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Quality of children's knowledge representations in digital text comprehension: Evidence from pathfinder networks

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ABSTRACT

Children in primary school read digital texts for school purposes while current research has shown that forming a coherent knowledge structure of such texts is challenging. We compared the quality of ninety 6th grade children's knowledge structures after the reading of four different hierarchically structured digital text types: linear digital text, digital text with overview, hypertext, and hypertext with overview. Psychometric pathfinder network scaling of relatedness ratings were used to assess children's knowledge structures. For each text type, we compared the similarity of the children's knowledge structures to both a sequential (linear) model and a qualitatively richer expert model. Moreover, we examined to what extent similarity of children's knowledge structures with the two models predicts their reading comprehension. Children's knowledge structures were overall more similar to the sequential model. Although similarity with the sequential model predicted reading comprehension in all four text types, similarity with the expert model accounted for additional reading comprehension variance in hypertext and hypertext with overview. Prior knowledge accounted for the variance in comprehension in linear digital text, even after controlling for similarity with the models. Evidence suggests that children can cope with the mental demands of a hierarchically structured digital text.

1. Introduction

Digital texts have an ubiquitous presence in primary schools. Many of these digital texts, i.e., Internet-texts presented on a computer screen, are complex and primarily attuned to skilled readers, requiring the construction of a coherent knowledge representation using embedded hyperlinks and navigable (graphical) overviews (DeStefano & LeFevre, 2007; Jin, 2013). It is by no means clear if children accomplish high-quality or sufficient knowledge representations after reading hierarchical digital text. Therefore, in the present study we aimed to examine the quality of children's knowledge structures across different hierarchically structured digital text types, while using the psychometric network scaling pathfinder technique (Clariana, 2010; Clariana & Wallace, 2009; Ifenthalter & Pirnay-Dummer, 2014) to compare children's knowledge structures with a sequential knowledge representation, on the one hand, and a qualitative richer adult expert knowledge representation, on the other hand.

1.1. Digital text comprehension research

Digital texts are often presented as hypertext with embedded hyperlinks and sometimes include graphical navigable overviews. Hyperlinks are direct, clickable links to other texts, or other parts within a text. Graphical overviews form a graphical representation of the structure of the hypertext, often with clickable links. Digital texts with a nonlinear structure can either be structured hierarchically or as a network. In a hierarchical structure, the text branches, as a tree, while in a networked structure, the links between the different text parts can go in all directions.

The Construction–Integration model (Kintsch, 2005) can be used as theoretical background in the research on digital text reading. In line with the interactive and cyclical pattern of the Construction–Integration model (Kintsch, 2005), a reader forms a *text base* model (bottom-up) of the digital text in the construction process. The formation of a text base is sequential in nature because the reader processes the content of the text linearly (Larkin & Simon, 1987). In the integration process, a reader makes inferences with the text base and his or her prior knowledge (i.e. all knowledge the reader has stored in long-term memory) on the fly to build a *situation model* (top-down) of what the text is about (Kintsch, 2005; Zwaan & Radvansky, 1998). In this latter process,

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it can be assumed that the reader activates prior knowledge (top-down) to draw inferences in order to accomplish coherent knowledge structures (Wolfe & Mienko, 2007; Wolfe & Woodwyk, 2010; Zwaan, 1998). In linear text comprehension research, it is assumed that readers build qualitatively different knowledge structures during the comprehension process (Johnson-Laird, 1983) based on both bottom-up (driven by the explicit text) and top-down processes (general knowledge and inferences) (Graesser, 2008; Graesser & McNamara, 2011; Kintsch, 2005; Kintsch & Van Dijk, 1987; Verhoeven & Graesser, 2008). It is also assumed that knowledge structures are stored as networks of concepts and are upgraded with new information being integrated through inferences and reorganized in relevant (prior-knowledge) networks (Clariana, 2010; Goldsmith, Johnson, & Acton, 1991; Jonassen, 1993; Trumpower, Sharara, & Goldsmith, 2010).

Research of digital text comprehension with adult readers evidenced the importance of the reader characteristics for the comprehension process in digital text. Compared to reading linear text the reader of a hypertext must control and determine a coherent reading order and flexibly reconstruct and integrate prior knowledge during reading to accomplish a coherent situation model (Amadieu, Tricot, & Mariné, 2010; DeStefano & LeFevre, 2007; Waniek, 2012). Thus, the quality of a reader's knowledge structures in digital text is facilitated by the coherence of the reading order and the amount of prior knowledge about the topic that a reader has (McNamara, Kintsch, Songer, & Kintsch, 1996; Tapiero, 2007). In hypertext reading, the reader's prior knowledge about the topic is crucial in finding a coherent navigational path and hence, for successful hypertext reading (Amadieu et al., 2010; Salmerón, Baccino, Cañas, Madrid, & Fajardo, 2009).

