Counting difficulties for students with dyslexia

Helen Thouless
University of Washington

Many studies have examined counting skills in young children with language-related disabilities but few studies have examined counting skills in older children with these disabilities. In this study I examined the counting skills of fifteen 9 to10-year-old students with dyslexia. During an individual clinical interview students worked on an object counting task, counting by tens tasks, and word problems. Video analysis of these tasks revealed that twelve students made errors on the counting tasks and that these counting difficulties impacted the students' abilities to complete the word problems accurately. Even in upper primary school students with dyslexia have difficulties with counting and these difficulties with counting impact their abilities to accurately solve more complex mathematical problems.

Keywords: dyslexia, counting, assessment

Introduction

Numerous studies have shown that learning the counting sequence is particularly difficult for young students with dyslexia and other language impairments (Donlan, Cowan, Newton and Lloyd, 2007; Fazio, 1996). An impaired counting sequence may make it difficult for these students to do more complex arithmetic because they have to focus too much attention on counting and do not have enough mental resources to devote to problem-solving or finding efficient strategies (Dowker, 2005). In this study, I examine whether counting difficulties for students with dyslexia continue into upper primary school and how this impacts their ability to solve mathematical word problems.

In this study I use the British Dyslexia Association's 2007 definition of dyslexia,

> Dyslexia is a specific learning difficulty that mainly affects the developments of literacy and language related skills. It is likely to be present at birth and to be life-long in its effect. It is characterised by difficulties with phonological processing, rapid naming, working memory, processing speed, and the automatic development of skills that may not match up to an individual's other cognitive abilities (http://www.bdadyslexia.org.uk/about-dyslexia/further-information/dyslexia-research-information-.html).

This definition includes students who have difficulties reading, writing, and/or processing oral language.

Following a brief summary of relevant research literature and the research methods, I investigate the counting skills of students with dyslexia and factors that adversely affect their counting skills. I then investigate how their counting skills affect their ability to complete word problems accurately.

Literature review

Learning and Assessment

Before we teach mathematics to students we need to know what they already understand about the subject (Allsopp, Kyger and Lovin, 2007), and this requires us to assess their knowledge. Most standardised assessments assess what the students already know independently, or their zone of actual development. However, Vygotsky (1978) posited that in order to assess for instructional purposes we should not assess what ideas have already developed but assess which ideas are in the process of development. He proposed the idea of the zone of proximal development as the "distance between actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance" (p. 86). Determining the zone of proximal development allows us to find out which ideas are in the process of maturing and are therefore in the ideal space for learning, whereas tests that measure the zone of actual development measure what has already been taught.

Ginsburg (1997) proposed clinical interviews as a powerful tool for assessing students and determining a student's zone of proximal development because, unlike in standardised or other written tests, it is possible to scaffold the children's understanding during a clinical interview. The main purpose of a clinical interview is to understand the thinking underlying the student's responses to a standard task. Therefore the interviewer can check that the student understands the question, ask questions that prompt the student to rethink their answer, and adjust the difficulty of the questions to match the children's understanding. As an experimental method the interview method has a good history of replication, in that any competent interviewer can obtain similar results.

The clinical interview is particularly appropriate for students with disabilities because these students may have different understandings of the problems and numbers than most students, and the clinical interview allows the interviewer to probe for these different understandings (Allsopp, Kyger and Lovin, 2007). In this study I probe the counting skills of students with dyslexia and their ability to use these skills in word problems by using a clinical interview.

Counting

Counting is fundamental to many other areas of mathematics, including: understanding the size of numbers, number sequences, patterns and place value (Franke, 2003). The National Curriculum for England (2013) acknowledges that counting is a fundamental skill in mathematics by devoting many of the statutory requirements in number and place value to counting in both years of key stage 1. Students are expected to use the correct count sequence both forwards and backwards by ones to and across 100, object count, read and write numbers to 100, and count in steps of two, three, five and ten. In this study I focus on the students' knowledge and use of the count sequence by ones and tens, and their use of one-to-one correspondence when object counting.

