From Words to Worlds: Is Mental Simulation a Driver of Individual Differences in Processing, Experiencing, and Liking Stories?

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Abstract: Stories allow people to (vicariously) experience other worlds, but what this subjective experience looks like varies from reader to reader. In this paper, we focus on the cognitive and neural mechanisms that give rise to these differences in experience and preference. We argue that differences in reading skill and in the reading "modes" that a reader has access to might be important predictors, together with factors such as the reader's propensity for mental simulation. We discuss evidence to suggest that these differences are reflected in behavioural and neural signatures.

Keywords: Reading, story world absorption, literary appreciation, mental simulation, lexical characteristics

Stories are thought to be a universal aspect of human culture: by providing a narrative context, they offer a cognitively ergonomic way of transmitting and receiving information, cultural values, and beliefs, and are an important source of entertainment and education (Bruner; Rubin). How people process, experience, and like stories, however, appears to be highly dependent on the individual: some people for instance enjoy reading complex literary stories that use defamiliarizing language, whereas others prefer easy-to-read, suspenseful, and action-packed stories. A recent paper showed that, counterintuitively, people who feel more absorbed in a story are also a bit more "detached" from the actual words they were reading as measured by eye tracking (Eekhof et al.), whereas detachment is usually regarded as a sign of disengagement (Faber, Krasich, et al.). Around the same time, it was observed that people vary somewhat systematically in their preferences for specific stories (Mak, Faber, et al., "Different Routes to Liking: How Readers Arrive at Narrative Evaluations"), but that it is unclear what drives this variation.

In the current paper, we aim to bring together these different lines of research, and set out to explore how different reader characteristics influence how people read, experience, and like stories. We ask whether mental simulation—the automatic activation of sensory and emotional information during language processing (Mak and Willems, "Mental Simulation during Literary Reading")—might be an explanatory factor: when the brain is constructing internal representations, the external environment might be processed less deeply, potentially leading to the observed detachment. At the same time, this process might form the basis for or be a driver of people's experience during reading: stronger or richer activations of sensory and emotional information might play a role in how absorbed people feel, and how much they like a story. However, these processes might not happen in isolation, but rather are likely to be constrained by characteristics of the reader, the text, and other factors.

The aim of this paper is to provide a (by no means comprehensive) discussion of evidence for the idea that there are individual differences in how people read, experience, and like stories, and that differences in reading skill and in the reading "modes" that a reader has access to might be important

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predictors of this variation, together with factors such as the reader's propensity for mental simulation. We will take individual differences in word-level reading behaviour as a starting point: as we will argue, these individual differences can likely be explained by both characteristics of the text as well as characteristics of the reader, and importantly, their mental simulation and experience of the story. We will then discuss how mental simulation might be reflected in reading behaviour and neural activity, and what evidence there is for individual differences in mental simulation on the behavioural and neural level. Bringing back the focus of the paper to the aforementioned individual differences in how people read, experience, and like stories, we will discuss some of the characteristics of readers, and what the role of simulation might (and might not) be in determining people's reading preferences and experiences. Finally, we will suggest avenues for further research to elucidate the cognitive and neural processes that underlie subjective reading experiences. We will limit ourselves mostly to the context of one common type of story, namely written, mostly literary, (short) stories and novels.

Individual differences in reading

A large proportion of research into how people process, experience, and like stories has been conducted in the context of reading. This is not entirely surprising given that, notwithstanding centuries of oral storytelling traditions as well as the more recent advent of audiobooks, much of our exposure to literary stories takes place through written books. Although we note that more and more studies also focus on the cognitive processing of stories via other media such as movies (e.g., Grall et al.; Milivojevic et al.) or comics (e.g., Cohn and Schilperoord), for the sake of this paper, we will mostly focus on written literature.

Written literature is a highly suitable medium for studying cognitive processes during reading as it allows for the measurement of reading times and eye movements. A long tradition of research has been built on the idea that eye tracking can be used to measure attention and processing speed during reading (Rayner, "Eye Movements in Reading and Information Processing: 20 Years of Research."; Rayner, "Eye Movements in Reading: Models and Data."; Kliegl and Laubrock; Just and Carpenter). For instance, words or passages that require increased attention are associated with longer reading times. This relationship can be observed in word features such as lexical frequency and word length. Historically, it has been found that words that occur frequently in a language are easier to recognize and process, thus requiring less attention (Juhasz; Juhasz and Rayner; Rayner, "Eye Movements in Reading and Information Processing: 20 Years of Research."; Rayner and Duffy). Although this word frequency effect has been replicated many times over the years (Kuperman et al.), it has been found that this effect is subject to individual differences, for example in language exposure (Brysbaert, Mandera, and Keuleers). Moreover, the word frequency effect has been found to be particularly visible in medium-frequency words as opposed to high-frequency (i.e., over-learned) or low-frequency (under-learned) words (Brysbaert, Mandera, and Keuleers). Similarly, word length has a strong effect on reading times: shorter words are easier to process and require less attention than longer words, as demonstrated by shorter gaze durations for these words (Rayner, "Eye Movements in Reading and Information Processing: 20 Years of Research."). Recent work has argued that word length might even be a stronger predictor of measures of both early- and late-stage language processing than, for instance, word frequency (Kuperman et al.). Additionally, reading speed is not only affected by the characteristics of individual words, but also by the context in which they occur. Words that are highly predictable in their context are easier to process and therefore associated with shorter gaze durations (Goodkind and Bicknell; Hale; Levy; Lopopolo et al.; Kuperman et al.).

