Psychological Research (2021) 85:259–267
https://doi.org/10.1007/s00426-019-01248-5

ORIGINAL ARTICLE

Spatial text processing: are estimates of time and distance influenced by the age of characters and readers?

Francesca Pazzaglia[1,3] · Tina Iachini[2] · Chiara Meneghetti[1]

Received: 3 January 2019 / Accepted: 14 September 2019 / Published online: 23 September 2019
© Springer-Verlag GmbH Germany, part of Springer Nature 2019

Abstract

It is widely accepted that, while hearing or reading a story, people continuously form and update mental representations of the characters, places and events being described, based on plausible spatial, temporal or intentional details. According to the embodied cognition approach, the mental representations that accompany text reading are grounded in each reader's own sensorimotor experiences. Two experiments were conducted to examine whether readers' estimates of time and distance are influenced by age, their own and that of the character being described. In Experiment 1, 182 young adults read the description of a route in a town being covered by a young or an elderly character. In Experiment 2, the same descriptions as in Experiment 1 were read by 121 young adults and 53 older people. To avoid a possible confound, a follow-up to Experiment 1 (Experiment 1a) repeated the study by removing from texts the adverbs describing the walking speed of characters. In all experiments, participants were asked to estimate: (a) the time the characters took to reach their destinations (time estimation task); and (b) the distance they covered (distance estimation task). The results showed that both characters' and readers' ages influenced the time estimated, whereas no effects were found on estimates of distance: the elderly character was estimated to take longer than the young character (Experiments 1, 1a and 2), and older readers estimated longer times than younger readers (Experiment 2). This prompts the conclusion that personal features of both the readers and the characters they read about were used to infer the temporal dimension of situations described in the narratives. The theoretical implications of the findings are discussed.

Introduction

It is widely accepted that, while hearing or reading a story, people continuously form and update mental representations of the characters, places and events being described, based on plausible spatial, temporal or intentional details. This conceptualization is in line with the influential construct of a mental model or situation model (Johnson-Laird, 1983; Kintsch, 1998; van Dijk & Kintsch, 1983). More specifically, in Kintsch's (1988, 1998) construction-integration model, the mental representation of a text is conceptualized as a network of propositions linked via the topics they share (van Dijk & Kintsch, 1983; Kintsch, 1998; see also Gernsbacher & Kaschak, 2013; Kurby & Zacks, 2013; Fischer & Zwaan, 2008; Zwaan & Radvansky, 1998). The event-indexing model is a persuasive attempt to clarify the relations between the elements of a mental model. This event indexing involves people tracking multiple dimensions—time, space, entity, causation, and motivation—while reading a text, and inserting in their mental models the chronological order and duration of actions, spatial positions and layouts, the causal structure of events, the characters' goals, and the relationships between characters and objects (Therriault, Rinck, & Zwaan, 2006; Zwaan, 2016; Zwaan, Langston, & Graesser, 1995; Zwaan, Magliano, & Graesser, 1995).

Taking the embodied cognition approach, these dimensions were framed theoretically as having basic sensorimotor foundations (e.g. Fischer & Zwaan, 2008; Zwaan & Radvansky, 1998). To be more specific, the embodied cognition approach proposes that the mental representations formed during reading stem from the partial re-enactment of previous sensorimotor experiences (e.g. Barsalou 1999, 2008). By

✉ Francesca Pazzaglia
francesca.pazzaglia@unipd.it

1 Department of General Psychology, University of Padua, Via Venezia, 8, 35131 Padova, Italy

2 Department of Psychology, University of Campania "L. Vanvitelli", Caserta, Italy

3 CIRPA, Centro Interuniversitario di Ricerca in Psicologia Ambientale, Inter-University Environmental Psychology Research Center, Rome, Italy

integrating information from the text with prior experience, readers would simulate the perceptions and actions being described, and these simulations would facilitate their linguistic comprehension and inferences (e.g. Barsalou 1999, 2008; Brunyé, Ditman, Mahoney, Augustyn, & Taylor, 2009; Fischer & Zwaan, 2008). Several reports have suggested that the mental representations accompanying text reading are grounded in each reader's own sensorimotor experiences (for reviews, Fischer & Zwaan, 2008; Horoufchin, Bzdok, Buccino, Borghi, & Binkofski, 2018). To give an example, information is more accessible when it is described in the text as being close in space (Bower & Rinck, 2001; Haenggi, Kintsch, & Gernsbacher, 1995: Morrow, Bower, & Greenspan, 1989; Morrow, Greenspan & Bower, 1987), and effects of contiguity have been found for the time dimension too (Speer & Zacks, 2005; Zwaan, 1996).