Research of digital text comprehension with adult readers evidenced the challenges and difficulties in building a coherent representation because of the specific hypertext features as hyperlinks and graphical overviews (DeStefano & LeFevre, 2007). In line with this, previous research with adult readers showed inconsistent results about the effectiveness of comprehending digital text, including hypertext, compared to traditional printed text (Mangen, Walgermo, & Brønnick, 2013; Waniek, 2012). It has been found that rather than 'reading' the digital text features (i.e., embedded hyperlinks in the text or graphical and navigable overviews), readers prefer to 'browse' nonlinearly through the sections, jumping from one text section to another. This process is related to their prior knowledge and their comprehension process (Amadieu et al., 2010; Salmerón et al., 2009). Such reading demands additional top-down processes and self-regulated metacognitive skills as monitoring, planning, and evaluating to prevent disorientation (Azevedo & Cromley, 2004; DeStefano & LeFevre, 2007). This active reading process increases the cognitive load and may degrade their comprehension of digital text (DeStefano & LeFevre, 2007). Amadieu et al. (2010) indicated that hierarchically structured hypertext is most appropriate for low-prior knowledge readers of the topic. There is evidence that hierarchically structured digital texts support coherence during reading, because these global coherence reduces the need to draw inferences by the reader (Amadieu & Salmerón, 2014; Waniek, 2012; Zumbach, 2006; Zumbach & Mohraz, 2008). Furthermore, in line with these previous findings, research with low-prior knowledge adults evidenced that the number of nodes read affected the text-base level understanding whereas the reading order affected the situation model (Madrid & Cañas, 2009; Salmerón, Kintsch, & Cañas, 2006). Otter and Johnson (2000) directly considered the accuracy of readers' situation models in digital text and compared these to disorientation. Their results indicated that associative hyperlinks (i.e., unpredictable links with information about the text) may induce disorientation due to high cognitive load in hypertext reading. However, on the other hand, the active and coherent reading of digital text could be beneficial for drawing inferences and the building of a coherent knowledge structure, as the reader is more focused on the understanding of the text (Salmerón et al., 2009; Waniek, Brunstein, Naumann, & Krems, 2003).

As said, in digital text, the text structure is expressed by means of textual features including hyperlinks and overviews that permit flexibility in reading order (Salmerón & García, 2011, 2012; Waniek, 2012). These features can, to some extent, support macro-level structure understanding, support coherence, and prevent the reader from becoming disoriented (Jin, 2013; Madrid, Van Oostendorp, & Melguizo, 2009; Meyer, Ray, & Middlemiss, 2012; Payne & Reader, 2006; Salmerón & García, 2011, 2012). Such features support the building of a rich and coherent knowledge structure (Clariana, 2010; Ritchey, Schuster, & Allen, 2008; Salmerón et al., 2009; Waniek, 2012; Waniek et al., 2003). However, Bezdan, Kester, and Kirschner (2013) showed that the continuous use of overviews may disadvantage learning on the micro-level of the comprehension process, often being reflected in qualitative differences in the readers' knowledge structures.

Research on children's digital text comprehension and the quality of children's knowledge structures is limited. Children read digital texts with still developing reading skills and may experience additional cognitive demands (Lawless, Mills, & Brown, 2003; Salmerón & García, 2011, 2012). So far, only one study compared children's comprehension in hypertext versus printed linear text (Salmerón & García, 2012). In line with previous studies with adults, Salmerón and García (2012) evidenced for children that structural features in hypertext facilitate children's comprehension on the situation model and that hypertext did not negatively affected children's text-base comprehension. An initial overview processing strategy as well as a cohesive link selection strategy enhanced sixth-graders hypertext comprehension (Salmerón & García, 2012). Regarding children's navigation strategies, two studies indicated that children and adolescents use the same navigational patterns and that reading skills predicted the use of hyperlink selection but not the use of overviews (Lawless et al., 2003; Salmerón & García, 2012). Rouet and Coutelet (2008) examined children's search strategies in digital text and indicated that older children search faster and used more top-down strategies based on the use of structural organizers. Coiro and Dobler (2007) found that digital text features prompt self-directed situation model construction via prior knowledge, inferential reasoning, and self-regulated reading processes for sixth-graders searching for information in digital text (Coiro & Dobler, 2007). On the other hand, Klois, Segers, and Verhoeven (2013) examined knowledge acquisition with the aid of mind maps in seventh-grade children and the relation between navigation pattern and construction of situation models. Their results suggested that hyperlinks in digital text may, in fact, foster a deeper level of learning in children. Analyses of the children's mind maps showed richer situation models in hypertext compared to texts without hyperlinks.

To sum up, research points to the difficulty of organizing knowledge structures when reading digital text especially due to high cognitive load and disorientation, but there is no consensus on the positive or negative effects of hypertext reading on reading comprehension. Research on digital text comprehension with children, furthermore, is quite limited and has primarily focused on strategy training. It is by no means clear how children structure their knowledge representations across various types of digital texts; describing these knowledge structures can help explain and account for comprehension difficulties.

1.2. Assessment of knowledge structures

Measuring the structure of reader's knowledge representations is complicated since directly tapping a text base and a situation