These word characteristics, together with others such as word prevalence (i.e., how well-known a word is; Brysbaert, Mandera, McCormick, et al.), age of acquisition (Brysbaert, Buchmeier, et al.), and similarity to other words (e.g., Brysbaert, Mandera, McCormick, et al.; Adelman and Brown) are strong predictors of word processing times, explaining almost 50-70% of variance in lexical decision times (i.e., deciding whether something is a real word; Brysbaert, Mandera, McCormick, et al.). These surface-level word characteristics are also important predictors of reading times in complex reading tasks such as poetry reading and literary reading (e.g., Xue et al.; Eekhof et al.) suggesting that they are robust indicators of cognitive processing across reading tasks.

Given the strong predictive value of surface-level word characteristics, the text in terms of its words thus appears to pose strong constraints on reading behaviour. Indeed, the alignment between reading times and complexity (also known as cognitive coupling) is an important predictor of text comprehension, as stronger alignment is associated with better comprehension (Mills et al.; Rayner et al.). However, this also implies that the strength of this alignment varies among readers. Indeed, it logically follows from the findings cited above that roughly 30-50% of variance is unaccounted for by the combination of lexical factors studied so far[1] (Brysbaert, Mandera, McCormick, et al.), suggesting that the words in the text itself might not be the only predictor of word processing times.

Indeed, another important predictor of word processing times is individual differences in the reader. Individual differences in reading skill have been shown to be predictive of low-level reading behaviour (Eekhof et al.). For instance, the degree to which reading times are predicted by word frequency depends on an individuals' reading skills (e.g., Ashby et al.), vocabulary (Mainz et al.), educational background (Tainturier et al.), and print exposure (Chateau and Jared; Sears et al.; Eekhof et al.). Similar relationships have been shown for the degree to which other word characteristics influence reading times, such as how similar words are to other words, and how long they are (Barton et al.; Chateau and Jared; Sears et al.; Spinelli et al.). It has been proposed that these differences between readers of different skill levels arise from differences in the level of automaticity in their word processing (Brysbaert, Mandera, and Keuleers). As readers are exposed to more words, they develop more stable lexical representations, which allow for faster word recognition. Less skilled readers therefore need to rely on word characteristics and word context more than skilled readers (Kuperman and Van Dyke; Perfetti et al.).

More developed reading skills are also linked to making better or stronger predictions about which words are upcoming based on what is being read: in a sentence like "the brave knight saw the fierce dragon and reached for his ...", most readers are likely to insert the word "sword" (example based on Otten and Van Berkum). The ability to accurately make such predictions allows for faster reading, and for skipping predictable words: around 25-33% of words in a text, and around 75% of the highly frequent two-letter words, are skipped by skilled readers (Leinenger and Rayner; Rayner and McConkie). Less skilled readers are likely to read more slowly (in terms of fixation durations), in particular when they encounter low-frequency words, and are less likely to skip short words (Ashby et al.; Haenggi and Perfetti; Leinenger and Rayner). Recent work has confirmed that word skipping might be a stable individual difference during literary reading, which might be relatively independent of what is being read and how the reader experiences the text (Faber, Mak, et al.).

However, the experience of reading a literary story is more than mere word processing: from time to time, people also feel absorbed or "lost" in a story. Recent work has shown that people not only vary in their sensitivity to surface-level word characteristics during literary story reading, but that these variations are also related to how absorbed people are in the story and how much they like it (Eekhof et al.). Absorption is an experiential state[2] in which readers feel transported to the world of a story, experience emotional responses to the described characters and events, have a vivid mental image of what they read, and are generally focused on the story world is known as story world absorption (Kuijpers, *Absorbing Stories: The Effects of Textual Devices on Absorption and Evaluative Responses*). How strongly a story "grasps" a reader might vary from reader to reader and from story to story (Gerrig; Green and Brock; Jacobs and Willems; Kuijpers et al.; Kuzmičová), as absorption is inherently a subjective phenomenon. Specifically, a higher degree of narrative absorption has been linked to lower degrees of sensitivity to word length, and liking a story more is associated with decreased sensitivity to word frequency, suggesting that being somewhat "detached" from the story in terms of word characteristics is associated with a more pleasant and engaging reading experience (Eekhof et al.).

How mental simulation influences reading

So far, we have argued that there might be a link between word characteristics, which influence reading on the lexical level, and reading experiences such as narrative absorption, which arises at the level of the story (or at least at the level of plot events; cf. Pianzola et al.), and is likely to influence reading both at higher and lower levels. An interesting phenomenon that might be one of the drivers of this link is mental simulation. In the context of language comprehension, an often-used definition of mental simulation is "the re-enactment of perceptual, motor, and introspective states acquired during experience with the world, body, and mind" (Barsalou, p. 618), which might occur when people encounter language that refers to these states. A word like "kick", for instance, can automatically elicit motor simulation, whereas a description of a visual quality of an object can elicit perceptual simulation (Pulvermüller et al.; Moody and Gennari). The simulation of introspective states, for instance what a character in a story is thinking or feeling, is also known as mentalizing (Goldman, "Theory of Mind").

Evidence for the role of mental simulation in language processing stems from the embodied cognition literature, which has proposed that language comprehension recruits mental simulations (although it has been debated to what degree this is the case; Muraki et al.). Tasks like the sentence-picture verification task (Stanfield and Zwaan) and the action-sentence compatibility effect (Glenberg and Kaschak) have been used as evidence that language processing does indeed rely on mental simulation: for instance, evidence has suggested that when presented with a picture of either a horizontally or vertically oriented picture of a pencil after hearing the sentence "John put the pencil in the cup", people find it easier to verify that a pencil was mentioned when they are presented with the congruent visual presentation (i.e., the vertical pencil) than the incongruent one (Stanfield and Zwaan). Similarly, after reading the sentence "Close the drawer", responses have been shown to be faster when they are in line with the direction of the movement (in this case, away from the body; Glenberg and Kaschak).