Another important, but under-investigated issue concerns whether the discrete multiple dimensions of time, space, entity, causation, and motivation taken into account while processing a text interact or merely act as discrete dimensions. Evidence in favor of an interaction between the spatial and temporal entities comes from a study by Rapp and Taylor (2004). In their Experiment 2, participants read about characters traveling from a starting point to a destination, engaging in activities that could take a long or short time to complete as they went along. Their results indicated that readers could glean information about the distance the characters walked (spatial dimension) by estimating how long it took them to complete a given activity while walking along (temporal dimension). What clearly emerged is that it is not only explicit statements about spatial distance that influence our mental representations and the associated accessibility of locations in a story but also statements regarding the passage of time. From an interactive view, characters' actions in a story may, therefore, give us an idea about their timing (or duration), and from this we can infer spatial characteristics, such as how long a character spends walking while completing another action.

While spatial descriptions give rise to mental representations grounded in sensorimotor experiences, spatial experiences are regarded as a fundamental building block of language and cognition (e.g. Casasanto & Boroditsky, 2008; Lakoff & Johnson, 1980), and several researchers have suggested that language processing is grounded in embodied simulations (e.g. Borghi 2012; Coello, & Bonnotte, 2013; Gudde, Coventry, & Engelhardt, 2016). The close link between spatial processing and sensorimotor simulations also emerges when we consider the embodied constraints on perceptual and memory-based representations of space. An abundance of literature supports the idea that judgments about the temporal and spatial features of everyday events are influenced by our body's previous sensorimotor experiences (e.g. Barsalou 1999; Glenberg 1997), and that we refer to these experiences not only when we actually perform actions or encounter events, but also when we imagine them (Bugmann & Coventry, 2008; Zwaan 2004). People's judgments of certain spatial attributes are influenced by non-spatial variables, such as the weight of something being carried, the sense of tiredness, the size of a ball being thrown, or the physical risks associated with an action (for reviews: Proffitt, 2006; Witt, 2011). Targets were judged as being farther away by respondents throwing a heavier ball than those throwing a lighter one (Witt, Proffitt, & Epstein, 2004). Hills were judged to be steeper by people who were tired or carrying a heavy backpack (Bhalla & Proffitt 1999; Proffitt, Bhalla, Gossweiler, & Midgett, 1995). Long-term factors can influence perceptual judgments too. People who were not physically fit judged hills to be steeper than individuals in better physical condition (Bhalla & Proffitt 1999). Patients with chronic pain who found walking painful and elderly people judged targets on the ground to be further away than controls who were pain-free or younger (Sugovic & Witt, 2013; Witt et al. 2008). Findings in the same vein also emerge in mental representations derived from text processing. In fact, people's own physical attributes affect not only their judgement of the perceived world but also the mental representations they form while reading (e.g. Horoufchin et al., 2018).

Implicit knowledge of the world is reflected in our attitudes and stereotypes (Steele & Aronson, 1995), and may affect how we perceive distance and gradients. Past research demonstrated that priming individuals with an elderly stereotype resulted in their estimating distances as greater and gradients as steeper than age-matched individuals who were not primed (Chambon, 2009). Automatic activation of the aging stereotype has also revealed an effect on motor behavior. In a study by Bargh, Chen and Burrows (1996), participants primed with words related to the elderly stereotype (e.g. old, lonely, grey, wise) walked down a hallway more slowly at the end of the experiment than participants primed with neutral words. A critical review of the replications of these findings and, more generally, of the social prime effect are far beyond the goals of this paper (for further information on this point e.g. Bargh, 2014; Cesario, 2014; Molden, 2014; Weingarten et al., 2016). What it is to note here is that the aging stereotype is particularly strong: the young assume that old people are slower in physical functioning, activities and exercises (Lineweaver, Kugler, Rabellino & Stephan, 2018), and weaker in spatial learning (Meneghetti, Muffato, Suitner, De Beni & Borella, 2015). This aging stereotype can, therefore, be expected to affect the mental representations derived from text processing as well.

This paper examines the mental representations elicited by spatial descriptions from route perspective to see whether explicit information about the age of the character

(Experiment 1) or features of the reader (Experiment 2) is used to infer aspects of the temporal and spatial correlates of the person covering the route.

The literature shows that spatial descriptions differ in terms of perspective, distinguishing between survey and route descriptions (Taylor & Tversky, 1992). Survey descriptions use an extrinsic frame of reference and canonical terms, while route descriptions adopt an intrinsic frame of reference (a person moving along a path), egocentric terms, and a linear organization deriving from the order in which landmarks appear along the way. It has been demonstrated that processing route descriptions involve sequential components of visuo-spatial working memory (Meneghetti, Labate, Pazzaglia, Hamilton, & Gyselinck, 2017; Pazzaglia, Meneghetti, De Beni, & Gyselinck, 2010), and the integration of sensorimotor information (Brunyé, Mahoney & Taylor, 2010) to a far greater degree than when processing survey descriptions. Given this integration of sensorimotor information in route descriptions, we expected information about a character's (and reader's) physical features to be spontaneously incorporated in the mental model derived from this type of spatial text.

