Polysemous estimation words in the mathemtics classroom: comprehension and task performance.

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Linguistic aspects of mathematics education are viewed as problematic for young children acquiring mathematical skills. This study examined the relationship between the comprehension of estimating words and phrases *(e.g.roughly, between, guess)* and children's estimations abilities. Sixty-four children (aged 6-7; 8-9; 10-11) completed an estimation word comprehension test before undertaking estimating tasks in mathematical and non-mathematical contexts. The results indicated that children across this age range find estimation words easier to understand when accompanied with number or measurement expressions. Comprehension of specific estimation words varied considerably and was significantly associated with only two of twenty-four estimation tasks. These findings highlight the need for caution when interpreting the relationship between mathematics discourse and mathematical ability itself.

Introduction

Within psycholinguistics and mathematics education research there has long been an interest in the relationship between language and mathematics learning. Over and above intrinsic interest, one overarching question has been whether language comprehension somehow influences (usually in a negative or constraining fashion) children's capacities for acquiring basic understanding of many mathematical ideas (Pimm, 1987). A particular theme of this research has focused on the kinds of words a child learning mathematics is likely to hear, particularly polysemous expressions, where words which have alternative everyday meanings (non-mathematical contexts) are used in the classroom in quite different, and often highly technical, contexts. Hanley (1978) notes the difficulties children have with spatial terms such as 'row' and 'column' when encountered learning arrays, Kerslake (1991) notes children's confusions with 'of' (3 lots of 4) when using fractions and Love and Tahta (1991) summarise many expressions (e.g. set, space, tangent) which require a particular kind of mediation between teacher and learner if they are to be understood appropriately.

One category or class of terms which children encounter in the talk and the texts of the mathematics classroom are those subsuming estimation and approximation. Ever since the introduction of the calculator in classrooms, mathematics educators have sought to establish what precisely might be involved in estimation ability. The teaching and acquiring of estimation skills in schools have been claimed both to consolidate, and contribute to, mathematical understanding in the domains of number and measurement (Bright, 1976; Sowder, 1992). Estimation skill also provides an essential practical means of operating within many mathematical and everyday situations where precise calculation or measurement are contextually defined as either impossible or unnecessary (Levine, 1982). However, the words estimation and estimating are polysemous terms which share the same semantic domain as approximate, approximation, guess and even guesstimate, evidenced in examples provided in the Oxford English Dictionary (see appendix note 1). Given the increasing importance of estimation as a mathematical ability and the potential difficulties children may have these polysemous words, the first aim of the present study was to establish when children acquire an appropriate understanding of terms associated with estimation.

A second aim was to look in more depth at the relationship between children's understanding of estimating words and expressions, and estimating ability itself. While prior studies have pointed to children's comprehension difficulties with mathematical language little is known of the precise nature of the relationship between linguistic competence and mathematical skill (in this instance their ability to estimate). In the study reported below children were assessed first on an estimation word comprehension test and then asked to carry out a variety of estimating tasks. A third aim of the present work is to consider the proposal that estimating words and phrases will be easier to understand in mathematical contexts compared to any alternative meanings they may have. Our argument is that when children first encounter estimating words and phrases in the mathematics classroom they utilise their prior knowledge of such words, and it so happens that the 'everyday' meanings of many of these words and phrases are associated with (or at least encountered alongside) number, measurement and other related 'mathematical' activities and discourses (see appendix note 2 for a list of the words and phrases employed in this study). This is in line with Durkin and Shire's (1991) evidence that children display a preference for the dominant meaning of a polysemous expression, but in contrast to proposals that mathematical language rests solely on the abstractness of the mathematics reference domain (Pimm, 1987). In this instance (estimation expressions) the language of the mathematics classroom rests upon equivalent meanings informing their use in the everyday world.

In the experiment reported below, we extended the method developed by Durkin and Shire (1991) to test children's (aged 6 to 11 years) comprehension of polysemous estimation words when employed either in mathematical contexts (estimation with numbers or measures) or in alternative nonnumeric contexts. It was reasoned that because of the nature of 'everyday' estimating words (overheard and used in association with number, measurement and so on) identification of words which supported the estimating-with-number meanings would be superior to identification of alternative secondary meanings. In addition, we reasoned that there would be a positive relationship between estimation word comprehension and estimation skill, on the rationale that greater comprehension was indicative of greater exposure to such words in their context, and context in this case would be estimating activities themselves.