The findings described above, together with many others, have led to the idea that language must at least to some extent be embodied. However, the degree to which language is embodied has been a topic of much debate (see, e.g., Muraki et al.). For instance, the action-language compatibility effect has been found to be difficult to replicate (Morey et al.; Winter et al.), and not all effects found in sentence-picture verification tasks have been found to be equally strong (Zwaan and Pecher). This has led researchers to conclude that strong embodied theories, in which all concept knowledge is solely represented in simulations, are difficult to substantiate (Muraki et al.). At the same time, consistent replications of colour and shape effects in sentence-picture verification tasks make it difficult to substantiate radically unembodied theories of language processing (in which mental simulations do not play a role in language processing whatsoever; Muraki et al.). Importantly, these findings combined are suggestive of some role of mental simulation in language processing, although it is not clear to what extent simulation is necessary or sufficient (for a review see Muraki et al.).

As recently reviewed by Muraki and colleagues, in the weakest embodied view, meaning is stored in amodal, symbolic representations that can be enriched with associated sensory information (Mahon and Caramazza). Slightly stronger but still weakly embodied views go a bit further in stating that sensory information in part constitutes the meaning of words, together with linguistic information (for a recent overview, see Muraki et al.). Without committing to a specific account of embodied cognition, a commonality across these theories is that each would predict that language processing might elicit the activation of (memory traces associated with) emotional, perceptual, social, and sensorimotor processes. Based on these commonalities, we will use the following working definition of simulation during language comprehension here: we regard simulation as the automatic (re-)activation of sensory and emotional information during language processing (Mak and Willems, "Mental Simulation during Literary Reading").

Providing evidence for a role of simulation in language processing, recent work has shown that mental simulation might be one of the factors driving individual differences in reading on the lexical level. Mak and Willems (Mak and Willems, "Mental Simulation during Literary Reading: Individual Differences Revealed with Eye-Tracking") used eye tracking to study individual differences in mental simulation (as defined above) during literary short story reading. One group of 90 participants read three literary short stories, and underlined all words, sentences, and passages that they considered to be motor descriptions, perceptual descriptions, and descriptions of mental events, leading to an average "simulation score" for each category for each word. These descriptions were hypothesised to afford elicitation of automatic activation of sensory and emotional information (or memory traces) stored along with the described concepts or situations. Descriptions that were underlined by more participants were considered to be more likely to (re-)activate such information. A second group of 109 participants then read each story, after which the simulation scores (and several important lexical characteristics) were regressed against their eye movements. The results revealed that while reading motor descriptions—presumably eliciting more motoric simulation—readers sped up, whereas during perceptual and mentalizing descriptions, readers slowed down. However, there were striking individual differences in these relationships: while readers on average slowed down during mentalizing, some participants sped up, suggesting that the degree to which readers simulate (or the nature of their simulation) might vary.

Importantly, this implies that there might be variation in the degree of simulation as revealed by readers' eye movements: some readers showed strong evidence for simulation (and did for all kinds of simulation studied), whereas other showed only weak evidence or no evidence at all for any of the kinds of simulation studied. Moreover, these individual differences in simulation were linked to absorption and story liking: for instance, people who experienced a stronger emotional response to the story had a stronger effect of mental simulation on their gaze behaviour. In addition, people who focused more on the story (which is an aspect of absorbed reading) displayed a weaker association between motor simulation and mentalizing on the one hand and gaze duration on the other hand. These findings suggest that indeed, mental simulation might be a factor that explains the observed link between reading at the lexical level and people's reading experience in terms of absorption.

Recent work has replicated these findings in a study that combined eye tracking with functional magnetic resonance imaging (fMRI) (Mak, Faber, et al., "Different Kinds of Simulation during Literary Reading: Insights from a Combined FMRI and Eye-Tracking Study"). Motor simulation was again linked to faster reading, and perceptual simulation and mentalizing to slower reading, with similar effect sizes as reported in the previous study, suggesting that these findings are robust across experimental settings, and that they are likely to be indicative of robust effects of simulation on mechanistic reading. Other recent work (Magyari et al.) has shown that the number of adjectives and verbs—which might be linked to simulation by providing (detail to) perceptual, motoric, or mentalizing descriptions that elicit simulation—on a page is also predictive of reading times: more adjectives lead to longer reading times (slower reading), whereas more verbs lead to shorter reading times (faster reading). These findings suggest that the use of different word categories might provide a potentially useful handle on manipulating simulation across texts.

In addition to variation across readers, the stories being read also impact the degree to which people mentally simulate during literary story reading. In stories that describe the interaction of characters with their environment as opposed to describing the environment without the interaction with a character, fixation durations are longer for stories that described interactions between characters and their environment, suggesting increased processing and possibly higher degrees of simulation (Magyari et al.).

The neural basis of mental simulation during story reading

As argued above, evidence suggests that individuals might vary in the degree to which mental simulation occurs during story reading. This prompts the question of what the neural basis of mental simulation during story reading is, and whether there is any evidence to suggest that neural activity associated with simulation is linked to how people subjectively experience stories. As we will discuss below, much of the "traditional" embodied language processing literature has focused on evidence for domain-specific simulation (e.g., Hauk et al.). However, more recently, the focus has shifted to identifying commonalities across different cognitive processes (e.g., Addis, "Are Episodic Memories Special? On the Sameness of Remembered and Imagined Event Simulation"). In our discussion here, we will follow this distinction: we will first discuss evidence for domain-general processes linked to simulation, followed by a discussion of domain-specific processes.