In two experiments, participants read the description of a man walking along a route through an urban environment. After reading the description, participants were asked to estimate the time it took the character to complete the route and the distance he covered.

In Experiment 1, participants were randomly assigned to one of two versions of this spatial description, which were identical except for the age of the character (young vs elderly) and his associated physical traits (e.g. black vs white hair). Consistently with an interactive view of text processing (Rapp & Taylor, 2004), we expected readers to use the explicit information provided about the walker's age to infer the length of the route and the time it took him to cover it. Taking an embodied cognition approach, and bearing in mind the evidence of how aging affects spatial perception (e.g. Sugovic & Witt, 2013), we expected participants reading about the elderly man to overestimate the time it took him to complete the route, and to underestimate the distance he covered, by comparison with participants reading about a younger walker due to older people being generally perceived as physically slower (Lineweaver et al., 2018).

In Experiment 2, we added another variable—the reader's age—to test the hypothesis that readers' own physical features might also affect their mental representations of a text. About half of the participants were young students, while the other half were elderly people. All participants read the same descriptions as in Experiment 1. For older readers, the expected effects should be even stronger if their representation was deeply embodied, i.e. if it reflected their own physical condition (Sugovic & Witt, 2013; for a review Coello & Iachini, 2015). In other words, when reading about the elderly walker, older readers should overestimate the time taken to cover a route and underestimate the distance, to a greater degree than younger readers.

Experiment 1

Method

Participants

The sample included a total of 182 undergraduates (151 females) attending the School of Psychology at the University of Padua, with a mean age of 20.71 (SD = 2.06). These participants were randomly assigned to read one of two texts: 89 read about a young man, and 93 about an elderly man. All participants gave their informed consent prior to their inclusion in the study.

Material

Texts. Two versions of a spatial text describing a route through a city were prepared. In both versions, a character named John was walking from his home to an outdoor market, but in one version he was a young man, while in the other he was an elderly man. Both versions included six landmarks, three located in the intersections, and three along the path covered by the man; these landmarks were balanced to create six versions of the same path.

The descriptions consisted of 14 sentences, eight spatial and six non-spatial. The spatial sentences provided details about the route and the positions of the landmarks from a route perspective (e.g. "turn left"; "go straight on towards"; "on your left you can see"). No information was provided about the timing of the action or the distances between the landmarks. The non-spatial sentences included information about the character, his age, appearance, hobbies, and so on. The spatial information was identical in the two versions. The non-spatial information differed, while the syntactic structure and length of the text remained the same. The elderly man was described as being 83 years old, with white hair, a pale complexion, tiring easily, fond of classical music and concerts. The young man was a dark-haired 23-year-old with a tanned skin, an athletic build, and a love of sports (see Table 1 for details of the two characters).

Estimation tasks. The distance estimation task involved answering the question: "Please estimate how far you think John walked to complete the route". The time estimation task involved answering the question: "Please estimate how long you think it took John to complete the route?"

Table 1 Classification of types of information provided in the descriptions of the young and old characters

Type of information	Young character	Old character
Physical characteristics	23 years old, sporty, athletic body, tanned face, dark hair	83 years old, distinguished appearance, slender shoulders, bent, pale face, white hair
Activities	Likes running, takes part in marathons, exercises regularly	Likes music, goes to concerts whenever possible, likes playing cards with friends
Beliefs about themselves	Thinks life is good and feels the energy levels typical of his age	Thinks life is good and feels his body shows the tiredness typical of his age
Relationships	On one side of the street, he sees three marathon runners who are friends of his. They are wearing running shoes. Their shorts and T-shirts cling to their legs and muscular chests. They are ready for their training	He sees three retired friends on a bench. One has a walking stick across his legs and his wrinkled face to the sun. The others have newspapers open in their unsteady hands
Changes in physical conditions during the walk	The sun is up in the sky. John takes out a large handkerchief and puts it on as a bandanna	The sun is up in the sky. John takes out a large handkerchief and mops the sweat off his neck and face
	John walks promptly to the first stall at the market	John walks wearily to the first stall at the market

Procedure

The experiment was conducted at a single group session. Each participant was given a pad with four sheets of papers. The first contained the text: participants were given 6 min to read the description and to try to memorize the route and the locations of the landmarks. They were told that taking notes while reading was not allowed. The two versions (about the young or elderly man) were randomly distributed among participants.

After the route learning phase, participants turned over the sheet of paper and answered the distance and time estimation questions, presented on separate sheets of paper. The order of the questions about distance and time was balanced across participants. On the last sheet of paper, they were asked to draw the route, showing the man's changes of direction and the locations of the landmarks.

