ARTICLE IN PRESS

Learning and Individual Differences xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Learning and Individual Differences

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

Irrelevant information in math problems need not be inhibited: Students might just need to spot them

Jeremy Ng*, Kerry Lee, Kiat Hui Khng

National Institute of Education, Nanyang Technological University, Singapore

ARTICLE INFO

Keywords:
Inhibition
Interference
Problem-solving
Word problems
Mathematics

ABSTRACT

This study examined whether individual differences in inhibitory abilities were related to word problem-solving performance. A sample of 10–11 year-old students ($N = 134$) were assessed on two types of inhibition: prepotent response inhibition and resistance to proactive interference. Word problems administered contained varying amounts of either numerical or literal irrelevant information. Working memory capacity and the students' ability to identify irrelevant information were also assessed. Numerical but not literal irrelevant information resulted in poorer problem-solving accuracy. Relevancy identification was associated with the observed drop in accuracy when numerical irrelevant information was added to word problems. Furthermore, neither inhibitory skills nor working memory explained significance variance in accuracy drop. We discussed these findings in relation to other research that considered inhibitory abilities and word problem-solving. We also discussed students' problem-solving errors in terms of strategy use and, in the larger socio-mathematical context.

1. Introduction

Problem solving is an important feature of mathematical curricula worldwide. For instance, in the United States and in Australia, problem solving is advocated from the early grades (Australian Curriculum Assessment and Reporting Authority, 2014; Schielack et al., 2006). In the United Kingdom, the ability to "solve problems by applying their [the pupils'] mathematics to a variety of routine and non-routine problems with increasing sophistication" is one of the aims of the national curriculum (Department for Education (UK), 2013). In Singapore, mathematical problem solving is at the core of the mathematics curriculum; and, similar to the United Kingdom, an important learning outcome is the ability to solve non-routine problems (Curriculum Planning and Development Division, 2006).

Central to the teaching of mathematical problem solving are word problems. Word problems are "verbal descriptions of problem situations" that require one to apply "mathematical operations" to the numbers to arrive at a solution (Verschaffel, Greer, & De Corte, 2000, p. ix). Several researchers have discussed the role of word problems in enabling students to apply mathematical knowledge gained in the classroom to real-world contexts (e.g., Chapman, 2006; De Corte, Verschaffel, & Greer, 2000; Reusser & Stebler, 1997; Wyndhamn & Säljö, 1997). The basic premise is that in the real-world, mathematical problems do not present themselves as "equations ready to be solved" but often take the form of different representations which "must be interpreted symbolically, manipulated and solved" (Cummins, 1991, p. 261).

Success in word problems can be influenced by the features of the word problems, for example, the position of the unknown terms (Garcia, Jimenez, & Hess, 2006), presence of realistic elements (Verschaffel, De Corte, & Lasure, 1994) and the problem type (Fan, Mueller, & Marini, 1994). Another feature of word problems that can influence problem-solving accuracy is the presence of irrelevant information. In a limited number of studies (e.g., Passolunghi, Marzocchi, & Fiorillo, 2005), researchers have specifically compared the effects of numerical versus literal irrelevant information on problem-solving. However, previous investigations have not examined factors like the amount of irrelevant information across conditions, making interpretations difficult.

Success in word problems is also influenced by students' domain general abilities. A large number of studies have shown that executive functions play an important role in mathematical problem solving (e.g., Fuchs et al., 2006; Lee, Ng, Ng, & Lim, 2004; Swanson, 2011). One aspect of executive functioning is inhibitory ability or efficiency in suppressing irrelevant or prepotent information. A number of studies have focused on inhibitory abilities, but findings have been inconsistent (Lee, Ng, & Ng, 2009; Passolunghi, Cornoldi, & De Liberto, 1999; Passolunghi & Siegel, 2001). One possible source of inconsistency is that the effect of irrelevant information has not been well controlled for

* Corresponding author at: National Institute of Education, Nanyang Technological University, 1 Nanyang Walk, 637636, Singapore.
E-mail address: n17ng9796my@e.ntu.edu.sg (J. Ng).

http://dx.doi.org/10.1016/j.lindif.2017.09.008
Received 30 December 2016; Received in revised form 5 September 2017; Accepted 10 September 2017
1041-6080/

Please cite this article as: Ng, J., Learning and Individual Differences (2017), http://dx.doi.org/10.1016/j.lindif.2017.09.008

across studies. Another possible source is that different studies have measured different types of inhibition.

Before reviewing the empirical work on inhibition and word problem-solving in more depth, we first revisit the studies that have examined the effects of different types of irrelevant information in the next section.

1.1. Effects of irrelevant information

Word problems that contain irrelevant information share features with another type of word problem that has frequently been used in the word problem solving research, namely problems with problematic realistic modeling assumptions (termed: P-problems or P-items). In several studies, P-problems have been used to demonstrate students' failure to activate real-world knowledge during problem-solving (e.g., Reusser & Stebler, 1997; Verschaffel et al., 1994; Yoshida, Verschaffel, & De Corte, 1997). For instance, in the well-known example of a P-problem below, students have been typically found to suggest 10 planks as the correct answer instead of 8 planks.