Counting for students with dyslexia

Most of the research on the counting skills of students with language-related disorders has focused on students in the early years of primary school. Fazio (1996) found that many 6 to 7-year-old students with language impairments have difficulties with declarative mathematical knowledge such as counting by ones or tens. Donlan, Cowan, Newton and Lloyd (2007) found that 8-year-old students with specific language impairments often had profound deficits in the production of the counting sequence, while Murphy, Mazzocco, Hanich and Early (2007) found that 8-year-old students with mathematics learning disabilities performing at the 10th percentile level or lower still had difficulties identifying counting errors.

An exception to the focus on students in lower primary is Houssart's (2001) study of the counting difficulties of Julie, a girl in year 5 (9 to 10-years-old). Julie had difficulties with extended counting, which meant that she had difficulties counting across tens and hundreds boundaries, counting forwards and backwards in different steps and from different starting numbers. These difficulties made it hard for her to be successful at various mathematics problems such as counting money, making change, measuring larger distances and subtraction of 3-digit numbers.

As students with dyslexia and language-related disorders tend to have counting difficulties in the primary grades, more research needs to be done to examine how long they continue to exhibit these difficulties and what effect counting difficulties have on their understanding of more complex mathematical concepts.

Current Study

In the current study I look at the accuracy of the counting knowledge of students with dyslexia and the factors that adversely affected their counting knowledge. I also examine how the students used their counting knowledge in solving problems in all four operations. My research questions were: (1) How accurate are students with dyslexia at object counting? (2) What are some factors that affect their accuracy in counting? (3) How do counting skills affect their accurate solution of word problems?

Methods

Participants

Fifteen 9 to 10-year-old students attending an independent school for students with dyslexia participated in this study during the 2012-2013 school year. All students at the school have been given or are in the process of receiving a diagnosis of dyslexia by a diagnostician who specialises in evaluating students with learning disabilities. This school was in the Pacific Northwest of the United States of America.

All the participants spoke English as their first language. Six of the participants were female and nine were male.

Procedures

In order to assess the students' knowledge of counting I conducted an individual clinical interview with each of the participants. The entire interview consisted of 17 questions but in this paper I only analysed the students' responses to eight of the questions. These questions were broken into two sets: one set were counting tasks and the other set consisted of word problems.

The first set of questions examined students' ability to count. First I asked the students to count 120 tiles and then represent their count (Schwedtfeger and Chan, 2007). Then students counted by tens as I placed completed tens frames on the table. There were thirteen completed tens frames so the students counted by tens to 130. Then students again counted by tens as I placed tens frames on the table but this time they started from 14 with one completed tens frame and one tens frame with only four dots. Again there were thirteen completed tens frames so they counted by tens from 14 to 134 (Wright, Martland and Stafford, 2006). I included these questions because Desoete and Grégoire (2006) found that many third grade students with mathematical learning disabilities still have difficulties with the counting sequence, and I wanted to know whether these difficulties with counting by ones and by tens continued into the fourth grade.

The next set of questions I analysed comprised five word problems. There was a Join Result Unknown (JRU), a Separate Result Unknown (SRU), a Join Change Unknown (JCU), a Grouping and a Division by Ten problem (Carpenter et al., 1999). I included these problems to see whether students' difficulties with counting impacted their ability to complete these problems accurately.

For all of the word problems, the students had a selection of manipulatives available to use if they wanted. These manipulatives included connecting cubes stacked in towers of ten, a hundreds number chart, base-ten blocks, tens frames, and coloured tiles. I read the students the word problems, asked them to retell the problem, and then asked them how to solve it.

In these interviews the initial tasks were standard across all of the participants but my follow-up questions were not, as they were designed to elicit more detailed descriptions and explanations of the students' strategies. For follow-up I asked questions such as, "How did you figure that out?", "Can you do it out loud?", "Can you show me how you did it?", "Is there another way to solve this problem?", or "How do you know?" (Ginsburg, 1997).

Data Collection & Analysis

I analysed the students' responses to the questions for accuracy and errors. This analysis helped me understand how much the students knew about counting and how they used this knowledge to solve word problems.

I video recorded the interviews. From the interview videos I transcribed 18 counts where the students made errors and 13 word problems where the students made counting errors.

When I had transcribed the counts and the word problems, I coded for student errors in the number sequence, one-to-one correspondence, units and due to attention. Having coded for these errors I further coded for whether the sequencing errors occurred between decades or above one hundred. I also coded for whether the one-to-one correspondence errors seemed related to the student's uncertainty with the number system or seemed to be more related to attentional issues.

