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LEARNING TO COUNT: A DIFFICULT TASK?

Jill Porter

School of Education, University of Birmingham, UK.

Abstract — This article is concerned with the acquisition of counting skills in pupils with Down syndrome. Data from a larger survey of pupils with severe learning difficulties is explored to investigate the types of errors children make at the earliest stages of learning to count. The pattern of responding was consistent with the view that children with Down syndrome have particular difficulties in tasks utilising auditory sequential memory, in this case learning the number string. The practical implications of these findings are discussed.

Keywords — *Down syndrome, counting, number*

Introduction

Until recently there has been limited interest in the attainments of children with Down syndrome in relation to numeracy, especially for those who attend schools for children with severe learning difficulties (SLD). Previous research has suggested that pupils achieve better in relation to reading than mathematics (Carr 1988; Byrne, Buckley, MacDonald & Bird, 1995) and those taught in mainstream settings fare better than those in special schools. In part, this may be due to differing expectations across settings. Indeed, a small-scale survey of teachers in SLD schools suggested that the teaching of number skills were regarded as a low priority, especially when compared to such aspects as communication and other elements of social interaction (Porter 1996). Given this limited interest, relatively little attention has been paid to how to enable pupils to learn, or indeed to any particular difficulties which they may encounter (Bird & Buckley 1994).

The study reported here presents data from a larger survey of the attainments of pupils with severe learning difficulties (Porter 1996). That larger survey examined pupil attainments in both the skills and the understanding of counting. Comparisons were made with typically developing children. The results supported the argument that children, with and without learning difficulties, have to acquire the skills of counting prior to being able to demonstrate what it means to count as measured by their ability to detect errors in the counting of others. This is in keeping with the findings of other research that the acquisition of procedures occurs before the demonstration of understanding (Briars & Siegler 1984; Frye et al 1989; Wynn 1990; Caycho et al, 1991; Fluck & Henderson 1996) but runs contrary to the findings of Gelman & Meck (1983).

The significance of these findings is important for the teacher. Whilst it does not imply that skills have to be taught in a rote fashion, it does suggest that the acquisition of these skills is essential for subsequent development. Indeed, counting underpins a number of later arithmetical activities (Carpenter & Moser 1984; Baroody 1987; Irwin 1991; Baroody 1996). The more we can discover about the acquisition of these early skills the better able we will be to develop appropriate learning environments.

When we attempted to make comparisons between children with Down syndrome and other children with severe learning difficulties, we found that the children with Down syndrome were not representative of the group as a whole. The children with Down syndrome had a slightly higher mean count score than other children in the group, but a slightly greater proportion of them were at the transitional stage of having acquired the skills of counting without yet being able to detect puppet errors. Given their mental age and proficiency in counting, it was surprising that they were not able to spot when the puppet made a mistake. It would, however, be hasty to reach a conclusion about any differences between the children with Down syndrome and other children with severe learning difficulties. Other differences between the groups included a higher mean mental age and chronological age in the pupils with Down syndrome. Given these two factors, it was unsurprising that their count score was higher but it was surprising that this was not reflected in their error detection scores. Whilst teachers might recognize that this group of pupils are often amongst the more able within their classes, we have to examine the grounds for proposing that they will respond any differently to the counting task.

Previous research has highlighted the considerable variation in numerical ability between children with Down syndrome (Thorley and Woods 1979; Gelman and Cohen 1988; Sloper, Cunningham, Turner, & Knussen 1990) with some pupils at the very earliest stages and others able to carry out quite complex operations. A recent review of numerical abilities in children with Down syndrome by Nye, Clibbens and Bird (1995), pointed to the need for more qualitative data to reveal patterns of responding, including an analysis of errors.