Results

Pearson's correlations between the time and distance estimates showed a significant, positive correlation ($r = 0.32$ $p \leq 0.001$).

Two univariate analyses of variance were performed on the time and distance estimates, comparing the character's age factor (young vs. elderly). In the time estimation, there was a significant main effect of character, F (1, 182) = 10.32, $p = 0.002$, $\eta^2 = 0.05$, the time estimated for the elderly man ($M = 39.17$, SD = 38.14) being longer than for the young man ($M = 24.31$, SD = 21.67). No significant effect emerged for the distance estimation ($F < 1$; young character: $M = 1224.16$ SD = 351.79; elderly character: $M = 1205.91$ SD = 374.39).

Discussion of results of experiment 1

The above results indicate that the distance and time estimates were related, i.e. when the path was estimated as being longer, it was also judged to take longer to complete, and vice versa. As expected, the time estimation was influenced by the character's personal features, the elderly man being judged to have taken longer to cover the path than the young man. The walker's personal features only affected the time variable, however, not the distance he was judged to have covered.

It is worth noting that the dispersion in the distance estimates was very high, indicating that other factors (e.g. individual differences in spatial abilities and spatial language comprehension, spatial representation, attention focused on routes or landmarks, etc.) might have affected these estimates. Further research might address this point.

Finally, the young character is described in the final sentences of the texts as walking "promptly" and the older character is described as walking "wearily" (see Table 1). These adverbs may explicitly convey information about walking speed, so it could be that the results relative to the time estimates are attributable to the adverbs alone, rather than the character's age. To clarify this issue, we ran a follow-up to Experiment 1 (experiment 1a).

Experiment 1a

Experiment 1a aimed to rule out the possibility of the results obtained in Experiment 1 being due merely to the presence in the texts of two adverbs (promptly and wearily, referring, respectively, to the young and older characters) that might suggest differences in the walking speed of the two characters, and thus implicitly influence time estimates. The two adverbs were consequently omitted from the final sentences in the texts used in experiment 1a.

Method

Participants

Ninety-five graduate students (M age = 33.09, SD = 8, 97, 72 females) from the University of Padua were randomly assigned to read one of the two texts: 46 read about the young man, and 49 about the elderly man.

Material and procedure

The material and procedure were the same as in Experiment 1 as regards the two texts and estimation tasks, with the exception that the two adverbs "promptly" and "wearily" were omitted from the version of the texts describing the young and older character, respectively.

Results

The results replicated the findings of Experiment 1. Pearson's correlation between the time and distance estimates was significant and positive ($r = 0.33$ $p \leq 0.001$). Univariate analysis of variance on the time estimates, comparing the characters by age (young vs. elderly), showed a significant main effect of character, F (1, 94) = 9.37, $p = 0.003$, $\eta^2 = 0.09$, the time estimated being longer for the elderly man ($M = 40.10$, SD = 39.13) than for the young man ($M = 20.91$, SD = 17.11).

Discussion of results of Experiment 1a

The results of Experiment 1a clearly showed that, even without the two adverbs, the same pattern of results emerged as in Experiment 1. Importantly, they demonstrated a consistent effect of age on the time estimates, which is due to the overall characteristics of the two characters, not to any more or less explicit suggestions about their walking speed.

Experiment 2

In Experiment 2 we examined whether not only the character's age, but also the readers' age might influence their estimation of the time it took for the walker to complete the route and distance covered.

Method

Participants

A total of 174 participants volunteered for the study, including: 121 undergraduate and graduate students from the School of Psychology of the University of Padua (M age 25.58, SD = 7.50, 99 females), and 53 healthy older people (M age of 66.98, SD = 6.27, 27 females), recruited at social centers or university courses for the third age, who were all community dwellers living independently, and none of them reported having any major health issues. The young and older samples had a mean of 16.43 (SD = 2.31) and 10.91 (SD = 3.78) years of formal education, respectively. The young adults were better educated than the older adults, F (1, 173) = 140.11, $\eta^2 = 0.45$, $p < 0.001$, consistently with the typical socio-demographic differences between young and older adults due to the cohort effect (see ISTAT, 2011), but all participants had completed their compulsory schooling. Sixteen older people and 20 young adults were assigned to each of the two text conditions (describing the young or the elderly character). All participants gave their informed consent prior to their inclusion in the study.

Material and procedure

The material and procedure were the same as in Experiment 1 as regards the two estimation tasks. The time assigned for text reading was shorter than in Experiment 1 (2 min) and was established on the strength of experience gained conducting Experiment 1.

Results

One participant's score was not included in the analysis because the time this participant estimated was 5 min, the shortest in either experiment and was identified as an outlier (1 SD below the mean).