Outside of the literature on language processing, simulation has been defined more broadly as "the mental rendering of experience" (Addis, "Mental Time Travel? A Neurocognitive Model of Event Simulation", p. 234; note that this definition is much broader than our working definition, which only captures the automatic activation of sensory and emotional information during language processing). Addis (Addis, "Are Episodic Memories Special? On the Sameness of Remembered and Imagined Event Simulation"; Addis, "Mental Time Travel? A Neurocognitive Model of Event Simulation") argues that simulation is a domain-general process, which is closely related to (or even overlaps with) semantic and episodic memory, mental time travel (remembering the past and imagining the future), counterfactual thinking, creativity, theory of mind, narrative comprehension, and event perception (Addis, "Mental Time Travel? A Neurocognitive Model of Event Simulation"). These processes rely on internally constructed representations (rather than externally driven ones), a process typically associated with activity in the Default Mode Network (DMN) of the brain (Buckner and DiNicola).

Although studies focusing on mental simulation in the (narrow) sense of our working definition in the context of story reading have been relatively scarce (see below), there is evidence to suggest that the DMN is involved in more general simulation and related processes such as event cognition during narrative processing as well. Striking evidence comes from a study that focused on neural synchrony across participants who had one of two possible interpretations of a story (i.e., the main character's wife is cheating on him, or he is paranoid) (Yeshurun et al.). Participants who had the same interpretation displayed greater synchrony across the group within the DMN during listening (Yeshurun et al.), suggesting that the DMN might be involved in processes that strongly relate to mentalizing (i.e., using inferences about the mental state of a character to interpret the story). Such synchronies across individuals during story processing have also been observed in movie watching (Chen et al.), where accessibility to prior information determines how similar neural activity in DMN areas is across participants. For example, when comparing two groups watching the second part of a movie that critically relies on information from the first part of the movie that one group watched immediately prior and the other group one day before, activity in the DMN during the first minutes of the second part of the movie is asynchronous between groups, but synchronous within groups, and increases in synchrony over the course of the movie (Chen et al.). Additionally, when participants read a story with alternating, independent storylines, they showed storyline-specific neural patterns, particularly in the DMN (Chang et al.). Memory performance for the story turned out to be best in those participants in which this activation was most pronounced (Chang et al.).

Within the DMN, a special role seems to be reserved for the angular gyrus (Addis, "Mental Time Travel? A Neurocognitive Model of Event Simulation"). Addis (Addis, "Mental Time Travel? A Neurocognitive Model of Event Simulation") proposes that activity in higher-level, posterior DMN regions, such as the angular gyrus, is non-linearly related to the associative strength between the elements of simulations: simulations comprised of information from multiple modalities or higher-order processing regions will often be more coherent than simulations comprised of information from one sensory modality, and will therefore have more associative strength, and place fewer constructive demands on the posterior regions of the DMN. In contrast, simulations with lower associative strength place higher demands on the DMN, resulting in stronger activation of these regions (Addis, "Mental Time Travel? A Neurocognitive Model of Event Simulation"). However, if too much demand is placed on these posterior regions of the DMN (when associative strength is too low), the activity in these regions diminishes at which point activity in anterior DMN and fronto-parietal network increases (Addis, "Mental Time Travel? A Neurocognitive Model of Event Simulation"). The angular gyrus, together with the adjacent supramarginal gyrus, has indeed been found to play a role in many of the cognitive processes that are important for simulation, such as stimulus-driven attention, social cognition, episodic memory, and self-generated, spontaneous thought (Igelström and Graziano), literary reading (Hartung, Wang, et al.), referential indexing (Matchin et al.), and situation model updating (with mental simulation playing an important role in building and updating a mental representation (or situation model) of a story; Zwaan and Radvansky; Kurby and Zacks, "The Activation of Modality-Specific Representations during Discourse Processing"; Zwaan). The angular gyrus also plays an important role in event segmentation across domains: a posterior-to-anterior hierarchy in the perception of event boundaries has been found in studies of listening to audio narratives, movie viewing, and music listening (Baldassano et al.; Williams et al.). Similarly, the supramarginal and angular gyri have been hierarchically associated with anticipation of event boundaries in repeated movie viewing (Lee et al.). The supramarginal and angular gyri modulate functional connectivity between domain-specific language areas and reading related domain-general executive processing regions in the prefrontal cortex (Kim et al.).

Taking together this evidence, the angular/supramarginal gyrus is a good candidate for a domain-general simulation area, which has been supported by neural evidence from Mak, Faber, and Willems (Mak, Faber, et al., "Different Kinds of Simulation during Literary Reading: Insights from a Combined FMRI and Eye-Tracking Study"). In a study that used simultaneous fMRI with eye tracking, Mak, Faber, and Willems asked forty participants to read two literary short stories (coded for motor descriptions, perceptual descriptions, and descriptions of mental events; Mak and Willems, "Mental Simulation during Literary Reading: Individual Differences Revealed with Eye-Tracking") in the fMRI scanner. Subsequently, the participants answered questions about their experience and comprehension of the stories, and about their personal characteristics (empathy, transportability) and reading habits in daily life. As mentioned above, this study replicated the associations between eye movements and words that elicit simulation that were observed in previous studies. The open question, however, was whether domain-general simulation areas could be discovered and/or whether there are modality-specific brain activation patterns that are associated with the different types of simulation (motor, perceptual, and mentalizing). Perhaps unsurprisingly, Mak, Faber, and Willems (Mak, Faber, et al., "Different Kinds of Simulation during Literary Reading: Insights from a Combined FMRI and Eye-Tracking Study") found evidence for a domain-general simulation area in the left supramarginal gyrus, in keeping with the existing theories and empirical evidence suggesting a role for this area in domain-general simulation.