A fundamental part of learning to count is to be able to produce the number words in the conventional order. Typically children's utterances are composed of a stable (or consistent) conventional portion followed by an idiosyncratic count word list. Fuson et al (1982) distinguishes between the first part of the idiosyncratic or unconventional portion being stable and the latter part being unstable. Research with typically developing pupils has not always confirmed the presence of a stable but unconventional count (Wagner & Walters 1982; Baroody & Price 1983) and this may be an artifact of repeated testing with large arrays. Siegler & Robinson (1982) have highlighted the rote nature of learning the first 20 words where there is no decisive structure to guide children. They propose that numbers are bound together by a "next" connection, presumably through associative learning and that children continue counting until there are no more "next" connections and then either stop or randomly produce numbers. These random numbers may be produced as single digits or as a string, dependent on whether they too have next connections. Children will omit numbers either because they have no "next" connection or an incorrect next connection. In this way they produce idiosyncratic counts.

One area where we might anticipate the child with Down syndrome could experience difficulty is with the acquisition of the number string, a serial recall task which, conventionally, is highly reliant on auditory sequential memory. Evidence suggests that pupils with Down syndrome may experience particular difficulties with encoding and storing information presented in the auditory channel (Marcell, Harvey & Cothran 1988; Marcell & Weeks 1988; Hulme & Mackenzie 1992) and that this may make learning new words difficult (Laws, MacDonald & Buckley 1996). Attempts have been made to link these difficulties to hemispheric specialisation within the brain and researchers have suggested an additional difficulty where tasks require cooperation between movement and auditory perception systems (Chua, Weeks & Elliott 1996). It could be argued that the initial stages of learning to count place particular emphasis on the co-ordination of speech and movement as the child learns to tag objects whilst uttering the number string.

In this study we set out to re-examine the data gathered (Porter 1996) and to look in more detail at the counting profile of the children with Down syndrome. In particular, we were interested to investigate their production of the number string during the counting task as well as their adherence to one-to-one co-ordination and response to the cardinal question “How many... are there ?”. Due to the availability of data, we were able to make some comparisons with other pupils with severe learning difficulties. Given the debate over the extent to which these abilities are related to measures of mental age (Nye, Clibbens & Bird 1995), pupils with Down syndrome were matched to a group of children from the wider sample of children with severe learning difficulties, (who did not have Down syndrome), on the basis of their count scores.

Method

The original sample of children included fifty-eight pupils, 27 boys and 31 girls, attending four schools (two primary, two all age) for children with severe learning difficulties. All schools had separate provision for pupils with profound and multiple learning difficulties, and those children were not included in the study. Fifteen of the pupils (26%) had Down syndrome. The pupils in the original sample were aged 7:0 years to 13:11 years (mean 112 months SD. 22.08 months), and ranged from unscoreable on the British Picture Vocabulary Scale (BPVS), falling below the minimum level of 20 months, (Dunn, Dunn, Whetton & Pintilie 1982) to 72 months (mean 32.2 months SD. 19.4 mths).

The participants were tested on two tasks, a simple count task and an error detection task. Full details of this test are provided elsewhere (Porter 1998). Children were presented with rows of three-dimensional small trinkets in six set sizes (3,4,5,8,9,10) and asked to count them and tell the investigator how many there were. For each set counted, children could receive a maximum of 3 points: one for producing the number string correctly (a stable conventional count list), one for tagging each object once and once only (a one-to-one correspondance) and one for answering the “how many” question by repeating the last tag (producing a cardinal response). Details of pupils’ actual responses, whether correct or incorrect, were recorded at the time of the count.

The error-detection task consisted of 28 trials in which a puppet either counted correctly or made stable order, one-to-one or cardinality errors. Trials were blocked into error types. Pupils were awarded a maximum of three points for each of the three error types provided that they scored above the 5% chance level. One point was awarded for scores above 10% level. Pupils’ scores in this section therefore ranged from 0 to 9.

Sample data from 15 children with Down syndrome were taken together with the data of one further pupil with Down syndrome who had been excluded for methodological reasons from earlier phases of the study because she fell outside the chronological age restrictions placed on that particular part of the study. There were 8 males and 8 females in the group with a combined count and error detection mean score of 11.94 (range 0-27, SD 7.31). They ranged in chronological age from 84-164 mths (mean 120.56, SD 25.18) and in mental age as measured by their performance on the BPVS from 0-61 mths (mean 35.13 SD 13.19).