Method

Subjects 64 children aged 6 to 11 years acted as subjects. The children were pupils of two schools in Kent (UK) selected at random from locally available schools willing to take part in a larger study of estimation abilities. The schools were chosen so as to represent the broad spectrum of SES. The children within each age band were: 6-7 years (n = 19), 8-9 years (n=28), 10-11 years (n = 17). *Language Materials* The language examples consisted of 30 words and phrases which contained or expressed estimation words or phrases (see list and all examples used in appendix note 3). The examples were selected by two of the authors from mathematics textbooks and collected in a pilot study interviewing children about estimation in the age range studied (from a school which took no further part in the research). For analysis purposes the examples and accompanying sentences were rated for comprehensibility by an independent group of adults (n=24) on a score of 1-7 (see below in data analysis). Extending the layout developed by Durkin and Shire (1991), each word/phrase was presented either in context alongside the use of number (numeric estimation context) or embedded within a sentence which supported a non-numeric alternative reading. Table 1 provides two examples, with (a) the target sentences, (b-e) the option choices, one of which was the target semantic equivalent:

Table 1: Estimating context examples: numeric vs non-numeric contexts

Numeric estimating context	*Non-numeric estimating context*
(a) The boy saw around a hundred ducks in the pond. [Target sentence]	(a) John thought the big dog was around somewhere. [Target sentence]
(b) The girl could see around forty people standing outside the shop.[Target equivalent]	(b) The girl could see around forty people standing outside the shop.
(c) Fred knew his toy car was somewhere around the house.	(c) Fred knew his toy car was somewhere around the house. [Target equivalent]
(d) Thinking about her numbers made Jenny's head spin around till she was tired.	(d) Thinking about her numbers made Jenny's head spin around till she was tired.
(e) Billy wanted to know how long it would take to travel around the moon.	(e) Billy wanted to know if there was around fifty of the sheep in the big lorry.

The target sentences were presented at the top of the computer display screen and the estimating word/phrase highlighted. Below each sentence, four possible response alternatives were shown with only one representing the equivalent meaning for the sentence. The sentences could also be heard (orally) by selecting a highlighted 'button' on the computer display. This was essential for nonreading children in the younger age groups. Each sentence contained approximately 10-12 words and the option sentences were presented randomly underneath the target sentence. All data were recorded directly by the computer, in a form suitable for subsequent analysis (see below).

Estimating tasks:- Building upon prior work on children's estimating skills (Forrester et aI, 1990) a number of estimating tasks were devised and computer administered. The tasks required children to make estimates of target lengths (i) and areas (ii), within both 'mathematical' (A) and 'nonmathematical' (B) contexts. **In** the 'mathematical' length estimation task (A(i», children were simply asked to estimate the length of a *target* line in terms of a shorter line of *unit* length, where both lines were presented simultaneously on screen in a manner typical of many school mathematics workbooks. **In** contrast, the 'non-mathematical' length (B(i» estimation task was framed within a story, and presented in the form of a multimedia animation. The story took place during a heavy rainstorm, and involved twigs of various sizes floating downstream towards a leaf on which were marooned a large number of ladybirds. For each twig, children were asked to estimate how many ladybirds they thought would be able to escape by walking onto the twig, which subsequently floated away to safety. Similarly, in the 'mathematical' area (A(ii)) estimation task, children were required to estimate the area of a *target* rectangle in terms of a smaller rectangle of *unit* area, again where both were presented simultaneously in the style of a school workbook, whereas in the 'non-mathematical' story context (B(ii)) they were asked to estimate how many ladybirds they thought would be able to fit onto a leaf. Each child made six estimates (two unit sizes x three unit: target size ratios) within each of the four task conditions (mathematical/non-mathematical x length/area), thus making twenty-four estimates in total.