Correlations between time and distance estimation performance (partial correlations after controlling for readers' age) were significant, $r = 0.26$ ($p = 0.03$).

Two univariate, 2 (character: young vs. elderly) × 2 (reader: young vs. older)—as between participant factors—ANOVAs were run, inputting the estimated time and distance as the dependent variable. Table 2 shows the means and standard deviations of the time and distance estimations, by type of reader.

The results for time estimation showed main effects of character, F (1, 170) = 22.55 $p \leq 0.001$ $\eta^2 = 0.12$, and reader, F (1, 170) = 12.16 $p = \leq 0.001$ $\eta^2 = 0.07$, where the time judged for the elderly character was longer than for the young character, and older readers estimated longer times than young readers (see Table 2). The reader × character interaction was not significant ($F < 1$).

Results on distance estimation showed no significant effects ($F < 1$ to $F = 2.51$ $p = 0.12$).

Table 2 Experiment 2. Means and standard deviations of times (minutes) and distances (meters) estimated for each type of character (young vs. old) and by each type of reader (young vs. older)

Estimates	Readers	Characters		Total
		Young	Old	
Time				
	Young			
	M	17.95	37.37	27.42
	SD	7.30	17.95	26.67
	Older			
	M	31.81	54.23	42.81
	SD	22.54	37.06	32.28
	Total			
	M	22.16	42.53	
	SD	15.11	36.22	
Distance				
	Young			
	M	1262.90	1103.39	1185.12
	SD	389.72	383.25	393.21
	Older			
	M	1127.78	1080.77	1104.72
	SD	361.18	467.56	413.39
	Total			
	M	1221.91	1096.47	
	SD	384.35	408.16	

Discussion of the results of Experiment 2

Our results show that estimates of the time it took to cover a route were influenced by the age of both the character described in the text and of the reader. No such effects on distance estimation emerged (as in Experiment 1). Consistently with Experiment 1, when the character walking along the route was elderly, readers estimated that he would take longer to cover the path than a young character. Experiment 2 specifically showed that features of the readers (young vs older adults) influenced their time estimation as well: the mean time that older readers estimated it would take to cover the path was longer than the time estimated by the young participants, irrespective of the character's features.

The novel, striking finding here is, therefore, that the time the character was estimated to take to complete the path was influenced by the readers' as well as the character's age.

General discussion and conclusions

This study generated new findings regarding the factors that influence the construction of a mental representation from narratives, and the part played by embodiment in this process. A first important result is that participants were able to provide reliable estimates of time and distance even when no indications of this kind were given in the text. Their responses were not random, and this is also supported by the fact that the estimates were influenced by experimental manipulations: the age of the character (Experiment 1 and Experiment 2), and that of the reader (Experiment 2), and that positive correlations were found between time and distance. More importantly, one text dimension (personal features of the character) was used to infer information about a completely different dimension (the time it would take the character to complete a route). This outcome supports and extends the findings reported by Rapp and Taylor (2004): in their study, information about a character's activity enabled inferences concerning the distance covered during said activity. In our study, a character's personal features were used to infer his walking speed, and this proved true for young and older participants. Overall, Rapp and Taylor's study (2004) and our own experiments show that mental representations are constructed not only by collecting information about each text dimension, but also that information on one dimension can be used to infer information about another.

It is worth noting that the two factors considered in our study (the age of the character and the age of the reader) only affected participants' estimates of the time taken to complete a route, not the distance covered. Old age was not associated with an idea of walking a shorter distance, but only of it taking longer to complete an action. This is in the same vein as the results reported by Bargh et al. (1996), who found that even just listening to terms associated with old age prompted young participants to walk down a hallway more slowly at the end of the experiment than participants primed with neutral words.

However, earlier work (e.g. Proffitt 2006) revealed that factors linked to the physical effort (e.g. carrying a heavy backpack) influence distance perception. Our data suggest that it is not likely for distance imagined. How can we explain this discrepancy? Spatial and temporal aspects are typically linked when we move in space, but it may be that the temporal dimension reflects the body's capacity for action much better than the spatial dimension (e.g. Iachini, Ruotolo, Vinciguerra & Ruggiero, 2017). For instance, the same distance—say 200 m—could seem very different depending on our ability to cover it: short if we are healthy and athletic; long if we have a broken leg. This could mean that previously reported effects, such as people who are tired or elderly overestimating distances (Sugovic & Witt, 2013; Witt et al. 2008) actually reflect a primary temporal judgment that is subsequently declined in spatial terms. If it takes us longer to cover a path from A to B than to go from B to C, then we may represent the distances involved as being greater in the former than in the latter case. From an embodied perspective, spatial encoding is closely linked to the mental representation of the movements needed to reach a target position (for a review, Coello & Iachini, 2015).

