Learning and Individual Differences 34 (2014) 86–92

Contents lists available at ScienceDirect

Learning and Individual Differences

journal homepage: www.elsevier.com/locate/lindif

The role of working memory, inhibition, and processing speed in text comprehension in children☆

Erika Borella [a,*], Anik de Ribaupierre [b]

[a] Department of General Psychology, University of Padova, Italy
[b] Faculty of Psychology and Educational Sciences, University of Geneva, Geneva, Switzerland

ARTICLE INFO

Article history:
Received 22 April 2013
Received in revised form 23 March 2014
Accepted 9 May 2014

Keywords:
Reading comprehension
Working memory
Inhibition
Processing speed
Children

ABSTRACT

The aim of the present study was to investigate age-related differences in text comprehension performance in 10- to 12-year-old children, analyzing the joint influence of working memory (WM), inhibition-related mechanisms, and processing speed. Children were administered: i) a text comprehension task in which the memory load was manipulated by allowing them to see the text while answering or withdrawing the text (text-present versus text-absent conditions); and ii) WM, inhibition and processing speed tasks. Results showed that age-related differences were not significant in the text-present condition, whereas older children performed better than younger ones in the text-absent condition. Regression analyses indicated that only WM accounted for a significant part of the variance in the text-present condition, whereas in the text-absent condition comprehension performance was explained by the combined contribution of WM and resistance to distractor interference. These findings confirm the crucial role of WM capacity in text processing and indicate that specific inhibitory mechanisms are involved in children's text processing when the comprehension task involves memory load.

It has been shown that processing resources (working memory, inhibition and processing speed) account for text comprehension performance in children (Cornoldi & Oakhill, 1996), once basic decoding skills have been sufficiently automated or acquired. In this article, we are concerned with how these processing resources are related to the text comprehension performance of 10- to 12-year-old children.

Among these processing resources, working memory (WM) – defined as the cognitive resources available for storing information while processing incoming or recently-accessed information for use in other cognitive tasks (de Ribaupierre, 2000; Miyake & Shah, 1999) – plays a crucial part in text comprehension. WM enables readers to process text information and keep it accessible in order to build a coherent representation of the text's meaning. In fact, poor comprehenders – individuals with a deficient reading comprehension performance despite a normal IQ and good decoding skills – have been found to perform poorly in WM tasks (see meta-analysis by Carretti, Borella, Cornoldi, & De Beni, 2009). A moderate-to-strong relationship between WM and text comprehension has also been demonstrated in typically-developing children of various ages (e.g. Swanson, 1996), and across the lifespan (e.g. Siegel, 1994). These results suggest that WM plays a central part in accounting for individual and age-related differences in text comprehension performance.

Cognitive inhibition has also frequently been considered in the text comprehension domain as contributing to the selection of relevant items that can subsequently be activated in WM – which has a limited capacity – to enable individuals to form a coherent representation of a text (e.g. Gernsbacher, Varner, & Faust, 1990). For instance, Lorsbach, Katz, and Cupak (1998) (see also Lorsbach & Reimer, 1997) attributed the worse comprehension performance observed in a "garden path" procedure (in which textual information is inserted to mislead readers by generating ideas that subsequently turn out to be wrong) of 9- and 12-year-olds, compared with young adults, to the children finding it more difficult to prevent the irrelevant information from occupying their WM, and to delete it. Poor comprehenders also reportedly encounter inhibitory problems. In particular, they have been shown to be more inclined to recall information that has become irrelevant; that is, they have a larger number of intrusions – recall of non-final words – in WM tasks than good comprehenders (De Beni, Palladino, Pazzaglia & Cornoldi, 1998). A number of studies have suggested that WM and comprehension deficits in poor or less-skilled comprehenders may be due to a deficit in inhibiting information that has been activated and elaborated, and later needs to be inhibited (for a meta-analysis, see Carretti et al., 2009).

Most studies focusing on the relationship between inhibition and text comprehension have considered inhibition as a single unitary construct, rather than as a family of functions (Nigg, 2000; de Ribaupierre, Borella & Delaloye, 2003; Friedman & Miyake, 2004). They consequently

☆ This work was supported by a grant from the Swiss National Science Foundation (No. 1114-52565.97).
* Corresponding author at: Department of General Psychology, Via Venezia, 8, 35131 Padova, Italy. Tel.: +39 049 8276035; fax: +39 049 8276600.
E-mail address: erika.borella@unipd.it (E. Borella).

http://dx.doi.org/10.1016/j.lindif.2014.05.001
1041-6080/

used a single measure, or studied inhibition by manipulating the text comprehension paradigm itself. Friedman and Miyake (2004) distinguished between three inhibition-related functions: i) "prepotent response inhibition", which blocks dominant and prepotent cognitive responses automatically activated by the stimulus presented; ii) "resistance to distractor interference", which helps attention to be focused on relevant items by ignoring simultaneously-presented irrelevant items; and iii) "resistance to proactive interference", i.e. the ability to limit the activation of no longer relevant items and thus resist memory intrusions. These three functions are akin to those previously defined by Hasher and Zacks (1988), as restraint, access, and deletion, respectively.

Another factor that influences text comprehension ability is the speed at which information is processed (read, encoded and retrieved) in an individual's memory. Processing speed has been seen to account for the ability to retain information from earlier sections of a text that will be needed to interpret later sections, both in children (Johnston & Anderson, 1998), and in young and older adults (e.g. Borella, Ghisletta, & de Ribaupierre, 2011). Significant differences in children's information processing speed were found, for instance, between skilled readers and poor comprehenders (Swanson, 1996).