The sixteen pupils were matched to other pupils with severe learning difficulties (without Down syndrome) on the basis of their combined count and error detection scores. Wherever there was a choice between subjects, gender was the deciding factor. The final matched sample included 7 females and 9 males with a combined count and error detection mean score of 11.81 (range 0-27, SD 7.05) A paired-sample t test confirmed that there was no difference between the scores of these two groups [t (15) =.56 p=.58]. The sample ranged in chronological age from 87-167 mths (mean 118.56, SD 23.23). An independent-sample t test revealed that despite the fact that we had not attempted to match children on this aspect there was no significant difference between the two groups [t (30) = .23 p=.82]. The scores of the matched group on the BPVS ranged from 0-67 mths (mean 41.38 SD 15.3) and again an independent samples t test revealed no significant difference between the groups [t (30)=1.24 p=.26].

Results

Table 1 below reveals the individual performances of the pupils with Down syndrome, with all but one pupil demonstrating some counting skills (he was able to recite the number string up to 4 but not in a count context). Five of the sample scored the maximum 18 points on the count task. Three of the sample demonstrated some understanding of the error detection task, two were able to detect cardinality errors above chance level, and one pupil was able to detect all three error types and scored the maximum of nine points.

Pupils' scores on the count task were found to be significantly correlated to mental age scores on the BPVS [r = .59 p<.001], even when the effect of chronological age was partialled out [r= .45 p=.05]

Patterns of Responding

We examined the scores on the simple count task in relation to children's adherence to each of the three rules of counting. Table 2 below sets out the scores for both the Down syndrome group and the matched group. Pupils with Down syndrome scored higher in their adherence to one-to-one correspondance than in their production of the number string in a stable conventional order, [F (15,1) = 5.5 p=.03]. This was the reverse of the pattern for the matched group. Using an Anova

	Stable Order	One-to-one correspondance	Cardinality
Pupils with Down syndrome (n=16)	3.38	4.69	3.06
Matched group (n=16)	4.44	3.81	2.69

Table 2. Mean scores (max = 6) for each pupil group on each counting principle

Sex	BPVS yr.mth	CA yr.mth	Simple Count Task (max. score 18)			Error Detection Task (max. score 9)			Total scores
			Stable order scores	One to-one scores	Cardi-nality scores	Stable order scores	One to-one scores	Cardi-nality scores	
1M	u/s	8.7	- (RC4)	-	-	-	-	-	0
2F	1.11	8.10	1	3	-	-	-	-	4
3F	2.3	9.4	2	6	6	-	-	-	14
4M	2.4	7.0	1	3	1	-	-	-	5
5F	2.8	8.1	2	5	2	-	-	-	9
6F	2.8	9.11	5	3	-	-	-	-	8
7F	2.10	9.5	6	6	6	-	-	3	21
8M	2.10	12.7	-	5	3	-	-	-	8
9F	2.10	10.7	5	5	-	-	-	-	10
10F	3.3	13.3	6	6	6	-	-	-	18
11M	3.3	11.5	6	6	6	6	6	6	27
12M	3.7	8.0	2	4	-	-	-	-	6
13M	3.7	9.5	6	5	5	-	-	-	16
14M	3.9	7.11	-	6	2	-	-	-	8
15M	4.0	13.8	6	6	6	-	-	-	18
16F	5.1	12.9	6	6	6	-	-	1	19

KEY: F= female, M= male, RC= rote count

Table 1. Performance of pupils with Down syndrome N=16

mixed design, we found a significant effect for rule [F (60,2)= 6.45 p<.001] and an interaction between group and rule [F (60,2) = 3.19 p=.05].