An alternative explanation is possible, however. Spatial representation is a primary mental category frequently used to represent other dimensions too, such as time (e.g. Boroditsky, 2000), and maybe less susceptible to the influence of irrelevant information. It is also worth noting that the spatial descriptions used in our two experiments provided an abundance of spatial indications in terms of streets, landmarks, squares, etc. Even in the absence of explicit metric information, readers might refer to spatial information (and their own knowledge of typical Italian cities) to infer the length of the route walked by the character described and, while keeping this in mind, they may have used information about the character to infer his walking time. If so, it could be that the spatial features (streets, buildings, changes of direction) affected participants' spatial representations much more than the character's personal features. It will be interesting to test this hypothesis in future research. Finally, it is worth noting that the dispersion in the distance estimates (e.g. in Experiment 1) was very high, making it difficult for any effect of the experimental conditions to emerge. A possible solution to adopt in subsequent studies would be to give participants a preset metrical range for expressing the estimated distance to reduce the dispersion. More studies are needed to see whether spatial and temporal attributes are similarly or differently sensitive to the body's physical characteristics.

Our texts included a number of items of information about the character, in addition to his age. The young character was described as a marathon runner, tanned, and energetic, while the elderly character was described as a lover of classical music and concerts, pale, and tiring easily. It may be that all the character's personal features—not just his age—influenced young and older participants' time estimates. The substance of our findings nonetheless remains: information about personal features potentially irrelevant to the situation is likely to affect time estimates. Further, the results of Experiment 1a rule out any possibility of the effects on time estimation being due to single words expressing speed: even without the two adverbs likely to convey information about speed ("promptly" and "wearily", referring to the young and old characters, respectively), the results were exactly the same as in Experiment 1.

Finally, another significant result that emerged from our study concerns the fact that not only the age of the character but also that of the reader affected the time estimates. According to an embodied view, people could build mental representations of spatial description by re-enacting their personal experiences of previous journeys (see Barsalou 2008). Alternatively, the slowness attributed to old people might reflect stereotyped beliefs about old age. The elderly are particularly liable to prejudice regarding their walking more slowly, tiring more quickly, and so on (Chasteen, 2000; Chasteen, Bhattacharyya, Horhota, Tam, & Hasher, 2005). Our results could, therefore, simply mean that such stereotyped ideas were incorporated in participants' mental representations of the text. Our second experiment, showing that older readers estimated longer times to cover a route would suggest instead that mental representations of spatial descriptions are based more on real body status than just on stereotyped beliefs.

In conclusion, readers would use their own, personal body experience to construct coherent mental models and infer information not explicitly stated in a text. Such mental representations would be much more than a combination of textual details with a reader's prior knowledge. They would derive from the integration of at least three sources of information: explicit data from the text; the reader's knowledge of the world; and the reader's body experience. Further research is needed to shed more light on this hypothesis, explore the role of other features of characters and readers (such as gender, physical condition, etc.) in influencing estimates of time and/or distance, and examine special populations with motor impairments. Younger and older individuals' implicit beliefs about old age might be recorded and placed in relation to their time estimates, such as readers' assessments of their own physical abilities. In our experiment, the character was a male. What would change if the character were a female or a sexless robot?

Another issue that will need to be further explored is reading speed, and how it might have influenced the results of Experiment 2. We did not record reading time in our two experiments, and we could not check for any effect of reading time on participants' estimates of time and distance. It may be that older adults were reading more slowly when reading about older characters, and this might have emphasized their longer time estimates (i.e., longer reading times might predict longer time predictions). Future research should take this issue into account.

Finally, our results contribute nothing on the topic of distance estimation in mental representations, and future studies should explore which characteristics affect this dimension. The literature on cognitive map distortions (Tversky 1992; Denis 2018) has pointed to a number of environmental characteristics likely to affect distance estimation. Examining their potential effects on mental representations derived from spatial text processing could be an interesting future line of research.

Compliance with ethical standards

Ethical approval The studies have been approved by the ethics committee of the Inter-departmental Psychology Area of the University of Padua and have, therefore, been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Informed consent All participants gave their informed consent prior to their inclusion in the study.

References

Bargh, J. A. (2014). The historical origins of priming as the preparation of behavioral responses: Unconscious carry-over and contextual influences of real-world importance. *Social Cognition, 32,* 209–224.

Bargh, J. A., Chen, M., & Burrows, L. (1996). Automaticity of social behavior: Direct effects of trait construct and stereotype activation on action. *Journal of Personality and Social Psychology, 71,* 230–244.

Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral & Brain Sciences, 22,* 577–660.

Barsalou, L. W. (2008). Grounded Cognition. *Annual Review of Psychology, 59,* 617–645.

Bhalla, M., & Proffitt, D. R. (1999). Visual–motor recalibration in geographical slant perception. *Journal of Experimental Psychology: Human Perception and Performance, 25,* 1076–1096.

