Journal of Mathematical Behavior xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Journal of Mathematical Behavior

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

The role of linguistic features when reading and solving mathematics tasks in different languages

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ARTICLE INFO

Keywords:
PISA
Word length
Sentence length
Task length
Information density
English
German
Swedish

ABSTRACT

The purpose of this study is to deepen the understanding of the relation between the language used in mathematics tasks and the difficulty in reading and solving the tasks. We examine issues of language both through linguistic features of tasks (word length, sentence length, task length, and information density) and through different natural languages used to formulate the tasks (English, German, and Swedish). Analyses of 83 PISA mathematics tasks reveal that tasks in German, when compared with English and Swedish, show stronger connections between the examined linguistic features of tasks and difficulty in reading and solving the tasks. We discuss if and how this result can be explained by general differences between the three languages.

1. Introduction

Tasks have a prominent role in mathematics education. They are a part of the teaching situation, used both for students to learn and for assessment of students' knowledge. Mathematics tasks are also used by agents external to the teaching situation, for assessment of students, teachers, schools, or countries, as in international assessments such as the Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS). Therefore, there is a strong need to use good tasks, whether used in learning situations or in assessments. Mathematics tasks have a focus on the learning or assessment of *mathematical* ability (i.e., acquired proficiency in mathematics). However, also other types of abilities could be needed to work with and solve a mathematics task. Reading ability is such an ability, especially for tasks in written form, which are very common in mathematics education. For example, it is often stated that tests intended to measure mathematical ability should not measure reading ability and that test constructors therefore should use simple wording (e.g., OECD, 2009, p. 116). Such a statement shows an attempt to separate reading ability from mathematical ability, which is problematic for two main reasons. Firstly, reading ability is always needed to solve a written task, since the students need to be able to read it to solve it. Secondly, and more importantly, mathematical communication is commonly considered to be one of the main aspects of mastering school mathematics, as can be seen in curriculum documents (e.g., NCTM, 2000; Niss & Højgaard, 2011) and in research frameworks (e.g., Lithner et al., 2010). That is, being able to read (and write) mathematics is seen as an important part of knowing mathematics. Still, it is important to avoid *unnecessary* demands of reading ability in mathematics tasks. Therefore, the relation between reading ability and mathematical ability is complex and important to examine in more detail, as is done in this study. In particular, we examine issues of *difficulty in reading*, which refers to a type of unnecessary demand of reading ability, together with issues of *difficulty in solving*, which refers to a

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https://doi.org/10.1016/j.jmathb.2018.06.009
Received 24 June 2016; Received in revised form 26 May 2018; Accepted 26 June 2018

holistic view of how difficult a task is to solve.

There are many different issues of language that are important within mathematics education. One is the existence of this relation between reading ability and mathematical ability. Another issue relates to the increasing globalization and internationalization of education and includes the use of many different languages in the same situations (Barwell et al., 2007; Morgan et al., 2014). For example, many students are second language learners and several languages can be used in the same teaching situation. Furthermore, mathematics tasks are translated to many different languages, both within countries and also in international comparative studies like PISA and TIMSS. In this study, we therefore focus on different languages by examining tasks that have been translated to many languages.

Research has shown that translated tasks can function statistically differently in different languages and therefore different language versions of a task might measure slightly different things (e.g., Ercikan & Koh, 2005). Empirical studies have shown that there can be many different reasons why different language versions of tasks measure different things. The reason can be pure translation errors, but sometimes it has been shown to be inherent properties of the languages that the tasks are formulated in (e.g., Allalouf et al., 1999). One type of inherent property concerns compound words. In some languages, many concepts are denoted with compound words, while in other languages concepts are denoted by using several separate words (cf. Pirkola, 2001), so that both word length and sentence length vary between languages. Another example of an inherent property is that subject-specific words might be more or less transparent in different languages. For example, the Chinese (Mandarin) word for *median* literally means *center number* (Han & Ginsburg, 2001), and similarly, the translation of *mean* is *medelvärde* in Swedish and *Mittelwert* in German, which both literally mean *middle value*.

Previous research described above highlights different issues concerning the relationship between language and mathematics, but also shows the need for more research on these issues.

2. Purpose and research questions

The purpose of this study is to deepen the understanding of the relation between *the language* used in mathematics tasks and the *difficulty in reading and solving* the tasks. By *language* we refer both to linguistic features of the tasks (e.g., wording and grammatical structure) and to the natural language used to formulate the tasks (e.g., English). This study therefore examines if there are any connections between different linguistic features on the one hand, and difficulty in reading and solving on the other hand, for mathematics tasks in English, German, and Swedish. In particular, we compare the results between the different languages. The overarching research question is:

Do linguistic features of mathematics tasks relate to difficulty in reading and solving the tasks in different ways for tasks written in English, German, and Swedish?

The three languages were chosen for two reasons. Firstly, even though these languages are closely related, we know from earlier research that there are some important differences between them regarding several linguistic features (Sigurd et al., 2004). For example, it is more common in both German and Swedish, compared to English, to create compound words (cf. Pirkola, 2001). Compound words make words longer in general, for example, *the bus station* is just one word in Swedish, *busstationen*, which combines the two words for bus and station, together with the suffix *-en* that corresponds to the determiner *the* in English. However, it is not clear whether longer or more words in a task might be related to some type of task difficulty, and therefore these are some of the issues studied in the present article. Secondly, the languages are chosen because of their closeness. We argue that large differences between tasks in these languages are less likely to be caused by bad translations and more likely to be caused by inherent and unavoidable properties of the languages. The reason is that it is easier to find more direct translations between such close languages, since they are very similar concerning both vocabulary (cf. Wichmann et al., 2016) and structural properties (cf. Dryer & Haspelmath, 2013). We also argue that when the case of similar languages has been examined more closely, we are more equipped to focus on the more complicated cases, that is, comparing mathematics tasks in languages from different language families.

We focus on four different linguistic features of the tasks: word length, sentence length, task length, and information density. These features are chosen because they are quite often examined in connection to reading difficulties or complexity of texts. Another reason is that there are known differences between English, German, and Swedish, regarding at least the first two features (Sigurd et al., 2004).

The overarching question concerns whether these linguistic features are related to difficulty in reading and solving in different ways in these different languages, and therefore we formulate the following, more specific, research questions:

1 What linguistic features are only in some languages connected to *difficulty in reading* and *difficulty in solving*, respectively?
2 Is there variation between the three languages in how much the linguistic features explain the variation of *difficulty in reading* and *difficulty in solving*, respectively?

By *difficulty in reading* we refer to a measure of demand of reading ability (DRA) that addresses an unnecessary type of demand, which focuses on relations between reading ability and mathematical ability. By *difficulty in solving* we refer to a measure based on students' success rate of the task. The concepts of difficulty in reading and difficulty in solving are described more in the Background (Section 3.3). The concrete measures are then described in more detail in the Method (Section 4.2).

By answering these research questions, we gain knowledge about if the relations between linguistic features of mathematics tasks and task difficulty are different in different languages. This knowledge is central for exploring how properties of different languages can influence the mathematical experience for students. More specifically, through answering our research questions, we gain