> "Steve has bought 4 planks of 2.5 m each. How many planks of 1 m can he saw out of these planks?"
>
> (Verschaffel & De Corte, 1997, p. 572)

Word problems containing irrelevant information are similar to P-problems because they both require that students represent and solve the problem in a non-routine and meaningful way. They can however be distinguished from P-problems because they contain additional pieces of information that students should not explicitly use. On the other hand, P-problems are presented like traditional word problems, without irrelevant information, and success on these problems is dependent on whether the student is able or willing to activate and include real-world considerations about the situation evoked by the problem statement.

Previous studies have examined the role of two types of irrelevant information in word problem-solving: numerical and literal. Numerical irrelevant information can be understood as numbers or quantities that are present in word problems, but are superfluous to their solution. In the following example, the number of green apples is numerically irrelevant: "John has 3 red apples. He receives another 5 red apples from his mother. The next day John buys 10 green apples. How many red apples does he have now?" Similar to numerical irrelevant information, literal irrelevant information are not necessary for solving the problems. In the following example, "John buys some green apples" is a piece of literal irrelevant information: "John has 3 red apples. He receives another 5 red apples from his mother. The next day John buys some green apples. How many red apples does he have now?"

According to Hegarty, Mayer, and Monk (1995), when solving word problems, students build a mental representation of the problem. This representation is then used to develop a solution plan. Incorporating irrelevant information into the mental model will likely lead to an incorrect solution plan. Numerical irrelevant information might be especially problematic given its semantic similarity to the relevant information (Cook & Rieser, 2005). In our previous examples, both relevant and irrelevant information referred to apples; they differed only in their color. Furthermore, irrelevant information can consume valuable mental resources that could have been spent on solving the problem.

The effects of these irrelevant information on problem-solving were examined in Englert, Culatta, and Horn (1987). They found numerical irrelevant information decreased problem-solving accuracy more than did literal irrelevant information. This was the case for both students with and without learning disabilities. Conversely, Marzocchi, Lucangeli, De Meo, Fini, and Cornoldi (2002) found literal irrelevant information to be more detrimental to problem-solving. However, as acknowledged by the authors, they used longer problems for literal irrelevant information than numerical irrelevant information. As a result, the findings may have been affected by the problem solvers' reading comprehension abilities. Another potential issue in Marzocchi et al. (2002) was that students' performance on word problems without any irrelevant information was not assessed. A baseline condition is needed to establish whether the presence of irrelevant information affects performance in the first place. We noted similar design issues in Passolunghi et al. (2005). The authors did not have a baseline condition. Furthermore, for word problems with literal irrelevant information, there were eight clauses of irrelevant information while for word problems with numerical irrelevant information, there were only four clauses. Thus the effects of information type were potentially confounded by the amount of irrelevant information in Passolunghi et al. (2005).

In the next section, we consider inhibition as a possible explanatory mechanism for the effects of irrelevant information together with a review of the empirical evidence linking inhibitory abilities to problem-solving.

1.2. Inhibition and word problem solving

Inhibition can be described as the "ability to suppress or resist irrelevant information, processes or responses" (Khng & Lee, 2014, p. 1). Research into students' predispositions have linked math problem-solving to differences in inhibitory abilities. Findings have, however, been mixed. In several studies conducted by Passolunghi and her colleagues (e.g., Passolunghi et al., 1999; Passolunghi & Pazzaglia, 2005), children who had difficulties in arithmetic word problem solving also had poorer inhibitory abilities than their normally-performing peers. On the other hand, Lee et al. (2009) did not find inhibition to be associated with problem-solving accuracy. Lee et al. (2009) argued that Passolunghi et al.'s studies included irrelevant information in their word problems, and that this might have increased the need for inhibition. Supporting Lee et al. (2009)'s premise, Aran Filippetti and Richaud (2016) similarly did not include irrelevant information in the word problems they administered and failed to find a relationship between inhibition and word problem-solving. Interestingly enough, Viterbori, Usai, Traverso, and De Franchis (2015) included only some literal irrelevant information in their word problems but also found that inhibitory skills did not affect problem-solving accuracy. This suggests that perhaps only certain types of irrelevant information may impose a load on inhibitory skills.

Another difference between the set of studies by Passolunghi et al. and Lee et al. (2009) is the type of inhibitory abilities measured. Passolunghi et al. used intrusion errors made in the context of a working memory complex span task for e.g., the listening span task. Lee et al. (2009) used reaction time on choice-reaction-time tasks: the Stroop and the stop-signal task. The different tasks likely measure different types or aspects of inhibitory abilities.

Passolunghi et al.'s measures of inhibition can best be classified as susceptibility to proactive interference or "ability to resist memory intrusions from information that was previously relevant to the task but has since become irrelevant" (Friedman & Miyake, 2004, p. 105). In the listening span task, participants have to verify whether simple statements were true, and then recall the last word of each statement. Passolunghi et al. argued that students' recall of non-last words (the intrusions) reflected their ability to control no-longer relevant information. This type of inhibitory abilities is similar to Harnishfeger (1995)'s *cognitive inhibition* or Lustig, Hasher, and Zacks (2007)'s *deletion* function of inhibition.

Conversely, inhibitory measures used in Lee et al. (2009) focused on prepotent response inhibition or "the ability to deliberately suppress dominant, automatic, or prepotent responses" (Friedman & Miyake, 2004, p. 104). This kind of inhibitory abilities may be especially important for solving word problems where students need to suppress ineffective heuristics or strategies that are well-entrenched. In the context of word problems, some students are known to use numerical information provided in questions in an arbitrary fashion (e.g., adding