In addition, Mak, Faber, and Willems also found some evidence for domain-specific simulation areas, in line with previous evidence for domain-specific brain activity associated with motor simulation (Nijhof and Willems; Chow et al.; Kurby and Zacks, "The Activation of Modality-Specific Representations during Discourse Processing"), visual simulation (Chow et al.; Tamir et al.), auditory simulation (Kurby and Zacks, "The Activation of Modality-Specific Representations during Discourse Processing"), and mentalizing (Nijhof and Willems; Tamir et al.).

Specifically, the results from Mak, Faber, and Willems (Mak, Faber, et al., "Different Kinds of Simulation during Literary Reading: Insights from a Combined FMRI and Eye-Tracking Study") revealed that motor simulation was associated with activity in brain areas that have previously been linked to processing motor verbs (e.g., Kurby and Zacks, "The Activation of Modality-Specific

Representations during Discourse Processing"; Moody and Gennari; Nijhof and Willems), such as the cingulate and paracingulate cortex, precuneus, parahippocampal gyrus, and middle and superior frontal gyrus. Furthermore, brain areas associated with inferencing, event segmentation, and situation model building, such as angular gyrus, subcallosal cortex, and frontal medial cortex (e.g., Kurby and Zacks, "Segmentation in the Perception and Memory of Events"; Speer, Zacks, et al.; Speer, Reynolds, et al.) were also activated when people read motor descriptions. Note that adjacent areas in these same networks were activated by domain-general mental simulation. This might indicate a special role for motor simulation (or action processing) in mental simulation in general.

One possible (but speculative) explanation for this finding would be that actions have been found to be drivers of event segmentation and hence, situation model building, as actions are often associated with changes in agents and objects (and their interactions), the intentions of the protagonist, causal relationships in a story, and shifts in space and time (Faber and Gennari; Faber, Radvansky, et al.; Zwaan and Radvansky; Kurby and Zacks, "Segmentation in the Perception and Memory of Events"). This could for example be studied by asking participants to segment passages, while modality-specific motor simulation areas are suppressed (for example with rTMS). If event segmentation is impaired while motor areas are suppressed (but not when motor areas are not suppressed), this can tell us more about the necessity of motor simulation for event segmentation. The potential necessity of motor simulation for these processes, however, does not explain why people speed up when they read motor descriptions, as people normally slow down when they need to update their situation model (Pettijohn and Radvansky). Although these findings are in line with previous research showing that more action-laden sentences are processed faster (Marino et al.), more research is needed to find out why motor simulation is processed at a higher speed than other kinds of simulation.

Perceptual simulation elicited activity in several modality-specific areas that were also observed in previous work, such as fusiform and parahippocampal gyrus, and inferior temporal cortex. Previous work has shown that these higher- and lower-level visual areas are involved in visual simulation (Chow et al.; Tamir et al.). These areas, together with others, are important components of the ventral visual pathway, which processes objects, faces, and scenes (Grill-Spector and Weiner; Kanwisher; Kravitz et al.), suggesting that perceptual simulation elicits domain-specific activation in the brain.

Mentalizing was found to elicit activity in areas that have previously been associated with mentalizing in general: regions in the temporal pole, parietal operculum, anterior cingulate, and angular gyrus (Frith and Frith; Igelström and Graziano; Laurita et al.; Paulus et al.; Saxe and Kanwisher). Apart from that, mentalizing was found to elicit activity in the reading network in the brain (e.g., middle temporal gyrus, inferior frontal gyrus, superior temporal gyrus, planum temporale, cerebellum). Associations between mentalizing and language processing have been found before, particularly in the context of social cognition and Theory of Mind (Tamir et al.; Hertrich et al.). The ability to understand and make inferences about the intentions of others relies on the Theory of Mind system, which is neuroanatomically distinct from the language network, but has been shown to co-activate during language comprehension (Paunov et al.; Hertrich et al.). This coordination between networks suggests that language might be important for our ability to understand others, and that our ability to understand language might (to some extent) be dependent on our social skills, suggesting that these two abilities might be closely intertwined. Indeed, recent evidence shows that performance on Theory of Mind-tasks is dependent on linguistic experience, where children with less linguistic experience due to later-than-normal first linguistic exposure perform worse on Theory of Mind tasks than their peers with more linguistic experience (and comparable to younger children with similar linguistic experience; Richardson et al.). Moreover, development of Theory of Mind (but also other cognitive functions) is proposed to be dependent on linguistic development (de Villiers).

Note that there were also passages in the stories that elicited more than one form of simulation (for example both motor simulation and mentalizing or motor simulation and perceptual simulation). In these instances, modality-specific activation could still be observed, but from different modalities simultaneously. In addition, there are of course other types of descriptions that afford mental simulation that were not explicitly studied here: physical motion of characters in stories has been shown to elicit activation in the posterior temporal cortex/angular gyrus (i.e., a region implicated in the perception of biological motion), dialogue in stories is associated with activity in many regions in the bilateral temporal and inferior frontal cortices and the temporo-parietal junction, and the identities of different story characters have been shown to activate the right posterior superior/middle temporal region (Wehbe et al.). It is likely—although to our knowledge not empirically validated to date—that these types of simulation also vary across individuals, and might play a role in subjective experiences during reading.

Different reader types?

As explained above, Mak, Faber, and Willems (Mak, Faber, et al., "Different Kinds of Simulation during Literary Reading: Insights from a Combined FMRI and Eye-Tracking Study") discovered domain-specific and domain-general areas associated with (different kinds of) mental simulation. In addition, they found evidence for individual differences in mental simulation: how strongly brain areas responded to simulation-eliciting content (in terms of percent signal change) was related to measures of story appreciation and trait-level, personal characteristics. Specifically, people whose brains showed stronger responses to motor descriptions on average thought that the stories were more beautiful, witty, or special, and scored higher on the Fantasy subscale of the Interpersonal Reactivity Index (IRI; Davis). Similarly, people who were more sensitive to perceptual descriptions in terms of percent signal change in the brain scored higher on the Fantasy subscale, and scored higher on the Perspective Taking subscale of the IRI. Being more sensitive to mental event descriptions was related to finding a story more suspenseful, interesting, captivating, or gripping. Taken together, these findings suggest that how mentally "involved" people are in a story is reflected in their brain activity.

