system in continually moving
11 towards stasis in response to an incoming flow of text (Spivey, 2007, p.36 and
12 elsewhere). A child hearer could experience this move to stasis yet still perhaps be
13 unable, if asked, to accurately reconstruct a timeline of the story or answer questions
14 accurately. Even scrub jays can “remember” sequences of their own actions without,
15 presumably, being able to represent those sequences to themselves or to others
16 (Clayton and Dickinson 1998, 1999; Suddendorf and Busby, 2003). As Elman points
17 out, “The representation of time – and memory – is highly task-dependent”. A
18 potentially explicit spatial representation of time may be essential to the task of
19 *reproducing* a story. But it is not necessarily essential to *experiencing* the flow of
20 verbal narrative as coherent.
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35 *The Juniper Tree* continues with the woman’s pregnancy, her death from
36 happiness on giving birth, and her husband’s remarriage:
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41 By the second wife he had a daughter, but the child of his first wife was a little
42 son as red as blood and as white as snow. Now when the woman looked at her
43 daughter she loved her so, but looking at the little boy cut her to the heart.
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50 Not long after, the stepmother kills the boy and hides the evidence by cooking the
51 body parts in a stew. The text never refers to her as “the stepmother” but as “the
52 woman” or, when addressed by the boy himself, “mother”: “Mother,” said the little
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3 boy, “how strange and wild you look!”. To avoid confusion with the real mother, and
4
5 experience the story as coherent, the child hearer must remember that the real mother
6
7 died and was replaced by a wicked stepmother. One solution is to tag the mother’s
8
9 death and the stepmother’s arrival as t_x and t_{x+1} , ready for incorporation in an SM by
10
11 situating them on a timeline. But the child’s experience of the text as coherent can be
12
13 explained without this explicit representation of time:
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18 And so the mother took the little boy and hacked him in pieces and put the
19
20 pieces in the pot and stewed him in the sour broth. But Ann Marie stood by and
21
22 cried and cried and the tears fell in the pot so that it didn’t need any salt.
23
24 When the father came home he sat down to supper and said, “And where is my
25
26 son?” And so the mother brought a big dish of black stew and Ann Marie cried
27
28 and couldn’t stop crying.
29
30

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32
33 I argued above that the real mother could be generated in areas of vector space which
34
35 involved the uncanny and the aesthetic effects of synaesthesia. The stepmother, on the
36
37 other hand, is developed through “taking” and “hacking”, and the objects surrounding
38
39 her are “the pot” and “the sour broth”, reinforced soon after as “a big dish” and “black
40
41 stew”. The difference in the areas of vector space activated in each case mean that
42
43 neither a timeline of death and remarriage, nor a consistent verbal distinction between
44
45 “mother” and “stepmother”, are needed for the child hearer to experience the text as
46
47 coherent. Indeed, at this point in the story she need not even explicitly remember that
48
49 there ever was a good mother. After all, many stories, including oral epic and
50
51 medieval romance, are experienced as coherent even when found, after performance,
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53 to be incoherent and flawed by “continuity errors” (Griffith, 2012).
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A predictive, vector space account of narrative immersion

There is growing evidence that language comprehension is predictive at every level, from phonemes and words to discourse. Probabilistic processing, for example, can pre-activate words in comprehension (DeLong et al, 2005). Grammatical inflections can be anticipated through semantic integration, and word meanings can be predicted on the basis of discourse context (Wicha et al, 2004; Van Berkum et al, 2005; Otten and Van Berkum, 2008). These findings are drawn from different languages, multiple linguistic levels and using varied methodologies (Kamide et al, 2003a; Kamide et al, 2003b; Knoeferle et al, 2005).

We can, then, characterise the downward connections discussed above as predictions about the incoming verbal signal (Clark, 2016, 285-286). In a PP framework, downward hypotheses are met by upward prediction error. Patterns of prediction error simultaneously modify the next wave of downward hypotheses and allocate precision, or increased weight, to the most reliable sources of error for the task at hand. Action is integral to this cycle of hypotheses, prediction error and precision allocation, through, for example, eye saccades.

One outcome of a move to PP, or hypothesising controlled by prediction error (Clark, 2016), is a new account of relationships between cognitive states such as dreaming, hallucination, delusion and imagination (Gerrans, 2014, p.1; Kirchoff, 2018; Seth, 2014, p.101). In what follows I characterise hearing or reading a narrative as a cognitive state in which prediction error is limited to the incoming verbal stream, so that the hearer or reader, to successfully predict the incoming signal, must predict her own inner states, sequestering her sensorimotor responses from the machinery of the world around her.

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3 Actions to probe the environment can help the hearer to predict the stream of
4 words in *The Juniper Tree* only to a limited extent. Perhaps the storyteller has a lisp,
5 and she must compensate for this when predicting phonemes, or perhaps he uses
6 particular gestures in their shared space, and her predictive system might direct
7 saccades to his face and body (Lwin, 2010). But greater attention to arm movements
8 and sound articulation will not help her predict the states of higher levels in her own
9 system, such as the combined effects of synaesthesia and the uncanny identified
10 above. For these, her best – indeed her only – source of information is the trajectory
11 of inner states arising from the experience of the text itself. It is these higher-level
12 inner states which must be explored and probed through the mechanism of precision
13 weighting. The hearer’s own states become her environment as far as predicting the
14 text goes. In this light, the potential for immersion is not surprising.