Procedure The children in the study were tested individually in a quiet and secluded section of their classrooms. Each example was available to be read from the screen and could be 'heard' by selecting the sound button. The language test was conducted across two sessions within which 30 presentation words contained 15 estimating words/phrase meaning and 15 alternative meanings, presented in random order. Each session with each child was approximately 30-40 minutes. To minimise familiarity effects of the sentence examples, there was always at least 3 weeks between each session for any child. Two weeks after completing both sessions of the language test, children carried out the estimation tasks. In order to control for effects due to sentence complexity and estimation word comprehensibility (i.e. some estimation words or phrases might simply be more difficult to understand per se), the language comprehension scores were adjusted. Prior to the study an independent group of adults rated each estimation word for ease of comprehension on a scale of 17 (details in appendix note 4). In addition each sentence was assessed for readability adopting the Flesch reading ease and Gunning Fox criteria (i.e. ensuring any variability across target and option sentences was minimised. The language comprehension index was calculated as l-(c * r) where c = the adult comprehensibility rating and r = the readability index. Thus rather than each correct response be scored as 1, it was adjusted in line with this formula. Percentage correct scores for each child were then calculated with respect to the maximum index score possible (all responses answered correctly).

Results *(A) Estimating word comprehension.*

A between and within-subject analysis of variance (ANOV A) was carried out (3 x 2) with age-group as the between subject variable and estimation word context the within-subject variable (numeric vs. non-numeric contexts). The dependent measure was the comprehension index as noted above. There was a main effect of context [F (1,61) = 18.32, P <.001], a main effect for age-group [F (2,61) = 19.49, p<.OOl], and some indication of an interaction effect [F (2,61) = 2.7, p<.07]. Follow up tests of the indicated trend showed that this was not due to any particular contribution from anyone agegroup (Table 2).

Table 2: Estimation comprehension index: age and language context comparisons

Age-group	Estimation Language Context	
	numeric	non-numeric
6-7 years	.34 (.16)	.32 (.19)
8-9 years	.51 (.27)	.46 (.21)
10-11 years	.76 (.16)	.66 (.17)

* SD's in brackets

The main effect of context describes the observation that all children found estimation words set in numeric contexts (alongside number words) easier to comprehend (numeric mean = .53; non-numeric mean = .47). And the age-group effect highlights a significant increase in comprehension across the years (6-7 year = .33; 8-9 years = .49; 10-11 years = .71).

(B). Relationships between estimation comprehension and task performance.

In order to ascertain whether estimation word comprehension influences estimation task performance a series of multiple regression analyses were carried out. The three independent variables were child age, numeric word comprehension index and non-numeric word comprehension index. Exploratory data analysis identified a consistently significant relationship between the numeric estimation index and the estimation of area tasks (i.e. the children's estimation ability on the area tasks overall was positively associated with their scores on the numeric estimation word comprehension index). There were no other consistent relationships between the other independent variables and the area tasks, or between any of the independent variables and the length estimation tasks. Table 3 summarises the comparisons for the length and area estimates with regard to age and language comprehension.

Table 3: Relationship between language and task for estimation

Dependent measure	Variable	Beta	Sig T.
Length Estimates	Age	-.16	.30
	Numeric estimation	.46	.11
	Non-numeric estimation	-.19	.46
	$F = 1.23$ (n.s). $R^2 = .01$		
Area Estimates	Age	-.07	.62
	Numeric estimation	.74	.008**
	Non-numeric estimation	-.3	.23
	$F = 5.15$ $p<.003$ $R^2 = .17$		

Discussion

This study highlights the observation that children being taught estimation in the early years of school may have a rather restricted understanding of many of the terms being used. Certainly we have only a limited knowledge of exactly how often children actually hear estimation expressions in the classroom (Pike and Forrester, 1996), however it is interesting to note how few of these expressions are understood by children under 8 years of age. It has also been possible to highlight support for the proposal that certain kinds of mathematical expressions (i.e. those associated with estimation) are actually understood *better* where they are embedded in mathematically related discourse, compared to other possible non-numeric meanings. In part this may be due to the fact that many of these alternative meanings are semantically complex (e.g. a map route 'approximating' a real route). This finding suggests that mathematics educators may wish to be more cautious with regard to the proposal that mathematics language somehow interferes with acquiring mathematical skills. With regard to the comprehension of estimating words and phrases, children's prior exposure to the use of these words in context should facilitate encounters within the mathematics classroom. What mathematics teachers may have to do is simply pay a little more attention as to the point in the curriculum when more complex examples of these epxressions should be introduced.

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