Contrary to their expectations, Mak, Faber, and Willems did not observe a relationship between the strength of the neural responses to simulation words and story world absorption. Although contrary to expectations, this finding may not be entirely surprising. For example, engagement with narrative movies was not found to be correlated with individual differences in time perception, due to viewers becoming more similar (individual differences decrease) with increased engagement (Cohen et al.). These findings have been shown to extend to spoken political speeches, where neural synchrony in language areas during processing is higher for rhetorically strong than rhetorically weak speeches (Schmälzle et al.). Although previous studies have pointed out that findings done in the context of narrative film do not necessarily translate to reading (Loschky et al.; Hutson et al.; Hubbell et al.), if individual difference findings from narrative movie processing *do* translate to the context of mental simulation during story reading, results might be most apparent when looking at individual differences between participants reporting low absorption scores, for example using inter-subject representational similarity analysis (Finn et al.).

Alternatively, the lack of a relationship between the strength of the neural response to simulation words and story world absorption as found by Mak, Faber, and Willems could be due to the fact that simulation is not an important factor driving absorption, but it might also indicate that reading on the neural level is better predicted by more stable, trait-level differences rather than experiential states. This is in line with multiple previous studies that found that trait-level individual differences were more strongly associated with simulation than readers' level of absorption in response to the stories they read (e.g., Faber, Mak, et al.; Hartung, Hagoort, et al.; Hartung, Wang, et al.; Mak, De Vries, et al.; Van den Hoven et al.). These findings suggest that although simulation might still play a role in absorption (Kuijpers, "Bodily Involvement in Readers' Online Book Reviews: Applying Text World Theory to Examine Absorption in Unprompted Reader Response"), individual variation in simulation is not directly predictive of individual variation in story world absorption.

As mentioned above, relatively stable, trait-level characteristics such as what kind of stories people like and their score on the interpersonal reactivity index are linked to how the brain responds to stories, with specific types of simulation being linked to specific patterns of preferences and interpersonal reactivity. This resonates with previous work that has shown that there are different "fingerprints" of aesthetic appreciation (Mak, Faber, et al., "Different Routes to Liking: How Readers Arrive at Narrative Evaluations"). Overall, people's interest in a story, how suspenseful it is, how amusing it is, and how beautiful people think it is were all positively associated with how much people like a story. However, people vary in the extent to which each of these components contributes to their assessment: some people for instance appreciate sadness in stories, whereas others do not. Such individual differences might be linked to the processing of emotional information on the neural level, as also suggested above. Readers might therefore—although the causal direction is unknown—have different preferences, and different reading styles.

Indeed, a survey of 501 fiction readers in The Netherlands has found that different readers take on different roles as a reader and have different expectations of the reading experience (Riddell and van Dalen-Oskam). Although the survey revealed no strict boundaries between different types of readers, it showed that they do vary in terms of how they engage with fiction: some readers are predominantly "identifying" readers who enjoy fiction that allows them to empathise with the main character, whereas more "distanced" readers predominantly enjoy aesthetic and stylistic aspects of literature. However, some readers characterise themselves as both identifying and distanced readers. The survey revealed that readers are perhaps best differentiated in terms of how many different experiences they expect during the reading process: some readers expect mostly to be transported by the narrative (being "swept away" by the story, Riddell and van Dalen-Oskam, p. 10), whereas others expect a story to also be intellectually challenging. Riddell and Van Dalen-Oskam speculate that the latter category might possess a number of different "reading techniques", such that they can choose how to approach a literary story and thereby experience it in different ways and/or on different levels. Despite this being a speculative account, it opens up the possibility that the extent to which an individual has access to an arsenal of different reading techniques is an important factor in determining how people experience and enjoy stories.

This idea is supported by the Neurocognitive Poetics Model of Literary Reading (Jacobs), which has proposed a distinction between two routes of literary reading: a fast route and a slow route. The fast route is evoked by reading familiar, high-frequency, and highly imageable words, leading to a fluent reading experience that makes a reader feel immersed in the story. As highly imageable words might also lead to higher degrees of simulation, the (subconscious and automatic) process of simulation might play an important role in evoking this reading experience (Mak and Willems, "Mental Simulation during Literary Reading"). This route is also known as the affective processing route, as people experience "fiction feelings" —feelings such as transportation, emotional engagement, and empathy. The slow route on the other hand is triggered by foregrounded elements —stylistic devices such as metaphors, abstract, rhythmic and rhetorical structure, and defamiliarizing language, evoking a disfluent reading experience, but also evoking aesthetic feelings. The latter is thought to lead to higher aesthetic appreciation of literature and poetry. In line with the observations made by Riddell and Van Dalen-Oskam (Riddell and van Dalen-Oskam), an open question is whether readers vary in the extent to which they can (intentionally or automatically) employ each route during reading. As such, whether or not readers appreciate a story and feel immersed might be an interaction between the reader and the text: the reading techniques that a reader possesses might determine their story preferences, and texts that appeal to techniques that a reader has limited access to might not be appreciated.