15
16 Seen like this, narrative experience in one respect resembles dreaming. Both
17 experiences engage the mind in actively predicting an incoming stream of data, but
18 without the body being able to act on its environment to direct that stream. Hobson
19 and Friston characterise sleep as a state “in which internal predictions are sequestered
20 from sensory constraints” (Hobson and Friston, 2012, p.92).

21
22 Embodied responses to language suggest that the reader or hearer of narrative
23 may similarly find her sensorimotor system engaged while sequestered from any
24 stimulus but the verbal stream, and inhibited from *acting* on any stimulus *but* the
25 verbal stream (for example by re-reading a sentence, or asking a reader to pause).
26 Narrative comprehension then, might be characterised as simultaneously active, in the
27 sense that the system has considerable work to do on internal states as it seeks to
28 optimise prediction and achieve stasis, and passive, in that the body has only very
29 limited opportunities to act on its environment in pursuit of that stasis, and must
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3 develop new trajectories from existing resources to account for the succession of
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5 internal states.

6
7 The analogy between narrative immersion and dreaming should not be
8
9 overdone. Narrative stimuli are artefacts, dreams are not. Readers can re-read, but
10
11 dreamers cannot pause and repeat a section of a stimulus. Narrative can engage and
12
13 require conscious effort at problem solving in way that dreams cannot. And readers
14
15 can stop at will. But shared constraints in the two conditions may explain at least
16
17 some of the dream-like phenomenology of narrative immersion.

18
19
20 This account of immersion does not require hearers and readers to feel
21
22 emotions for characters, as some existing theories of transportation do (Gerrig, 1993;
23
24 Green & Brock, 2002). Fairy stories like *The Juniper Tree* can be immersive, but do
25
26 not necessarily encourage direct emotional responses to characters. Stock characters
27
28 are central, not peripheral, to this and other oral genres (Propp, 2010; Lord, 2000).
29
30 The same could be said of immersive responses to a range of other non-realist (in
31
32 Barthes' sense of 'the reality effect'; 1986) fictions, which some readers/hearers find
33
34 immersive, from Homer to Virginia Woolf.

35
36
37 The sketch above does not assume immersion always happens, just as existing
38
39 models do not assume that comprehension always happens. Some stories, or some
40
41 readers, might reveal an easy to predict causal structure involving little emotion, so
42
43 that attention wanders. With others, prediction might be too hard to permit flow, at
44
45 least on a first reading (Csikszentmihalyi, 1990). But a predictive account can explain
46
47 the possibility of later immersion through practice and re-reading, as readers grow
48
49 more expert at predicting a text, like Joyce's *Ulysses* (a tough first read for many, an
50
51 immersive re-read for some), an author or a genre (Kibbe et al, 2017).

52 53 54 Problems

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3 There are potential problems in at least three areas: the cognitive framework;
4
5 a role for conscious reflection; and empirical testing.
6

7 I have drawn on Clark's (2016) account of Bayesian predictive processing
8
9 implemented in a neural network. Clark himself has identified some problems with
10
11 both elements (pp.297-300). Alternative approaches to probabilistic inference have
12
13 been explored in both neural simulations and in studies of the biological brain (Egner
14
15 & Summerfield, 2013). Neural networks may not be the best, or even a possible,
16
17 architecture for a generative, probabilistic approach to cognition (Hinton, 2006;
18
19 Wacongne et al, 2012).
20
21

22 Another concern is the role of higher domain areas, such as conscious verbal
23
24 reasoning, in probabilistic, generative predictive processing (pp.299-300). I have
25
26 argued that implicit, rather than explicit, representations of time may be enough to
27
28 support at least some narrative processing. But conscious reflection on narrative
29
30 experience may be needed to retell, interpret and experience stories as meaningful and
31
32 instructive. Reducing the role of reflection may mean missing some of the point of
33
34 narrative in the first place (Mulhall, 2007; Malinowski, 1926).
35
36

37 A third issue concerns making and testing predictions. Spivey and others have
38
39 pioneered methods to measure language processing in real time (Spivey, 2007, pp.74-
40
41 77). In combination with real time measures of affect, these could test predictions
42
43 about how, for example, affect guides hearers towards inferences in narrative
44
45 processing. Rapid advances in the verbal classification of images by neural networks
46
47 suggest that upending these networks to produce images from text (as readers do) may
48
49 reveal surprising implicit causal frameworks (Mordvintsev, 2015).
50
51

52 Conclusion

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3 Describing narrative experience in a PP, neural network framework reveals
4
5 that the range of benefits we reap from stories may be both more subtle and more
6
7 widely diffused than we realise. Narrative experience may be a highly creative
8
9 process, reconceiving the world as recognisable, yet with a different causal structure
10
11 to that in which we live and move and have our being.
12

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