Borghi, A. M. (2012). Language comprehension: action, affordances and goals. In Y. Coello & A. Bartolo (Eds.), *Language and action in cognitive neuroscience* (pp. 143–162). New York: Psychology Press.

Boroditsky, L. (2000). Metaphoric structuring: Understanding time through spatial metaphors. *Cognition, 75,* 1–28.

Bower, G. H., & Rinck, M. (2001). Selecting one among many referents in spatial situation models. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 27,* 81–98.

Brunyé, T. T., Ditman, T., Mahoney, C. R., Augustyn, J. S., & Taylor, H. A. (2009). When you and I share perspectives: Pronouns modulate perspective taking during narrative comprehension. *Psychological Science, 20,* 27–32.

Brunyé, T. T., Mahoney, C. R., & Taylor, H. A. (2010). Moving through imagined space: Mentally simulating locomotion during spatial description reading. *Acta Psychologica, 134,* 110–124.

Bugmann, D., & Coventry, K. R. (2008). Action and the representation of distance in cognitive map acquired through imagined traversal: The development of a new methodology. *Memory & Cognition, 16,* 515–533.

Casasanto, D., & Boroditsky, L. (2008). Time in the mind: Using space to think about time. *Cognition, 106,* 579–593.

Cesario, J. (2014). Priming, Replication, and the Hardest Science. *Perspectives on Psychological Science, 9,* 40–48.

Chambon, M. (2009). Embodied perception with others' bodies in mind: Stereotype priming influence on the perception of spatial environment. *Journal of Experimental Social Psychology, 45,* 283–287.

Chasteen, A. L. (2000). The role of age and age-related attitudes in perceptions of elderly individuals. *Basic and Applied Social Psychology, 22,* 147–156.

Chasteen, A. L., Bhattacharyya, S., Horhota, M., Tam, R., & Hasher, L. (2005). How feelings of stereotype threat influence older adults' memory performance. *Experimental Aging Research, 31,* 235–260.

Coello, Y., & Bonnotte, I. (2013). The mutual roles of action representations and spatial deictics in French language. *The Quarterly Journal of Experimental Psychology, 66,* 2187–2203.

Coello, Y., & Iachini, T. (2015). Embodied perception of objects and people in space: Towards a unified theoretical framework. In Y. Coello & M. Fischer (Eds.), *Foundations of embodied cognition* (pp. 198–219). New York: Psychology Press.

Denis, M. (2018). *Space and spatial cognition. A multidisciplinary perspective*. New York: Routledge.

Fischer, M. H., & Zwaan, R. A. (2008). Embodied language—a review of the role of the motor system in language comprehension. *Quarterly Journal of Experimental Psychology, 61,* 825–850.

Gernsbacher, M. A., & Kaschak, M. (2013). Text comprehension. In D. Reisberg (Ed.), *The oxford handbook of cognitive psychology* (pp. 462–474). London: Oxford University Press.

Glenberg, A. M. (1997). What memory is for? *Behavioral & Brain Sciences, 20,* 1–55.

Gudde, H. B., Coventry, K. R., & Engelhardt, P. E. (2016). Language and memory for object location. *Cognition, 153,* 99–107.

Haenggi, D., Kintsch, W., & Gernsbacher, M. A. (1995). Spatial situation models and text comprehension. *Discourse Processes, 19,* 173–199.

Horoufchin, H., Bzdok, D., Buccino, G., Borghi, A. M., & Binkofski, F. (2018). Action and object words are differentially anchored in the sensory motor system—A perspective on cognitive embodiment. *Scientific Reports, 8,* 6583.

Iachini, T., Ruotolo, F., Vinciguerra, M., & Ruggiero, G. (2017). Manipulating time and space: Collision prediction in peripersonal and extrapersonal space. *Cognition, 166,* 107–117.

ISTAT. (2011). 15° Censimento della popolazione e delle abitazioni 2011(15th Census of population and housing 2011), https://www.istat.it/it/censimenti-permanenti/censimenti-precedenti/popolazione-e-abitazioni/popolazione-2011, Retrieved on 18 Dec 2018.

Johnson-Laird, P. N. (1983). *Mental models: Towards a cognitive science of language, inference, and consciousness*. Cambridge: Cambridge University Press.

Kintsch, W. (1988). The role of knowledge in discourse comprehension construction-integration model. *Psychological Review, 95,* 163–182.

Kintsch, W. (1998). *Comprehension: A paradigm for cognition*. New York: Cambridge University Press.

Kurby, C. A., & Zacks, J. M. (2013). The activation of modality-specific representations during discourse processing. *Brain and Language, 126,* 338–349.

Lakoff, G., & Johnson, M. (1980). The metaphorical structure of the human conceptual system. *Cognitive Science, 4,* 195–208.