There is some neural evidence to support the idea that readers vary in how they approach a story. Nijhof and Willems (Nijhof and Willems) found that some readers (or in the case of this fMRI study, listeners) might focus mostly on concrete events and descriptions of actions, whereas others mostly attend to descriptions of thoughts, emotions and beliefs (i.e., mentalizing). These differences were reflected in the relative strength of each type of mental simulation in the brain: people who focused more on action content showed stronger responses in the left and right motor regions of the brain, whereas people who were more oriented towards mentalizing showed stronger responses in mentalizing regions such as the temporo-parietal junction, precuneus, and medial prefrontal cortex. It is important to note, however, that participants were not bimodally distributed, but rather formed a gradual "simulation spectrum" ranging from more action-oriented to more mentalizing-oriented. Although these findings do not directly map onto the distinction between the "fast" and "slow" processing route, they do lend support to the idea that there might be quantifiable differences in how individuals approach and/or process stories that are reflected in brain activity, providing insight into the neural underpinnings of how people experience stories.

Discussion

In this paper, we have discussed work that has studied how individuals vary in how they read, experience, and appreciate literary stories, and what that can tell us about the human mind. In particular, we have taken mechanistic reading behaviour as a starting point, and have argued that the way in which people read is linked to how people experience stories: being somewhat "detached" from the story is linked to stronger feelings of absorption. However, how people read might be more strongly linked to their reading abilities than it is to their current experience, and similarly, their reading preferences might be best predicted by the reading strategies or reading "modes/roles" that they have access to. This idea is supported by neural data that shows that people's preferences and personal characteristics such as how they engage with literature is linked to the strength of their neural response to words that elicit simulation, an automatic and involuntary cognitive process. How people experience and like stories might therefore be best predicted by a combination of an individuals' reading abilities, their propensity for simulation (which in turn might be linked to their reading abilities), and personal characteristics such as interpersonal reactivity, and the story that is being read.

Arguably, in defining mental simulation as "the automatic (re-)activation of sensory and emotional information during language processing", we have opted for a relatively "narrow" definition of simulation in comparison to colleagues studying, for example, the relationship between reading and empathy (e.g., Mar and Oatley; Bal and Veltkamp). In this area of research, stories themselves are seen as potential simulations of social situations, through which readers can practice their social skills. Historically, the term mental simulation has its origins in Simulation Theory, a theory in the philosophy of mind which describes how people understand the mental states of others (e.g., Goldman, *Simulating Minds: The Philosophy, Psychology, and Neuroscience of Mindreading*). According to Shanton and Goldman, in mental simulation "one mental event, state or process is the re-experience of another mental event, state, or process" (Shanton and Goldman, p. 528). The 're-experience' in this description resonates with the definition of simulation by Barsalou (p. 618; "Simulation is the re-enactment of perceptual, motor, and introspective states acquired during experience with the world, body, and mind") as well as our proposed working definition of mental simulation. However, we do acknowledge that our working definition of mental simulation, although grounded in established research traditions within Philosophy and Psychology, is fairly narrow (as is the scope of this paper) and would perhaps not be sufficient to capture phenomena studied in different fields of research.

Of course, there are other important processes at work when going from single words to representations of sentences and larger pieces of discourse such as stories (see, e.g., Kendeou and O'Brien), some of which might border on simulation-related processes. For instance, people vary in how associated knowledge is activated and integrated during reading (e.g., Kintsch, "The Role of Knowledge in Discourse Comprehension: A Construction-Integration Model."; Kintsch, *Comprehension. A Paradigm for Cognition*). Recent theories argue that this knowledge is passively activated through a process called resonance (Myers and O'Brien; Sonia and O'Brien), and is then integrated and validated. These processes play an important role in narrative reading, as they determine how for instance world knowledge is used to validate the consistency of a story (Cook and O'Brien). Importantly, they might also to some extent pose a limitation on how much transportation can take place, as readers cannot "switch off" their own (world) knowledge when taking the perspective of the protagonist (Creer et al.). Although theories of resonance are beyond the scope of the present paper, they do provide an important avenue for future research, as it is currently an open question to what extent these processes overlap with people's propensity to mentally simulate language.

One important limitation of almost all of the studies cited here is that they rely on naturalistic variation in and across stories, without manipulations of variables of interest. In order to make causal claims about how individuals process specific narrative information, it might be necessary to conduct more controlled experiments that manipulate specific text characteristics, such as the amount of simulation-inducing content without changing other aspects of the text. Another important limitation of studying mental simulation in the context of naturalistic variation in and across stories, is that most studies reported in this paper only use a limited number of stories. Since naturalistic narratives are rather long, the experiment would simply take too much of participants' time if more than a few stories would be used in each experiment. In the case of Mak, Faber, and Willems (Mak, Faber, et al., "Different Kinds of Simulation during Literary Reading: Insights from a Combined FMRI and Eye-Tracking Study"), for example, only two stories were used in the study of individual differences in simulation in the brain. This makes it difficult (if not impossible) to study story differences in most studies using naturalistic stories, and future studies with different stories would be necessary to determine whether the found effects also translate to other stories. That said, Mak, Faber, and Willems looked specifically at words and passages in stories, rather than at entire stories. Although this cannot completely account for possible differences between stories (either in plot or in language use), it does make that the number of observations on which their conclusions are based is larger than two (also note that their eye-tracking findings show *some* differences between stories, but they are slight differences in the *strength* of the found effect, and not in the *direction* of the effect).

Despite the abovementioned disadvantages, the use of naturalistic narratives does also have important advantages: results are high in ecological validity, and relative contributions of different variables can easily be assessed due to their natural occurrence (Willems et al.). A mixed approach that makes small changes to existing, naturalistic narratives might therefore be an important way forward to obtaining new insights into the relationship between readers, their reading experience and appreciation, and the stories that they read.