Next we turned to investigating whether there were any differences between the two groups in relation to their production of the count string. Firstly, we looked simply at the number of different count words they produced, irrespective of order, i.e. their number vocabulary size. The range and mean number of words produced are set out below in Table 3. To avoid contamination of a ceiling effect by those who were perfect counters, we examined the count strings of the 11 pupils in each group who could be described as still acquiring the counting procedures.

	Range	Mean	SD
Pupils with Down syndrome (n=11)	4-13	7.91	3.21
Matched group (n=11)	0-11	7.55	3.21

Table 3. Number vocabulary size

	Range	Mean	SD
Pupils with Down syndrome (n=11)	2-10	5.45	2.94
Matched group (n=11)	0-10	6.36	2.98

Table 4. Length of number string

There was no significant difference between the pupils with Down syndrome and those pupils with mixed aetiologies, [F (19,1) = .2018, p=.66].

Next we turned to investigate the maximum length of the correct number strings they produced. These are set out for the two groups below in Table 4.

Again, there was no significant difference between the groups [F (19,1) = .18 p=.67]. For the group with Down syndrome there was a significant difference between their production of number words in a string and their production when order was not taken into account [t (10) = 2.31 p=.04], but this was not the case for the matched group [t (10) = 1.69 p=.12]. Looking at the type of error made, seven of the eleven pupils with Down syndrome omitted words (e.g. 1,2,4,5,6) but kept counting forwards, and three pupils sometimes recycled parts of the count string (e.g. 1,2,7,8,9,6,7,8,9). This pattern was slightly different for the group of eleven matched pupils three of whom omitted words, five of them recycled parts of the count string, and three presented a mixed pattern. Sample sizes were not sufficiently large to see if this difference reached statistical significance.

The ability to produce number words could have an impact on other elements of the count task. For example difficulty in producing number words in the correct sequence might make pupils more inclined to make skipped object errors or point no word errors rather than double counting objects.

Errors made by the 11 pupils in each group were recorded trial-by-trial, although as the pupils with Down syndrome were better able to tag each object once and once only, they produced fewer error trials, only 19 in all. In contrast, the profile of the matched group revealed 31 trials with one-one errors. The percentage of mistakes of each type are presented in Table 5. Consistent with our prediction, it appeared that pupils with Down syndrome who made one-to-one errors were more likely not to count items

	Skipped object (including skim)	Double count objects	Combine skip & double count	Point no word
Trials by pupils with Down syndrome (n=19)	9 (47%)	5 (26%)	1(5%)	4 (21%)
Trials by matched group (n=31)	23 (74%)	1 (3%)	7 (23%)	0

Table 5. One-to-one error trials

	Repeat sequence or recount	Random	Last tag +/- 1	Other	No Response
Trials by pupils with Down syndrome (n=49)	11 (22%)	6 (12%)	3 (6%)	6 (12%)	23 (47%)
Trials by matched group (n=51)	16 (31%)	15 (29%)	1 (2%)	7 (14%)	12 (24%)

Table 6. Cardinal response error trials

than to double count. Skipped object trials together with point no word trials accounted for 68% of error trials. This profile is similar to that of the matched pupils, although in contrast to our prediction they were less likely to produce double count trials than pupils with Down syndrome. Cell sizes were too small to test the significant of these differences.

Finally, we turned to look at the type of responses pupils made to the "How many question". Pupil responses fell into a number of different types. Almost half the responses of the pupils with Down syndrome (49%) and the matched group (47%) were correct last tag responses. The errors made on the remaining trials are set out in Table 6 above. These trials reveal that the pupils with Down syndrome were most likely to make no response at all (47%) to the how many question and were least likely to make a single digit response that was either one more or one less than the last number tag (6%). For the matched group the responses were distributed across repeating the count (31%); making a random single digit response (29%) or making no response (24%). Again the least likely response was the single digit that differed by 1 from the last tag (2%). Some cell sizes were too small to test the significant of these differences.