Although the crucial importance of one and/or the other of these processing resources for text comprehension in children is widely acknowledged, they have rarely been seen together as accounting for age-related differences. In the literature, text comprehension is measured with our without allowing participants to refer to the text while answering the questions (Cain & Oakhill, 2006), although there is clearly a memory load to consider when the text is withdrawn, but not when the text remains available while answering the question.

One of the objectives of the present study was therefore to examine the joint influence of WM and inhibition on text comprehension. Moreover, we have argued elsewhere (e.g. de Ribaupierre, 2000) that inhibition and processing speed exert an influence on WM capacity. The faster information can be processed, the more it can be considered almost simultaneously. On the other hand, when inhibition is efficient, less irrelevant information clutters the processing system and a larger part of WM can be allotted to elaborating and maintaining relevant information. Text comprehension was consequently examined in children in the final grades of elementary school, when reading has become relatively automatized, i.e. at 10–12 years of age, by: i) manipulating the role of memory, and ii) focusing on the combined influence of WM, inhibitory functions, and processing speed. Concerning the first aim, two experimental conditions were used: in the text-present condition (TP), participants could refer to the text while they answered the questions; in the text-absent condition (TA), the text was withdrawn. The TA condition thus imposes an additional memory load in the retrieval phase, and possibly also in the encoding phase (e.g. Borella et al., 2011). These two conditions are believed to measure reading comprehension (Kintsch, 1998), and they reflect common situations in the learning domain. They are rarely distinguished in the literature (Cain & Oakhill, 2006), and yet – given the extra memory load in the TA condition – they are likely to give rise to a different performance, particularly in individuals with fewer processing resources, such as young children, or low-span individuals.

As for our corollary aim, a multivariate design was adopted in which the children were administered tasks measuring WM and processing speed, and tasks assessing inhibitory functions. The following set of tasks was used: i) the Color Stroop and the Hayling tasks to tap prepotent response inhibition (e.g. Borella, Delaloye, Lecerf, Renaud, & de Ribaupierre, 2009; de Ribaupierre et al., 2003); ii) intrusion errors to measure resistance to proactive interference (e.g., Carretti et al., 2009); and iii) a negative priming paradigm, embedded in the Color Stroop task (see Borella et al., 2009; Hartley, 1993) to identify resistance to distractor interference.

We expected age-related differences in all the tasks, since older children have more resources available to them than younger children and should consequently perform better. As concerns the two text comprehension conditions, we predicted that age-related differences should be larger in the TA condition, as it presumably taxes processing resources more heavily: older children have more resources available to them than younger children and should consequently perform better. Furthermore, younger children were expected to perform less well in WM and processing speed tasks than older children (e.g. de Ribaupierre, 2000; Fry & Hale, 1996). Given that developmental changes take place gradually, 11-year-old children's performance was generally expected to lie in between (and possibly differ little from) that of the 10- and 12-year-olds. We also explored whether age-related differences were detectable in each of the three inhibitory functions, since few studies have looked into this issue in typically-developing children (but see de Ribaupierre et al., 2003, 2004).

Regarding the relations between processing resources and text comprehension, WM was expected, in line with the literature (e.g. Kintsch, 1998; Seigneuric & Ehrlich, 2005), to influence both text comprehension conditions because it affects an individual's ability to carry out many of the processes involved in constructing a mental representation of a text. We also explored whether processing speed could explain text comprehension performance, and which of the inhibition-related functions, if any, might account for text comprehension in typically developing children. Our hypothesis was that both WM and inhibitory functions have a more important role in the TA condition because it demands more cognitive resources than the TP condition.

1. Method

1.1. Participants

The sample included 20 ten-year-olds, 20 eleven-year-olds, and 20 twelve-year-olds attending the 4th, 5th and 6th grades, respectively (see Table 1). They were selected by age, school year (normal age for grade) and gender. Concerning the families' socio-economic status, based on the Geneva educational yearbook data, 33% of parents were in higher managerial occupations, 33% in lower management roles, 12% were small employers, 20% were blue-collar workers, and 2% were unemployed. This is representative of the general Geneva population.

A series of tests were presented to assess automatic word components based on reading speed, with the one-minute test (Khomsi, 1998), and on the reading of non-words (Mousty et al., 1994). Reading comprehension performance was assessed with the standardized Orlec-L4 reading comprehension task (Lobrot, 1980). In all these tasks, each age group performed adequately when compared with available normative scores; this also ensured that reading skills were automatized and ruled out any comprehension difficulties.

1.2. Materials

1.2.1. Working memory

As WM serves essentially to retain and process attentionally-relevant information and is relatively domain-free (e.g. Engle, Kane, & Tuholski, 1999; de Ribaupierre, 2000), one verbal and one visuospatial WM task were presented.

1.2.1.1. Reading span task – Rspan. In this task, adapted from Daneman and Carpenter (1980; see de Ribaupierre & Bailleux, 1995; de Ribaupierre & Lecerf, 2006; Delaloye, Ludwig, Borella, Chicherio, & de Ribaupierre, 2008), participants were asked to read a short series of simple sentences aloud (from 2 to 5 sentences in each series), and to say whether each sentence was semantically plausible, and at the end of each series they had to recall the last word in each sentence. Four items were administered at each level of difficulty to all the children, irrespective of how accurate their answers were. WM was scored as the mean number of words correctly recalled across the 16 items.