Lineweaver, T. T., Kugler, J., Rabellino, A., & Stephan, Y. (2018). Beliefs about age-related changes in physical functioning across the adult life span and their relationship with physical activity levels of older adults. *Aging, Neuropsychology, and Cognition, 25,* 613–631.

Meneghetti, C., Labate, E., Pazzaglia, F., Hamilton, C., & Gyselinck, V. (2017). The role of visual and spatial working memory in forming mental models derived from survey and route descriptions. *British Journal of Psychology, 108,* 225–243.

Meneghetti, C., Muffato, V., Suitner, C., De Beni, R., & Borella, E. (2015). Map learning in young and older adults: The influence of perceived stereotype threat. *Learning and Individual Differences, 42,* 77–82.

Molden, D. C. (2014). Understanding priming effects in social psychology: What is "social priming" and how does it occur? *Social Cognition, 32,* 1–11.

Morrow, D. G., Bower, G. H., & Greenspan, S. L. (1989). Updating situation models during narrative comprehension. *Journal of Memory and Language, 28,* 292–312.

Morrow, D. G., Greenspan, S. L., & Bower, G. H. (1987). Accessibility and situation models in narrative comprehension. *Journal of Memory and Language, 26,* 165–187.

Pazzaglia, F., Meneghetti, C., De Beni, R., & Gyselinck, V. (2010). Working memory components in survey and route spatial texts processing. *Cognitive Processing, 11,* 359–369.

Proffitt, D. R. (2006). Embodied perception and the economy of action. *Perspective on Psychological Sciences, 1,* 110–122.

Proffitt, D. R., Bhalla, M., Gossweiler, R., & Midgett, J. (1995). Perceiving geographical slant. *Psychonomic Bulletin & Review, 2,* 409–428.

Rapp, D. N., & Taylor, H. A. (2004). Interactive dimensions in the construction of mental representations for text. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 5,* 988–1001.

Speer, N. K., & Zacks, J. M. (2005). Temporal changes as event boundaries: Processing and memory consequences of narrative time shifts. *Journal of Memory and Language, 53,* 125–140.

Steele, C. M., & Aronson, J. (1995). Stereotype threat and the intellectual test performance of African Americans. *Journal of Personality and Social Psychology, 69,* 797–811.

Sugovic, M., & Witt, J. K. (2013). An older view on distance perception: Older adults perceive walkable extents as farther. *Experimental Brain Research, 226,* 383–391.

Taylor, H. A., & Tversky, B. (1992). Spatial mental models derived from survey and route descriptions. *Journal of Memory and Language, 31,* 261–292.

Therriault, D. J., Rinck, M., & Zwaan, R. A. (2006). Assessing the influence of dimensional focus during situation model construction. *Memory & Cognition, 34,* 78–89.

Tversky, B. (1992). Distortions in cognitive maps. *Geoforum, 23,* 131–138.

van Dijk, T. A., & Kintsch, W. (1983). *Strategies of discourse comprehension*. New York, NY: Academic Press.

Weingarten, E., Chen, Q., McAdams, M., Yi, J., Hepler, J., & Albarracin, D. (2016). On priming action: conclusions from a meta-analysis of the behavioral effects of incidentally-presented words. *Current Opinion in Psychology, 12,* 53–57.

Witt, J. K. (2011). Action's effect on perception. *Current Directions in Psychological Science, 20,* 201–206.

Witt, J. K., Linkenauger, S. A., Bakdash, J. Z., Augustyn, J. S., Cook, A., & Proffitt, D. R. (2008). The long road of pain: chronic pain increases perceived distance. *Experimental Brain Research, 192,* 145–148.

Witt, J. K., Proffitt, D. R., & Epstein, W. (2004). Perceiving distance: A role of effort and intent. *Perception, 33,* 577–590.

Zwaan, R. A. (1996). Processing narrative time shifts. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 22,* 1196–1207.

Zwaan, R. A. (2004). The immersed experience: Toward an embodied theory of language comprehension. In B. H. Ross (Ed.), *The Psychology of learning and motivation* (Vol. 44, pp. 35–62). San Diego: Academic Press.

Zwaan, R. A. (2016). Situation models, mental simulations, and abstract concepts in discourse comprehension. *Psychonomic Bullettin Review, 23,* 1028–1034.

Zwaan, R. A., Langston, M. C., & Graesser, A. C. (1995a). The construction of situation models in narrative comprehension: An event-indexing model. *Psychological Science, 6,* 292–297.

Zwaan, R. A., Magliano, J. P., & Graesser, A. C. (1995b). Dimensions of situation model construction in narrative comprehension. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 21,* 386–397.

Zwaan, R. A., & Radvansky, G. A. (1998). Situation models in language comprehension and memory. *Psychological Bulletin, 123,* 162–185.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.