Discussion

The aim of this study was to look in depth at the performance of a group of pupils with Down syndrome who took part in a larger investigation into the skills and understanding of counting in pupils with severe learning difficulties. Like the larger group, there was considerable variation in performance, with some pupils at the earliest stages of acquiring the skills of counting and just under a third able to count flawlessly on the set sizes tested here. Just under a fifth were able to detect errors in the puppet counts and demonstrate some understanding of the count task, and all of these pupils scored the maximum on the simple counting task. Pupils' scores were significantly correlated with mental age as measured by the BPVS. This finding coincides with that of Sloper et al. (1990) and in part with that of Caycho et al. (1991). These results are consistent with those obtained more generally for pupils with severe learning difficulties (Porter 1996).

The main focus of the study, however, was to look specifically at the nature of the responses made by the pupils, notably the errors made, and to investigate whether there were any differences in the types of mistakes made by a similarly proficient group of pupils with mixed aetiologies. Although these two groups were matched in relation to their count scores, it appeared that they had accumulated points in a slightly different way. The children with Down syndrome had significantly higher scores for adhering to one-to-one correspondance than producing a stable conventional order of number words. This was the opposite pattern to the matched group and is in contrast to the pattern revealed by typically developing preschoolers (Fuson 1988; Porter 1998).

One possible explanation of this difference is that pupils have not learnt sufficient number words, perhaps due to the effect of auditory memory on the acquisition of vocabulary (Laws, MacDonald &

Buckley 1996). However, there was no significant difference between the two groups in relation to the size of their number vocabulary.

An alternative explanation lies with their ability to produce the number words in the conventional sequence. For the group of children with Down syndrome, these strings were significantly fewer in number than their number word vocabulary. Moreover, this group of children produced a slightly different profile of errors. They were more likely to produce strings with numbers missing than to recycle parts of the count string. The reverse pattern was shown by the matched group. This profile of omitting words with the string produced in a forward direction, is consistent with not having formed appropriate next connections between adjacent numbers. Research on working memory suggests that to learn a string of numbers requires repetition and rehearsal (Hulme and Roodenrys 1995), both of which could be areas for remediation (Hulme and MacKenzie 1992; Porter 1996).

We were interested to see whether difficulty with producing the number string impacted on tagging objects one-to-one. For example, pupils might be more likely to spread their string of number words over a set, skimming or skipping objects, than they would be to double count items. In fact, there were relatively few trials in which one-to-one correspondance was violated, but where it did happen pupils were more likely to skip objects or point without saying a number word, than they were to double count. This profile is largely consistent with that of typically developing preschoolers (Briars and Secada 1988).

Turning to the third element which was investigated, pupils' responses to the cardinal question suggested that if pupils did not know to respond with the last tag word, they were likely to make no response at all. In contrast, our matched group made a variety of different responses. The profile for typically developing preschoolers is to pass from responding with a single incorrect digit to recounting the set, before learning to make an appropriate last tag response (Fuson 1988). Elsewhere, it has been argued that the variety of responses made by children prior to correct responding is consistent with pupils trying out alternative "rules" (Porter 1998). It is therefore of concern that such a high percentage of pupils with Down syndrome make no response at all. Whilst it could be argued that this reflects pupils at a very early stage of skill acquisition it was not the profile of our matched group.

In the larger survey (Porter 1996), it had been noticeable that a slightly higher proportion of pupils with Down syndrome than would be expected, given their BPVS scores, were at a "transitional" stage, that they were able to count correctly but not yet able to detect errors made by the puppet. It is interesting to note that two of the three pupils in this study who were able to detect some errors only succeeded with respect to cardinality. In attentional terms, these are the least demanding errors to spot as they consistently occur at the same point in the task, the end. Conversely, pupils in the larger survey who succeeded on the stable order and one-to-one elements of the task often did so by developing strategies for monitoring or checking the puppet's performance. Gelman and Cohen (1988) argued that pupils with Down syndrome revealed neither a problem-solving approach to the constrained counting task nor the development of strategies. It is possible that the pupils in our study were also limited in this important respect. These are key elements to the development of mathematical skills and ones for teachers and parents to foster.