Results

In this section I first examine how accurate these students with dyslexia were at object counting by ones and by tens. Then I examine what factors affected their skills at these tasks. Finally I examine whether their counting skills affect their ability to solve word problems accurately.

Counting accuracy

Eleven of the fifteen students made number sequencing mistakes either when counting by tens or by ones. Nine students counted the 120 tiles inaccurately, eight students made number sequencing errors, and seven made one-to-one correspondence errors. In the tens frames tasks, three students made errors when counting in tens and six students made errors when counting on in tens from fourteen. Most of these 9 to 10-year-old students with dyslexia had difficulties counting accurately.

Counting errors

When students made counting errors they made four types of errors: number sequences between decades, number sequence beyond one hundred, switching units, and attentional lapses (see Table 1). The one-to-one correspondence errors were either due to uncertainty about the number sequence or due to attentional lapses.

Two students made errors between decades. Paul[10] made decade errors when he got into the decades above fifty. In English these higher decade numbers are fairly regular, with sixty, seventy, eighty, and ninety all sounding related to the digits they contain. Paul's difficulties with these higher decade numbers suggest that he did not use the patterns in the numbers to help him remember the counting sequence. Abigail's decades errors came early in the count sequence where the decades are irregular and harder to distinguish. For example, when counting by tens from fourteen she skipped the forties decade, going straight from 34 to 54. "Thirty" and "forty" often sound similar when said by students with language delays and so often get confused for one another.

Table 1 Students' counting errors

Error	Student	How many episodes per student	Examples
Decades	Paul	3	"79, 30[11]"
	Abigail	2	"14, 24, 34, 54"
Above 100	Paul	4	"102, 104"
	Rosie	4	"109, How do you write ten hundred again?"
	Abigail	3	"one hundred [Took one block] and eleven [Took another block]"
	Luke	2	"hundred and four then plus ten more would be um: a hundred forty-four"
	Kevin	1	"one hundred [Takes one block] twelve [Takes another block]"
	Kyle	1	"114, 116"
	Lily	1	"14, 24…104, 204"
	Robbie	1	"90, 100, 120, 120"
	Robin	1	"74, 84…104, 204"
Switching Units	Francesca	2	"14, 24, 34, 35"
	Robin	1	"14, 24, 25, 26, 27"
Attention	Sam	3	"87 [Another teacher entered room], 86, 88, 87, 89"
	Kyle	3	"70, seventy [Dropped tile on floor, picked it up and continued counting] seventy, 71"

[10] All names are pseudonyms.

[11] "," denotes tagging or that a new tens frame was placed down.
"…" denotes that the counting sequence is accurate between the numbers that are written.

The majority of the errors occurred at or above one hundred, with nine students making eighteen errors at or above one hundred. Students made numerous errors when counting above one hundred: two students skipped one hundred, one student had difficulties counting from 102 to 107, three students had difficulties counting 110, seven students had difficulties counting in the teens above one hundred, and one student had difficulties writing 120. The counting sequence above one hundred was not secure for this population.

Both Kevin and Abigail made one-to-one correspondence errors above one hundred that they had not made earlier in the count. For example, Abigail said, “one hundred [Took one block] and eleven [Took another block]”. In this example she took two blocks but only said one number. She said the number slowly, so slowly that her hands had time to take two blocks in the time that she completed saying the number. Her attention was occupied with remembering the count sequence and she did not notice that she took two blocks.

When counting tens frames from 14, two students counted several tens frames by tens and then switched to counting the tens frames as if each tens frame counted as one. Francesca made several switches of units, she counted the first three tens frames by tens, then she counted the next tens frame as one, counted the next tens frame as a ten, and then counted the remaining tens frames as if they were ones. Robin counted, “14, 24, 25, 26, 27, wait” at which point she went back to the beginning and counted again by tens. Robin made one switch of units from counting by tens to counting by ones, but she realised her mistake and rectified it. These two students were having difficulties distinguishing between counting by tens and counting sets of ten.