In this paper, we have mostly focused on the cognitive process of mental simulation as a window into people's reading experience. However, as we have argued above, simulation is only one aspect of language processing, and might in and of itself only be weakly predictive of people's mental state. Indeed, loosely based on Jacob's Neurocognitive Poetics Model of Literary Reading (Jacobs), reading experiences (or 'fiction feelings') can be defined as absorption, transportation, emotional engagement, empathy, story enjoyment, and reading fluency, among others. As can be gleaned from the literature discussed here, most neuroscientific research has focused on one of these aspects, rather than on their constellation. These factors are likely to influence how people appreciate literature: behavioural research has for instance shown that people like a poem better when it is presented in an easy-to-read font, suggesting that reading fluency is important for appreciation (Gao et al.). An open challenge for neuroscientific research is therefore to assess the contributions of and interplay between different subjective reading experiences, how they are represented or "implemented" in the individual reader, and how they are linked to people's reading preferences.

As mentioned above, the observation that readers whose reading is more "detached" from the actual text on average experience higher degrees of absorption, is an interesting observation, as detachment is often regarded as a sign of disengagement (e.g., Mills et al.), and has been linked to the process of "mindless reading" or "mind wandering" (Faber, Krasich, et al.; Faber and D'Mello; Faber, Bixler, et al.; Dias da Silva, Postma, et al.; Dias da Silva, Faber, et al.). Mind wandering is often defined as a state in which people's attention shifts from the (reading) task to self-generated, task-unrelated, stimulus-independent thoughts (Smallwood and Schooler), and is linked to activity in the default network of the brain (DMN; e.g., Christoff et al.). However, previous work has shown that approximately 50% of mind wandering thoughts during reading or movie watching are directly triggered by what people are reading or watching (Faber and D'Mello), suggesting that some degree of engagement with a text might be necessary to instigate those mind wandering episodes. Indeed, recent theoretical work has taken the stance that mind wandering might be a "by-product" of task-relevant, attention driven processes, such as the construction of situation models during reading (Fabry and Kukkonen).

Indeed, in the study by Mak and Willems (Mak and Willems, "Mental Simulation during Literary Reading: Individual Differences Revealed with Eye-Tracking") described above, it appeared that people who focused more on the story (which is an aspect of absorbed reading) displayed a weaker association between motor simulation and mentalizing on the one hand and gaze duration on the other hand. The authors interpreted this finding as being somewhat reminiscent of "mindless reading". While the theories proposing an association between attention, absorption, and mind-wandering await further empirical validation, we would like to add to this challenge that paradoxically, mind wandering and story world absorption might share cognitive and neurobiological underpinnings: both rely on or cause a certain degree of perceptual decoupling (i.e., the detachment from the external world, and shifted focus toward the internal world), which is linked to activity in the default network of the brain that includes the domain-general simulation area that Mak, Faber, and Willems (Mak, Faber, et al., "Different Kinds of Simulation during Literary Reading: Insights from a Combined FMRI and Eye-Tracking Study") observed in the inferior parietal lobe (the supramarginal gyrus). The default network of the brain has additionally been found to play a role in counterfactual thinking (see De Brigard and Parikh): imagining oneself outside of the here and now. Taken together, the results from these different areas of research imply that the DMN is indeed involved in simulation, since it is activated whenever people are mentally simulating themselves in a different world (i.e., a story world, or a world outside of the here and now).

Above, we discussed several of the individual-level characteristics that influence mechanistic reading—and thereby, the subjective reading experience—such as print exposure, vocabulary size, and education level. However, there are other factors that vary between readers, such as people's own experience. If we take an embodied perspective on reading (i.e., meaning is to some extent grounded in people's own [bodily] experiences), then people's physical (and mental) experience and expertise should be predictive of their reading experiences. Indeed, research has shown that for instance expert volleyball players more strongly simulate action verbs depending on whether the words refer to the domain of their motor expertise (Tomasino et al.). Differences in (embodied) representation across individuals (and potentially cultures) might therefore play an important role in how individual readers experience stories.

In this paper, we set out to discuss how individual differences in story processing, experience, and liking can inform us about the human mind and brain. We have discussed individual differences in reading behaviour, both in sensitivity to certain word characteristics and in subjective experiences such as story appreciation. Although relatively little research has studied the link between mental simulation and reading experiences using neuroimaging techniques, there is some evidence to suggest that people vary in the degree to which they mentally simulate words, and that these differences are reflected in neural activity in both domain-specific and domain-general areas of the brain. However, as we discussed, mental simulation by itself is only a weak predictor of state-level subjective reading experiences. In future research, it is important to therefore move away from mental simulation in isolation, and instead focus on the constellation of factors that contribute to subjective experiences during reading. Fruitful steps have recently been taken in this direction, for example in studies looking at the experience of "flow" and mind wandering during reading. Only when investigating these kinds of experiences further, not only with paper and pencil tasks or questionnaires, but for example also with eye tracking or neuroimaging, will we uncover what makes readers so different from each other and what factors contribute to the uniquely human experience of enjoying a story.

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Notes

[1] Note that, although many lexical word characteristics can be distinguished, they do not all equally influence reading behaviour (Xue et al.). A possible explanation could be that some are highly correlated, taking one into account may limit the additional explanatory power of another. Although it is impossible to state with certainty that exactly 30–50% of variance is unaccounted for by any lexical factor at all, we can be fairly certain that a significant portion of the variance in lexical decision times is unaccounted for by lexical factors.

[2] We are talking about an experiential state, however, this does not mean that subjective experiences during story reading remain at the same level throughout a story reading experience. Indeed, just as word processing times vary between words depending on word characteristics (as explained above), absorption in stories has been proposed to vary throughout the story, depending on plot events or language errors, for example (Pianzola et al.).

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