Practical Implications

We have stressed the importance of acquiring the skills of counting and, by making a distinction between stable order, one-to-one, and cardinal aspects of the task, we hope that teachers will be enabled to recognize achievements, even though the child may not yet be able to count. Although teachers in SLD schools have been found to view the learning of number words as a low priority, it is clear that if pupils are to progress then they need to be exposed to appropriate models. It has been encouraging to note that whilst teachers may not initiate many instances of the use of number words, pupils, when given a choice, often select activities with a numerical component (Porter 1996).

Young children are exposed to the number string in a whole variety of contexts, sometimes accompanied by counting, other times not (Reim, 1985; Durkin, et al 1986; Munn & Schaffer 1993), and Durkin (1991) suggests that the very ambiguity of the use of number words may lead children to actively deduce meaning, although young children appear to see learning to count as learning the number words (Munn 1994). Fuson (1988) draws our attention to the stages of acquisition where initially the number words are learnt as a chant or unbreakable chain, then as breakable chain. Initially the child always has to start counting at one, and only later can start at other points before being able to move up and down the number chain with fluency. This has important implications for our expectations of how pupils will be able to respond to help, and the different contexts in which they will be able to produce the number words. For example, if pupils are at a chant stage, they will not be able to alter their delivery to coincide with one-to-one tagging of items. If pupils are at the stage where they always have to start counting at one they will not be able to "count on" and may have difficulty when the teacher prompts counting by giving the next number word.

In addition to being exposed to the number string pupils may well benefit from the direct teaching of memory strategies such as rehearsal. Laws, MacDonald & Buckley (1996) describe one approach to teaching rehearsal strategies in relation to words and pictures.

Given the particular demands of making co-ordinated motor movements whilst producing the number string (Chua, Weeks & Elliott 1996), teachers might consider how they might share a counting task to benefit a pupil at the early stages of counting. Research by Wilkinson (1984) indicates that performance may be better under these conditions. Wynn's (1990) study with typically developing children also points to an order of difficulty regarding the manner of presenting sets, with children at the earliest stages achieving greater accuracy with fixed items, followed by counting items as they are put away in a "cave", followed by counting jumps and sounds.

Finally, an important area for consideration is whether children's learning could be aided by alternative approaches. Gibson (1996) summarises some of the evidence for utilising a visual modality in preference to an auditory one with tasks which require successive rather than simultaneous processing, as is the case with counting where children usually produce the number words whilst making motoric responses to the items tagged. In much the same way that teaching approaches to the development of language have capitalised on presenting the visual word, (Buckley 1993; Bird & Buckley 1994) children could be taught the number string by using visually presented number sequences. Hanrahan & Neman (1996) describe a dot notation aid to counting and addition using visual numerals which are assigned a requisite number of reference points.

An alternative approach put forward by Grauberg (1995) for children with specific language impairment, who also experience difficulties in learning the number string, is to build on visual recognition of arrays, discrimination of which has been shown by infants as young as 5 months (Wynn 1992). Grauberg proposes that children learn the numerical label for these arrays, an approach not dissimilar to the early work of Doman (1979). Controlled intervention studies are required to explore these alternative teaching approaches and to validate their usefulness.

Conclusion

This small scale study has confirmed the variation in performance in skills and understanding of the counting task in pupils with Down syndrome attending SLD schools. It has provided some evidence that pupils may find particular difficulty with learning the number string. This is consistent with research which suggests that pupils may experience particular difficulties with encoding and storing information when it is presented in an auditory channel. It is possible that these difficulties are compounded when the pupil is simultaneously required to make a motoric response. Clearly, further investigation is needed with a larger sample of pupils but the findings suggest that we need to rethink the ways in which we teach pupils this fundamental mathematical skill.

Correspondence:

Dr Jill Porter, Lecturer in Special Education,
School of Education,
The University of Birmingham,
Edgbaston, Birmingham, B15 2TT, UK.
E-mail J.M.Porter@bham.ac.uk

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