Two students made sequencing errors that seemed to be more related to attentional issues than a problem with the counting sequence. Sam made sequencing errors when another teacher entered the room and when he was searching for a particular tile. Kyle made errors when he changed counting strategies or when he dropped a tile on the floor. Although these two boys made counting errors that seemed more related to attention than to knowledge of the number sequence, they both made counting errors elsewhere in the interview that suggest that their knowledge of the counting sequence was insecure.

Miscounts in word problems

Ten students made 13 counting errors when solving the word problems. All of these counting errors occurred as students direct modelled by ones or by tens, counted by ones or skip counted. Students’ difficulties with object counting by ones and tens impacted their ability to solve the word problems correctly, with 17% of the error in the word problems being due to counting errors.

Eight of these counting errors were one-to-one correspondence errors. Four of the seven students who made one-to-one correspondence errors in the word problems had not made this type of errors in the object counting task. It seems that the added burden of making sense of the word problems made it more difficult to keep track of whether they were adhering to one-to-one correspondence.

Five of the counting errors were due to number sequence errors. Paul’s miscount on the JRU was hard to interpret. Both Francesca and Sam made between decades errors when solving the word problems. Francesca counted, “27, 28, 29, that's forty” when solving the SRU problem with direct modelling by ones. In this problem Francesca skipped the thirties decade, which was not an error she had made when counting the tiles. As Sam solved the division problem by counting out 158 tiles in groups of ten he counted, "1…69, seven—eighty, 81…158", skipping the seventies decade. Unlike during the counting task, Sam did not seem to be distracted by anything other than the task of keeping track of how many tiles there were in each group at the same time as keeping track of how far he had counted.

Lily made a different type of counting error. Lily counted, "5, 10…60, 75, 80" when counting by fives to solve the grouping problem. This error is probably due to the familiarity of the count in fives sequence. When practising multiplication facts, students normally only count up to $5 \times 12 = 60$, so the count in fives beyond 60 is probably less familiar than the counting sequence up to 60. Lily had also made a sequencing error as she counted the tens frames beyond one hundred, which is often as high as teachers ask students to count in tens. For Lily the counting sequence was secure if it was within the range that she had practised extensively.

Robin made a miscount when counting by tens above one hundred to solve the division problem. She correctly direct modelled by tens up to a hundred, putting ten sticks of ten in a box and saying, "that's ninety, a hundred", but then she counted out five single cubes to make 150. Robin's counting error in this problem seems similar to the errors that she made when counting the tens frames. When counting the tens frames she switched from counting the tens frames in tens to counting each frame in ones. In this problem she switched from counting the tens sticks in tens to counting the ones in tens. Robin's miscount was due to her switching units mid-way through the count.

Discussion

Although the expectations are that children should have mastered object counting by the end of key stage 1, this study shows that many students with dyslexia still have significant difficulties with object counting in upper primary school. In this study twelve of the fifteen students had difficulties with counting on at least one of the three types of tasks. This study confirms and expands previous research that had found that students with language-related disorders have difficulties with counting in lower primary school (Donlan, Cowan, Newton and Lloyd, 2007; Fazio, 1996; Murphy, Mazzocco, Hanich and Early, 2007).

In the counting tasks the majority of the errors these students made were with number sequences, particularly with number sequences above one hundred. Even when students made one-to-one correspondence errors most of these errors were not due to a lack of knowledge of the principles of one-to-one correspondence but because their attention was focused on the counting sequence. Two students had difficulties crossing decades, two students switched from counting by tens to counting by ones, and two students made attentional errors that seemed separate from their knowledge of the number sequence. These results confirm Houssart's (2001) findings that even in upper primary school students with learning difficulties may have difficulties with extended counting.

In completing the word problems, counting errors accounted for 17% of the problems that the students solved incorrectly. The additional burden of making sense of a word problem made the students with dyslexia even more likely to make one-to-one correspondence errors or to make errors in the counting sequence below one hundred than when they were solving simple counting tasks. Students' difficulties with the foundational task of counting made it difficult for them to accurately solve more complex tasks like word problems.

The implications of this study are that even in upper primary school teachers should assess students' counting skills, particularly focusing on their ability to count above one hundred and to use their counting skills in context.

The limitations of this study include a small sample size. Future studies should examine how widespread this issue is within the population of students with dyslexia and what effect counting difficulties have on problem solving and computation.

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